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Safety Improvement through the Application of Lean Construction Techniques in Construction Projects

تحسين السلامة من خلال تطبيق تقنيات البناء السلس في مشاريع البناء

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Abstract

Purpose: The poor safety situation in the Gazan Construction Projects adversely influenced the human health and is associated with financial and social costs. The application of Lean Construction techniques has been proposed as an effective strategy to reduce the causes of accidents in construction projects. Therefore, this research explored the current state of using Lean Construction techniques to promote safety in construction projects in Gaza Strip. The objectives were to investigate the applicability level of Lean Construction techniques to reduce the causes of accidents in construction projects, investigate the benefits expected from the application of Lean Construction techniques; and identify the barriers and success factors that affect the application of Lean Construction techniques to improve safety in construction projects in Gaza Strip.

Design/methodology/approach: A quantitative approach was used in this research. To achieve the research objective, a structured questionnaire survey of 107 supervising engineers was carried out. The data collected were analyzed with IBM (SPSS) version 22 software using the mean scores, standard deviations, relative importance index, effect index and factor analysis.

Findings: Ranking results revealed that the Lean Construction tools are not adequately known and applied to reduce the causes of accidents in Gazan Construction Projects. 5whys tool was the highest implemented tool to reduce the causes of accidents. The benefit gained from implementing Lean Construction techniques that got the top rank was improving the rate of workflow on-site, however, the strongest barrier to the application of Lean Construction techniques was lack of Lean Construction concept understanding. Furthermore, good leadership was the most influential success factor.

Factor analysis results demonstrated that the highest used component in the application of Lean Construction techniques to reduce the causes of accidents in construction projects was communication and planning. Additionally, Communication and trust was found as the most important component in the benefits of implementing Lean Construction techniques. Regarding the barriers to the application of Lean Construction techniques to improve safety, educational related was the strongest component. Finally, governmental factors was the most influential component in the success factors.

Theoretical and practical implications of the research: The findings of this research will aid professionals and companies in the Gaza Strip to shift their attention towards implementing Lean Construction techniques to reduce the causes of accidents. In addition, the roadmap derives would guide the construction practitioners to the main barriers and the measure should be taken to successfully implement Lean Construction techniques in safety improvement around he construction projects.

Originality/value: This research is considered as one of the first studies among the Middle East which links between Lean Construction techniques and safety improvement. This research results will open the door for more discussions about all subjects related to Lean Construction techniques and impacts in construction safety.

ملخص البحث

غرض الدراسة: إن إهمال السلامة في مشاريع البناء في قطاع غزة تؤثر سلبًا على صحة الإنسان وما يرتبط بها من تكاليف مالية واجتماعية. تم اقتراح تطبيق تقنيات Lean Construction كاستراتيجية فعالة للحد من أسباب الحوادث في مشاريع البناء. لذلك ، تهدف هذه الدراسة لتحديد الحالة الراهنة لاستخدام تقنيات Lean Construction لتعزيز السلامة في مشاريع البناء في قطاع غزة. تتمثل أهداف الدراسة في دراسة مستوى تطبيق تقنيات Lean Construction لتقليل أسباب الحوادث في مشاريع البناء والتحقيق في الفوائد المتوقعة من تطبيق تقنيات Lean Construction. بالإضافة إلى تحديد العوائق وعوامل النجاح التي تؤثر على تطبيق تقنيات Lean Construction لتحسين السلامة في مشاريع البناء في قطاع غزة.

منهجية البحث: تم استخدام نهج كمي في هذا البحث. ولتحقيق هدف البحث ، تم تم توزيع الاستبانة على عينة تشمل 107 مهندسا مشرفا. تم بعد ذلك تحليل البيانات التي تم جمعها باستخدام برنامج (SPSS22) باستخدام مجموعة من الوسائل الإحصائية و التي تشمل: متوسط الدرجات ، والانحرافات المعيارية ، ومؤشر الأهمية النسبية ، ومؤشر التأثير وتحليل العوامل.

نتائج الدراسة: أشارت نتائج الدراسة إلى أن أدوات Lean Construction غير معروفة بشكل كافٍ و لا تطبق بشكل واسع لتقليل أسباب الحوادث في مشاريع البناء في غزة، حيث كانت أداة 5whys هي الأداة الأكثر استخداما. يعتبر تحسين معدل تدفق العمل في الموقع من أهم الفوائد المكتسبة من تطبيق تقنيات Lean Construction ، ومع ذلك فإن هناك مجموعة من العوائق التي تحد من استخدام تقنيات Lean Construction أهمها هو عدم فهم مفهوم Lean Construction. علاوة على ذلك ، إن القيادة الجيدة هي عامل النجاح الأكثر تأثيراً.

أظهرت نتائج تحليل العوامل أن أعلى عنصر يستخدم في تطبيق تقنيات Lean Construction للحد من أسباب الحوادث في مشاريع البناء كان الاتصال والتخطيط. بالإضافة إلى ذلك ، فإن الاتصال والثقة تعتبر العنصر الأكثر أهمية في فوائد تنفيذ تقنيات Lean Construction. فيما يتعلق بالحواجز التي تحول دون تطبيق تقنيات Lean Construction لتحسين السلامة ، كانت العوامل المرتبطة بالتعليم هي العنصر الأقوى. وأخيرا ، فإن العوامل بالمتعلقة بالحكومة هي أكثر العناصر تأثيرا في عوامل نجاح تطبيق تقنيات Lean Construction في قطاع غزة.

الآثار النظرية والعملية للدراسة: تساعد نتائج هذا البحث المهنيين والشركات في قطاع غزة على تحويل اهتمامهم نحو تطبيق تقنيات Lean Construction للحد من أسباب الحوادث. بالإضافة إلى ذلك ، فإن roadmap المستمدة ستوجه المهنيين إلى العوائق الرئيسية و الإجراءات التي يجب اتخاذها لتطبيق تقنيات Lean Construction بنجاح في تحسين السلامة حول مشاريع البناء.

قيمة الدراسة: تعتبر هذه الدراسة واحدة من الدراسات الأولى في الشرق الأوسط التي تربط بين تقنيات Lean Construction وتحسين السلامة. نتائج البحث ستفتح الباب لمزيد من المناقشات حول جميع المواضيع المتعلقة بتقنيات Lean Construction وتأثيرها في سلامة البناء.

Dedication

A lean expression is

"What I can do today, I can do better tomorrow."

(Tommelein, 2015)

A pause of love for every parents who believe that the true meaning of investment is in the minds of their children. This work is dedicated to my parents, Maher and Ahlam Saleh, who have always loved me unconditionally and their good examples have taught me to work hard for the things that I aspire to achieve

Nour

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List of abbreviations

Abbreviations	The interpretation of Abbreviation
BPR	Business Process Re-engineering
BRE	British Research Establishment
CAD	Computer Aided Design
CE	Concurrent Engineering
CFA	Confirmatory Factor Analysis
CI	Continuous Improvement
CIRIA	The Construction Industry Research and Information Association
CLIP	Construction Lean Implementation Program
CPN	Construction Productivity Network
CSF	Critical Success Factors
DFMA	design for manufacturing and assembly
DHM	daily huddle meeting
EFA	Exploratory Factor Analysis
EI	Effect Index
FA	Factor Analysis
FRS	First Run Studies
HSE	Health and Safety Executive
IGLC	International Group for Lean Construction
IPD	Integrated Project Delivery
IV	Increased Visualization
JIT	Just in Time
KMO	Kaiser Meyer Olkin

Abbreviations	The interpretation of Abbreviation
LC	Lean Construction
LCI	Lean Construction Institute
LM	Lean Manufacturing
LP	Lean Production
LPDS	Lean Project Delivery System
LPS	Last Planner System
MS	Mean Score
OSHA	Occupational Safety and Health Administration
PAF	Principal Axis Factoring
PCA	Principle Component Analysis
PCs	Product Circles
PPC	Percent Plan Complete
RII	Relative Importance Index
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
TPM	Total Productive Maintenance
TPS	Toyota Production System
TQM	Total Quality Management
TVD	Target value design
UK	United Kingdom
USA	United States of America
VSM	Value Stream Mapping
WWP	Weekly Work Plan

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Expression	Definition	References
Safety	An absence of danger	Suresh et al., 2017
Danger	Danger of accident or injury to health	Aminbakhsh et al., 2013
Hazard	The potential to cause harm, including ill health and injury; damage to property, plant, products or the environment, production losses or increased liabilities	Health and Safety Executive (HSE), 2010
Risk	The chance that someone or something will be adversely affected by the hazard	Aminbakhsh et al., 2013
Fatal	Work-related death	HSE, 2010
Major injury/ill health	Any injury or acute illness resulting in unconsciousness, requiring resuscitation or requiring admittance to hospital for more than 24 hours	HSE, 2010
Serious injury/ill health	Where the person affected is unfit to carry out his or her normal work for more than three consecutive days	HSE, 2010
Minor injury	All other injuries, where the injured person is unfit for his or her normal work for less than three days	HSE, 2010
Damage only	Damage to property, equipment, the environment or production losses	HSE, 2010
LC tool	The interaction of Lean thinking principles generate LC tools. LC tool comprise of one, two or more LC techniques	Bashir, 2013
LC techniques	The features or practices which are adopted in LC tools	Bashir, 2013
5S	A Lean tool developed from five Japanese words: Seiso (shine), Seiton (straighten), Seiri (sort), Seiketsu (standardize) and Shitsuke (sustain)	Gambetese and Pestana, 2014, Abdelhamid and Salem, 2005

Expression	Definition	References
5 Whys	The five times repetition of “why” when facing a problem helps to find the root cause of construction related problem	Sarhan et al., 2017, Gambetese and Pestana, 2014, Bashir, 2013
Andon	A system to notify management, maintenance, and other workers that assistance is needed	Gambetese and Pestana, 2014
Kaizen	The Japanese word for continuous improvement	Sarhan et al., 2017, Vieira and Cachadinha, 2011, Senaratne and Wijesiri, 2008
Kanban	A Japanese word means ‘card’ or ‘sign’ that gives instructions to pull materials or parts in a certain amount	Chahal and Narwal, 2017, Gambetese and Pestana, 2014
Kitting	Creating sets of parts that are consolidated and delivered to a work area as a unit. The kit helps to prevent errors.	Gambetese and Pestana, 2014
Six Sigma	Develop work quality, work performance and work systems.	Chahal and Narwal, 2017
Hazard analysis	A study prepared before an assignment was released which aims to improve both inspection and root cause analysis	Sacks et al., 2009, Howell et al., 2002

Chapter 1

Introduction

Chapter 1

Introduction

This chapter presents an overview of the thesis with the problem statement and justification of the research. The aim and objectives of this research, key questions to be answered and hypothesis are also detailed in this chapter. This is followed by the scope of the study, research design and the contribution to knowledge. Moreover, the chapter summarizes the research limitations and thesis structure and organization.

1.1 Background

Construction industry is one of the largest and most important industries in Palestine (Enshassi et al., 2009). It is a very important sector of economy in developing countries (Enshassi et al., 2008). With rapid economic development, the construction industry continues to be ranked among the most hazardous industries in both developed and developing countries (Awada et al., 2016, Khosravi, et al., 2014, Fewings, 2013). In Gaza Strip, safety is one of the most difficult issue facing the construction industry. The accident rate in construction is highest when compared with other industries. The Palestinian Ministry of Labor (2011) stated that the recorded work injuries since 2006 to 2011 approximately 611 injury, which resulted in 11 deaths, 37% of the total number of these incidents were in the construction industry.

Safety cannot be considered as luxury, it is a human need firstly (Enshassi et al., 2008). Occupational injuries and fatalities within the construction industry has not only an impact on human health, but also associated with financial costs as productivity losses and additional project cost incurred through medical treatment, workers compensation, litigation cost, insurance cost and rehabilitation programs (Couto et al., 2017, Khosravi, et al., 2014). Furthermore, accidents lead to social costs in the form of emotional and psychological impacts to families, friends and co- workers of the victims (Couto et al., 2017, Bashir, 2013).

Hence, the issue of preventing accidents on construction sites has become a significant matter that needs an innovative approach (Khosravi, et al., 2014, Ghosh and Young-Corbett, 2009). Many research studies suggest that the application of Lean Construction (LC) techniques on construction sites could help to improve safety on construction sites (Awada et al., 2016, Gambatese et al., 2016, Camuffo and Stefano, 2015, Enshassi and Abu Zaiter, 2014, Gnoni et al., 2013, Bashir et al., 2011). Nahmens and Ikuma (2009) noted that specific Lean strategies appear to have some positive effects on safety.

LC identified accidents as sources of waste of time, money and labor which acts as an obstacle to reliable workflow and value delivery (Gambetese and Pestana, 2014, Bashir, 2013). Therefore, the relationship between Lean and safety is clear (Enshassi and Abu Zaiter, 2014). Thus, accidents on construction site need to be eliminated using LC techniques which support safety programs (Camuffo and Stefano, 2015, Awada et al., 2016).

1.2 Problem statement

Contractors in Palestine consider safety as a legal requirement that means spending money without any profit (Enshassi et al., 2014a). Additionally, safety rules do not exists and work hazards at the workplace are not perceived (Enshassi et al., 2015, Enshassi et al., 2008). As a result, the Palestinian Construction Industry suffers from poor safety conditions (Enshassi et al., 2015, Ibrahim and Al Hallaq, 2015, Enshassi et al., 2008). It is vital to find a new technology to reduce accidents on construction site using (Enshassi and Abu Zaiter, 2014).

Enshassi et al. (2016) revealed in their study that construction practitioners were not satisfied with the technologies currently used for improving safety. However, they had low commitment in adopting new technologies to improve their safety performance (Enshassi et al., 2016). As Lean is one of these new technologies, LC is not implemented in Gaza Strip in construction industry yet, and LC is unfamiliar for both contractors and consultant engineers (Enshassi and Abu Zaiter, 2014).

This study aims to open the door for the practitioners in the construction industry to realize the importance of LC adoption to improve safety in the projects and to attract their attention to the LC techniques that can be applied at Gaza Strip to improve safety. Hence, safety improves quality and reduces financial costs as productivity losses and additional costs like medical treatment and workers' compensation. Moreover, Safety improvement reduces social costs as emotional and psychological impacts to families. As a result, project stakeholders will be satisfied about the completed project.

1.3 Research justification

Worldwide, a little literature addressed both Lean and safety simultaneously (Gambatese et al., 2016, Camuffo and Stefano, 2015, Cudney et al., 2015, Gnoni et al., 2013, Bashir et al., 2011). Around the Middle East region, there is few studies correlate LC with safety on construction industry (Awada et al., 2016, Enshassi and Abu Zaiter, 2014). As part of the Middle East, the Palestinian Construction Sector has not taken any step to push the industry towards adopting Lean thinking. Such efforts remain as an individual initiative by academics, construction professionals and students depending on their Lean awareness and their willingness to adapt it in construction and to know to what extent it's applied in Gaza Strip.

This study is a starting point to explore the applicability level regarding LC techniques among construction practitioners in Gaza Construction Projects to reduce the causes of accidents. This study will also identify the safety benefits resulted from the application of LC techniques to encourage the construction practitioners to adopt LC techniques in construction projects. Moreover, the barriers impede the application of LC techniques in safety improvement will be detailed in this study with the success factors which can be adopted by construction firms to remove or mitigate the identified barriers.

1.4 Research aim

This research aimed at developing a clear understanding of the relation between Lean Construction and safety improvement and exploring the current state of using Lean Construction techniques to promote safety in construction projects in Gaza Stip.

1.5 Research objectives

1. To investigate the applicability degree of LC techniques to improve safety in construction projects.
2. To identify the benefits of applying LC techniques which is related to safety improvement in construction projects.

3. To investigate the barriers to the application of LC techniques to improve safety in construction projects.
4. To investigate the critical success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects.
5. To create a roadmap to overcome the barriers to the application of LC techniques to improve safety in construction projects.

1.6 Research key questions

- **RQ 1:** What is the applicability degree regarding LC techniques to improve safety in construction project?
- **RQ 2:** What are the benefits of the application of LC techniques which is related to safety improvement in construction projects?
- **RQ 3:** What are the barriers to the application of LC techniques to improve safety in construction projects?
- **RQ 4:** What are the critical success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects?
- **RQ 5:** How can professional engineers overcome the barriers with integrating LC techniques to improve safety in construction projects without barriers?

1.7 Research hypothesis

- **First H_0**: There is a positive relationship between the applicability degree regard to LC techniques and benefits of LC.
- **Second H_0**: There is an inverse relationship between applicability degree regard to LC techniques and barriers.
- **Third H_0**: There is an inverse relationship between benefits of LC techniques and barriers that face implementing LC techniques.

1.8 Scope of the study

The study covers the following central aspects:

- *Knowledge*: the study focused on the adoption of LC techniques to reduce the causes of accidents in construction projects in Gaza strip. It aimed to develop a clear understanding about

LC techniques by identifying basic factors (applicability level regarding LC techniques, benefits, barriers and success factors) which helps to incorporate LC techniques by construction practitioners to improve safety in the construction projects. According to that, intensive literature were reviewed to present the previous studies conducted in this field.

- *Approach and instrument*: The research adopted the deductive approach which is known as a quantitative approach to measure objectives. A questionnaire is used as a research method to collect data to meet the research objectives.
- *Population and Sample*: research population includes the construction projects in Gaza Strip which are funded from external parties and LC techniques are expected to be applied there (like Qatar Committee). 107 questionnaires were distributed to the supervising engineers in Gaza Strip. Purposive sample was chosen as the type of sample.
- *Time*: The questionnaire survey (distribution and collection) was conducted in January, 2018. It was collected in a period of two weeks.

1.9 Research design

To fulfill research objectives the following tasks were done:

- It was initiated to identify the problem, establish aim, objectives, key research questions and hypothesis, then develop research plan and determine the research methods.
- Intensive literature review was conducted to review the previous studies made in this subject.
- Factors from literature reviews were used to design the questionnaire.
- Face validity was conducted with experts in the LC and safety to assess the clarity of the items, to remove the items far from the relation between LC and safety improvement; and to generate new items, if any. Similarly with statistics to evaluate the validity of questionnaire.
- Pre testing was needed to test the survey questionnaire (Arabic questionnaire) before using it to collect data in order to identify questions that don't make sense to participants or can't be understood.
- Pilot study: Thirty completed questionnaires were entered into the SPSS to check their validity and reliability to delete any item that has a value less than the minimum ranges of both validity and reliability.
- After pilot study, the questionnaire was modified and distributed to the whole sample.
- The collected data have been analyzed using IBM SPSS (version 22).

- Findings were concluded and appropriate graphical representations and tables were obtained to understand the questions of the questionnaire.
- Recommendations were suggested through the conclusion of the research.

1.10 Contribution to knowledge

This research is considered as one of the first studies among the Middle East which links between LC techniques and safety improvement. The findings of this research will aid professionals and companies in the Gaza Strip to shift their attention towards implementing LC techniques in order to reduce the causes of accidents. The findings will guide the selection of appropriate LC techniques on the construction projects to reap the full benefits of LC techniques. In addition, the findings would guide the construction practitioners to the main barriers and the measure should be taken to successfully implement LC techniques in safety improvement around he construction projects.

1.11 Limitation of research

The main limitations related to this research including lack of information and published studies regarding the linkage between Lean and safety especially in the Middle East. The research focused on studying the implementation of the LC techniques in the construction phase only. Findings in this research were dependent on the accuracy and reliability of the collected data from construction projects by questionnaire. The questionnaire survey that has a limited number of samples and within a specific period with professionals working in construction projects funded externally (like Qatar Committee), so results may not represent the whole Gazan construction projects.

1.12 Structure of the thesis

The thesis is divided into six chapters. The structure of the theses is therefore summarized as following:

Chapter 1: Introduction

This chapter will give an introduction about the research, it will include: introduction about the topic, problem statement, research justification, aim and objectives, research key questions, research hypothesis, scope of the study, research design, contribution to knowledge, limitation and future research; and research organization.

Chapter 2: Literature review

This chapter will summarize a general introduction about safety in construction industry, application of Lean thinking in construction industry and the relationship between LC and safety. Then literature review is divided according to the study objectives into four sections. Section of literature review includes the applicability level of LC techniques in safety improvement, benefits of using LC techniques in safety improvement, barriers to the application of using LC techniques in safety improvement; and the critical success factors should be used to overcome the barriers.

Chapter 3: Research methodology

This chapter will summarize the research approach, research framework, target population and sampling methods, questionnaire design and development; and the methods used to analyze data collected quantitatively.

Chapter 4: Data analysis and results

This chapter will present the statistical questionnaire analysis and results. Research results includes the results of respondents' profile and awareness of LC tools. Moreover, this chapter concludes the results according to the research objectives including applicability level of LC techniques to reduce the causes of accidents in construction projects, benefits, barriers and success factors of using LC techniques in safety improvement.

Chapter 5: Discussion of the results

This chapter will discuss the research results and connect them with the previous studies worldwide and in the Middle East.

Chapter 6: Conclusions and recommendations

This chapter summarized the research results and conclusions, also it will give some recommendations to properly apply LC techniques in safety improvement in construction projects around Gaza Strip.

Chapter 2

Literature Review

Chapter 2

Literature review

2.1 Safety in the construction industry

Construction sector is viewed worldwide as an accident-prone industry (Suresh et al., 2017, Pestana and Gambatese, 2016, Zhou et al., 2013, Bashir et al., 2011). The unique nature of activities involved in construction industry (Khosravi et al., 2014) and its complexity increase the chances of accidents occurring on sites (Bashir, 2013). Accident is defined as 'an event without planning and uncontrollable in which the property or person results in injury or death' (Tsang et al., 2017, p1). It can result in: fatal, major injury/ill health, serous injury/ill health (3 days), minor injuries (first aid less 3 days) or damage only (HSE, 2010).

According to Occupational Safety and Health Administration (OSHA, 2015), the major kinds of accidents in the construction industry were falls, followed by struck by object, electrocution, and caught-in/between. These "Fatal Four" were responsible for more than half (64.2%) of the construction worker deaths in 2015. In other words, eliminating the fatal four would save 602 workers' lives in America every year (OSHA, 2015). Accidents result not only from normal physical dangers, but also from human factors, which may include lack of training, poor supervision, attitudes, and poor planning (Enshassi, 2010).

2.1.1 Safety records in construction industry

Substantial efforts have been made to improve safety in the construction industry (Wong et al., 2016). As a result, construction accident rates in many countries have been significantly reduced (Shishlov et al., 2011). In spite of this progress, construction remains to face more occupational injuries and fatalities compared with the other industries (Suresh et al., 2017, Kukoyi and Smallwood, 2017, Goh and Binte Sa'adon, 2015). Fatality in the construction is five times more than in a manufacturing based industry (Ibrahim and Al Hallaq, 2015, Enshassi and Abu Zaiter, 2014, Khosravi et al., 2014), whilst the risk of a major injury is 2.5 times higher than other industries (Ibrahim and Al Hallaq, 2015, Enshassi and Abu Zaiter, 2014).

Across the United States of America (USA), construction industry produces 11.1% fatalities per 100000 workers (Saunders et al., 2016). In the United Kingdom (UK), 27% of fatal injuries and 10% of major injuries are accounted for construction industry (Wong et al., 2016). Whereas construction accidents are responsible of 30% - 40% of the overall industrial accidents in Japan (Irumba, 2014).

Difference between developed and developing countries in accident rates among construction industry is remarkable. While developed countries have embraced a zero accident policy to implement effective safety practices, developing countries are unable to even identify their hazards (Irumba, 2014). Therefore, fatalities in developing countries are three times more than it in developed countries (Awwad et al., 2016). For instance, Turkish Construction Industry is responsible for 30.1% in occupational deaths, however it employs 9.9% of total employment injuries in the country (Priyadarshani et al., 2013). Across Gulf countries, fatal occupational accident rates is ranged from 5.9 to 9.8 per 100,000 workers employed (Fass et al., 2017). The Palestinian Ministry of Labor stated that work-injuries since 2006 to 2011 approximately 611 injury, which resulted in 11 deaths, 37% of the total number of these incidents were in the construction industry (Ibrahim and Al Hallaq, 2015).

2.1.2 Causes of accidents in construction industry

As the previous statistics indicated, safety in construction remains a global big problem (Kukoyi and Smallwood, 2017, Bashir et al., 2011, Ghosh and Young-Corbett, 2009). The number of accidents on construction sites can be reduced if the causes of those accidents can be identified and eliminated (Wong et al., 2016, Chi and Han, 2013, Enshassi, 2010).

While some studies share similar causes of accidents, some are completely different. According to Tsang et al. (2017), accidents occur due to lack of training, lack of supervision, uneven workload or overload working conditions, excessive stress and organizational pressure. Couto et al. (2017) identified the inappropriate planning and unsafe site conditions as contributors to accident causation. Furthermore, Kukoyi and Smallwood (2017) suggested that poor safety in the construction industry is because of lack of workers self-protection and awareness and unsafe workers' behavior. Nevertheless, Kalatpour and Khavaji (2016) believed that lack of training, inappropriate planning and lack of management commitment to safety are main factors of accidents causation in construction industry. Ibrahim and Al Hallaq (2015) and Tam et al. (2004) further identified inadequate safety equipment as one of the causes of poor safety performance.

Khosravi et al. (2014) found other factors affecting safety beside lack of training and lack of supervision which are current procurement methods, deficient enforcement of safety standards and violation of regulations, competitive tendering, extensive subcontracting and poorly organized workplace. Irumba (2014) suggested that the poor safety in the construction industry is due to lack of training, inappropriate planning, lack of supervision, uneven workload or overload working conditions, excessive stress and organizational pressure, deficient enforcement of safety standards and violation of regulations, extensive subcontracting, falls and site congestion.

Nevertheless, Alkilani et al. (2013a) reported that the main contributing factors to the causes of accidents are lack of training, lack of workers self-protection and awareness, current procurement methods, insufficient safety meeting time with workers, insufficient insurance schemes, insufficient penalties schemes, research and technology, high percentage of uneducated/unskilled labor, insufficient support for innovation, poor accident record keeping and inadequate safety equipment.

Bashir (2013) believed that ineffective communication and feedback control, lack of motivation and lack of physical or mental ability and poorly organized workplace are main factors of accidents causation in the construction industry. Furthermore, Hosseinian and Torghabeh (2012) found that lack of management commitment to safety, human error, unsafe workers' behavior, unsafe site conditions are other contributors of accident causation.

In addition, others factors that are associated with accident causation include exposure to hazardous injury sources (Chi and Han, 2013, Tam et al., 2004, Suraji et al., 2001), insufficient accident investigation and root-cause analysis program (Hinze et al., 2013, Haslam et al., 2005), site congestion (Zhang et al., 2013), lack of personal protective equipment (Zou and Zhang, 2009), safety violation (Shrestha et al., 2011), contractor belief that safety implementation is high cost and time consuming (Abu-Alqumboz, 2007), poor safety culture (Toole, 2002), poor work methods (Toole, 2002, Lubega et al., 2000). Table (2.1) summarizes the causes of accidents mentioned by several researchers.

Table (2.1): Causes of accidents

Causes of accidents	Sources
Lack of training	Tsang et al., 2017, Irumba, 2014, Kalatpour and Khavaji, 2016, Khosravi et al. 2014, Alkilani et al., 2013a, Hinze et al., 2013, Priyadarshani et al., 2013, Wilkins, 2011, Zou and Zhang, 2009
Lack of supervision	Tsang et al., 2017, Irumba, 2014, Khosravi et al., 2014, Priyadarshani et al., 2013, Chiocha et al., 2011, Enshassi, 2010, Al-Humaidi and Tan, 2010, Yung, 2009
Uneven workload or overload working conditions, excessive stress and organizational pressure	Tsang et al., 2017, Irumba, 2014, Haslam et al., 2005, Suraji et al., 2001
Inappropriate planning	Couto et al., 2017, Kalatpour and Khavaji, 2016, Gambatese et al., 2016, Irumba, 2014, Alkilani et al., 2013b, Hinze et al., 2013, Toole, 2002
Unsafe site conditions	Couto et al., 2017, Enshassi and Abu Zaiter, 2014, Chi and Han, 2013, Hosseinian and Torghabeh, 2012, Nahmens and Ikuma, 2009, Abdelhamid and Everett, 2000
Lack of workers self-protection and awareness	Kukoyi and Smallwood, 2017, Gambatese et al., 2016, Ibrahim and Al Hallaq, 2015, Alkilani et al., 2013a, Enshassi, 2010, Zou and Zhang, 2009
Unsafe workers' behavior	Kukoyi and Smallwood, 2017, Khosravi et al., 2014, Chi and Han, 2013, Hosseinian and Torghabeh, 2012, Nahmens and Ikuma, 2009, Toole, 2002, Abdelhamid and Everett, 2000
Lack of management commitment to safety	Kalatpour and Khavaji, 2016, Hinze et al., 2013, Zou and Sunindijo, 2013, Hosseinian and Torghabeh, 2012, Chiocha et al., 2011, Enshassi, 2010, Zou and Zhang, 2009
Inadequate safety equipment	Ibrahim and Al Hallaq, 2015, Alkilani et al., 2013a, Tam et al., 2004, Toole, 2002
Current procurement methods	Khosravi et al., 2014, Alkilani et al., 2013a, Hinze et al., 2013

Table (2.1): Causes of accidents

Causes of accidents	Sources
Deficient enforcement of safety standards and violation of regulations	Irumba, 2014, Khosravi et al. 2014, Priyadarshani et al., 2013, Abu-Alqumboz, 2007
Competitive tendering	Khosravi et al. 2014, Alkilani et al., 2013 b, Hinze et al., 2013, Chiocha et al. 2011
Extensive subcontracting	Khosravi et al. 2014, Irumba, 2014, Hinze et al., 2013
Poorly organized workplace	Khosravi et al., 2014, Bashir, 2013, Howell et al., 2002, Suraji et al., 2001
Falls	Irumba, 2014
Site congestion	Irumba, 2014, Zhang et al., 2013
Insufficient safety meeting time with workers	Alkilani et al., 2013a, Priyadarshani et al., 2013, Abu-Alqumboz, 2007
Insufficient insurance schemes, insufficient penalties schemes, research and technology and high percentage of uneducated/unskilled labor	Alkilani et al., 2013a
Insufficient support for innovation	Alkilani et al., 2013a, Zou and Zhang, 2009
Poor accident record keeping and reporting systems	Alkilani et al., 2013a,b, Abu-Alqumboz, 2007, Kartam et al., 2000
Communication and feedback control, lack of motivation and lack of physical or mental ability	Bashir, 2013
Human error	Hosseinian and Torghabeh, 2012, Ghosh and Young-Corbett, 2009, Katsakiori et al., 2009, Sacks et al., 2009, Saurin et al., 2006, Howell et al., 2002, Abdelhamid and Everett, 2000
Exposure to hazardous injury sources	Chi and Han, 2013, Tam et al., 2004, Suraji et al., 2001,
Insufficient accident investigation and root cause analysis program	Hinze et al., 2013, Haslam et al., 2005

Table (2.1): Causes of accidents

Causes of accidents	Sources
Lack of personal protective equipment	Zou and Zhang, 2009
Safety violation	Shrestha et al., 2011
Contractor belief that safety implementation is high cost and time consuming’	Abu-Alqumboz, 2007
Poor safety culture	Toole 2002
Poor work methods	Toole, 2002, Lubega et al., 2000

Some activities are viewed by Hinze et al. (2013) to improve safety as worker involvement through pre-task planning meetings, worker-safety perception surveys, suggestion-box programs, safety committees, near-miss reporting programs, and a wide assortment of other programs that rely on worker input and feedback for program success. The key factor in motivating construction practitioners to develop the safety programs is having enforceable and strict safety legislations (Awwad et al., 2016).

Several researchers have begun to emphasize Lean Construction (LC) as an opportunity to improve safety on construction sites (Gambatese et al., 2016, Forman, 2013, Bashir et al., 2011, Ikuma et al., 2011, Alinaitwe, 2009). Based on the understanding that accidents and worker injuries are examples of waste as defined in LC (Gambetese and Pestana, 2014, Losonci and Demeter, 2013, Ghosh and Young-Corbett, 2009).

2.1.3 Onsite and offsite causes of accidents

LC techniques can be used to minimize the onsite causes of accidents (Enshassi and Abu Zaiter, 2014, Forman, 2013, Bashir et al., 2011). Onsite causes of accidents are those that are directly associated with operations on construction site like lack of training and supervision. They could also be attached to the working environment like unsafe site conditions. On other hand, offsite causes of accidents do not occur on site because they have no direct involvement with the operational work onsite as excessive subcontracting (Bashir, 2013). Therefore causes of accidents which are mentioned in the previous section in Table (2.1) will be classified into onsite and offsite causes. Table (2.2) presents the classification of the causes into onsite and offsite causes. The sources of the following causes are mentioned in Table (2.1)

Table (2.2): Onsite and offsite causes of accidents

Onsite causes of accidents	Offsite causes of accidents
Lack of proper training	Current procurement methods
Lack of supervision	Deficient enforcement of safety standards
Excessive stress and organizational pressure	Competitive tendering
Inappropriate planning	Extensive subcontracting
Unsafe site conditions	Insufficient insurance schemes
Lack of workers self-protection and awareness	Insufficient penalties schemes
Unsafe workers' behavior	Research and technology
Lack of top management commitment to safety	Inadequate support for innovation
Inadequate safety equipment	Contractor belief that safety implementation is high cost and time consuming
Poorly organized workplace	
Falls	
Site congestion	
Insufficient safety meeting time with workers	
Uneducated/unskilled labor	
Poor accident record keeping and reporting systems	
Communication and feedback control	
Lack of physical or mental ability	
Human error	
Insufficient accident investigation and root causes analysis program	
Exposure to hazardous injury sources	
Safety violation	

Table (2.2): Onsite and offsite causes of accidents

Onsite causes of accidents	Offsite causes of accidents
Lack of personal protective equipment	
Poor safety culture	
Poor work methods	

2.2 The application of Lean thinking in the construction projects

2.2.1 The concept of Lean thinking

The Lean thinking is a philosophy based on the concepts of Lean Production (LP) (Sarhan and Fox, 2013). The Lean principles were based in the early 1900's when Henry Ford's changed the assembly line that led to mass production (Sarhan et al., 2017, Arleroth and Kristensson, 2011, Vieira and Cachadinha, 2011). In the early of 1950's, Eiji Toyoda and Taiichi Ohno at the Toyota Motor Company in Japan established the concept of LP or Toyota Production System (TPS) (Bashir, 2013, Ayarkwa et al., 2012a,b, Marhani et al., 2012). The TPS aimed at satisfying the customer needs in the most efficient way with full utilization of workers' capabilities in which waste was minimized so that the reduction of costs is achieved (Nikakhtar et al., 2015, Hicks et al., 2015, Bashir, 2013).

In the Early 1960s a number of principles had been developed that later become known as the foundation of LP (Arleroth and Kristensson, 2011). LP methods have been applied in the Japanese car industry as a key to success from 1970's to 1980's (Marhani et al., 2012, Arleroth and Kristensson, 2011). The term "lean" was invented by the research team working on the international auto production and it reflects the waste reduction nature of the TPS (Alinaitwe, 2009). Lean was defined as "Give customers what they want, deliver it instantly with no waste" (Alinaitwe, 2009, p. 15). It is about "Doing more with less: less time, inventory, space, labor, and money" (Chikhalikar and Sharma, 2015, p. 1067). Lean thinking is "the endless transformation of waste into value from the customer's perspective" (Douglas et al., 2015, p. 970).

According to Ogunbiyi (2014), Lean is a management philosophy focused on identifying and eliminating waste throughout a product's entire value stream, extending not only within the organization but also along the company's supply chain network. On the other hand, Douglas et al. (2015) revealed that Lean is not only a management philosophy but also a methodology. It can be considered from a philosophical perspective as guiding principles or overarching goals and from a practical perspective as a set of management practices, tools, or techniques that can be observed directly (Boyle et al., 2011)

In the various definitions presented in Table (2.3), all the definitions are centered on customer, value, and waste. Thus, the general definition of Lean is ‘a philosophy and a production management based system that uses tools and techniques to create a change in organizational culture and maximize value to the customer by identifying and eliminating waste, and pursuing perfection in the execution of a construction project’ (Ogunbiyi, 2014, p. 28).

Table (2.3): Definitions of Lean

Definition	Source
Is essentially about getting the right things to the right place at the right time, in the right quantity whilst minimizing waste and being open and responsive to change	Adegbembo, et al. (2016, p. 758)
The endless transformation of waste into value from the customer’s perspective	Douglas et al., (2015, p. 970)
What we were trying to improve, it was part of an overall cultural change in the company, focusing on adding value and minimize defects	Bygballe and Swärd (2014, p. 8)
A systematic approach to identifying and eliminating waste through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection	Avinash and Ramesh, (2013, p. 1576)
An integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability	Shah and Ward, (2007, p. 791)

2.2.2 Key characteristics of Lean Construction and its elements

Principles of Lean thinking have been widely accepted by many firms and have been applied quite successfully across many disciplines (Zhou, 2012, Alinaitwe, 2009). Furthermore, the construction industry has borrowed it due to the success of the LP system in manufacturing (Sarhan et al., 2017, Aziz and Hafez, 2013, Ogunbiyi et al., 2013, Ogunbiyi et al., 2014, Shang and Pheng, 2014, Eriksson, 2010). The term Lean Construction (LC) was first brought up in 1992 by Lauri Koskela (Bashir et al., 2010). LC was coined by the International Group for Lean Construction at its first meeting in 1993 (Sarhan et al., 2017). According to Marhani et al. (2013), LC is the practical application of Lean manufacturing principles or Lean thinking to the building environment.

Pradeepkumar and Loganathan (2015) defined LC generally as “a combination of original research and practical development in design and construction with an adaption of Lean manufacturing principles and practices to the end to complete design and construction process”. LC is a new production philosophy (Nikakhtar et al., 2015, Aziz and Hafez, 2013, Ogunbiyi, 2014). It conceives a construction project as a temporary production system dedicated to three goals of delivering the project, maximizing value, and minimizing waste (Ogunbiyi, 2014). Table (2.4) shows various definitions of LC presented by several researchers.

Table (2.4): Definitions of Lean Construction

Definition	Source
A combination of original research and practical development in design and construction with an adaption of lean manufacturing principles and practices to the end to end design and construction process	Pradeepkumar& Loganathan (2015, p.2)
A new production philosophy which has the potential of bringing innovative changes in the construction industry	Ogunbiyi (2014, p. 48)
A production management strategy for achieving significant continuous improvement, in the performance of the total business process of a contractor through elimination of all wastes of time and other resources that do not add value to the product or delivered service to the customer	Issa (2013, p. 698)
A way forward to design production systems in minimizing waste of materials, time and effort which leads to possible generation of maximum amount of value	Marhani et al. (2012, p. 87)
A concurrent and continuous improvement to the construction project by reducing waste of resources and at the same time able to increase productivity and secure a better health and safety environment in order to fulfil customer’s requirements.	Marhani et al. (2012, p. 90)

In construction, there is a tradeoff between time, cost, and quality. However, Lean aims to achieve all three at the same time (Tommelein, 2015). The core elements of LC can be grouped into six core elements: (1) Waste reduction (Sarhan et al., 2017, Gambetese and Pestana, 2014, Ogunbiyi et al., 2014, Ayarkwa et al., 2012a,b, Marhani et al., 2012, Ogunbiyi et al., 2011, Eriksson, 2010); (2) Process focus in production planning and control (Ogunbiyi et al., 2014, Ogunbiyi et al., 2011, Eriksson, 2010); (3) End customer focus (Ogunbiyi et al., 2014, Ogunbiyi et al., 2011, Eriksson, 2010); (4) Continuous improvements (Ogunbiyi et al., 2014, Ogunbiyi et al., 2011, Eriksson, 2010); (5) Cooperative relationships (Ogunbiyi et al., 2014, Ogunbiyi et al., 2011, Eriksson, 2010); (6) Systems perspective (Ogunbiyi et al., 2014, Ogunbiyi et al., 2011, Eriksson, 2010).

LC can also maximize value for the client, increasing quality and productivity (Sarhan et al., 2017, Ogunbiyi et al., 2014, Ayarkwa et al., 2012a, Marhani et al., 2012), improving communications (Ogunbiyi et al., 2014), improving health and safety conditions (Sarhan et al., 2017, Ogunbiyi et al., 2014, Marhani et al., 2012). It also minimizes the direct cost of effective project delivery management (Sarhan et al., 2017). Figure (2.1) concludes the core elements of LC mentioned by (Ogunbiyi et al., 2014, Eriksson, 2010, Ogunbiyi et al., 2011).

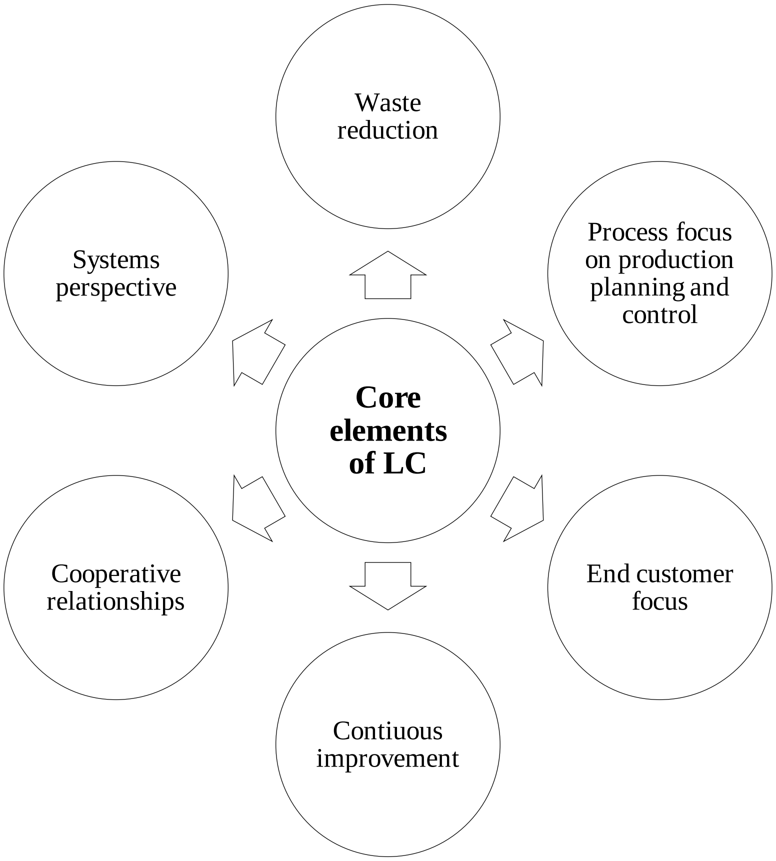


Figure (2.1): Core elements of Lean Construction

2.2.3 Lean Construction principles

Koskela (1992) has summarized LC into eleven basic principles which were (1) Reduce the share of non-value adding activities; (2) Increase output value through systematic consideration of customer requirements; (3) Reduce variability; (4) Reduce cycle times; (5) Simplify by minimizing the number of steps, parts and linkages; (6) Increase output flexibility; (7) Increase process transparency; (8) Focus control on the complete process; (9) Build continuous improvement into the process; (10) Balance flow improvement with conversion improvement; and (11) Benchmark. These principles were also adopted and ensured by (Aziz and Hafez, 2013, Marhani et al., 2013, Bahir et al., 2011).

Later, Womack and Jones (1996) have simplified the LC principles stated by Koskela (1992) into five LC principles. The five principles are general Lean thinking principles, which are were noted to be more suitable for the construction industry (Bashir, 2013). These five principles have to be followed step by step to gain the maximum benefit of the Lean (Aziz and Hafez, 2013), which are:

1. Identify value: from customer own definition (Ogunbiyi, 2014) and identify the value of activities, which generate value to the end product (Aziz and Hafez, 2013).
2. Identify the value stream: by elimination of everything, which does not generate value to the end product (Anvari et al., 2011a, Ogunbiyi, 2014). This means, stop the production when something is going wrong and change it immediately (Aziz and Hafez, 2013)
3. Flow: ensure that there is a continuous flow in the process (Aziz and Hafez, 2013)
4. Pull: produce exactly what the customer wants at the time the customer needs (Ogunbiyi, 2014, Aziz and Hafez, 2013).
5. Perfection: which involves producing exactly what the customer wants in terms of quality and quantity at the right time at a fair price and with minimum waste (Ogunbiyi, 2014).

In practice, these principles are implemented through kaizen which is an intensive and focused approach to process improvement (Ikuma et al., 2011). These principles were cited in various studies (Hicks et al., 2015, Ogunbiyi, 2014, Aziz and Hafez, 2013, Anvari et al., 2011a, Bashir et al., 2011, Ikuma et al., 2011). Figure (2.2) summarizes the five core principles of LC.

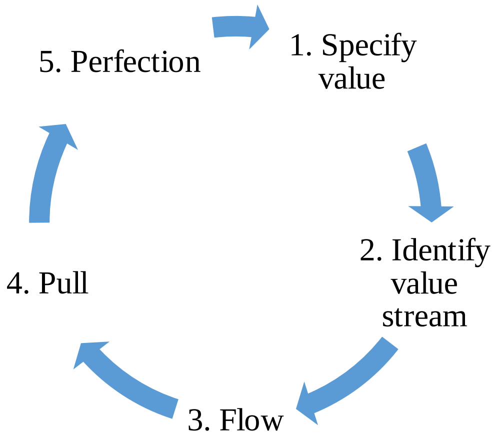


Figure (2.2): Five Principle of LC

Meanwhile, Liker (2004) revealed that the Toyota philosophy based on fourteen principles. It were organized in four categories starting all with P (4P): Philosophy, Process, People and Partners and Problem Solving (Aziz and Hafez, 2013, Ballard et al., 2007). Figure (2.3) concludes the 4P of Lean principles which adopted from Ballard et al., 2007.

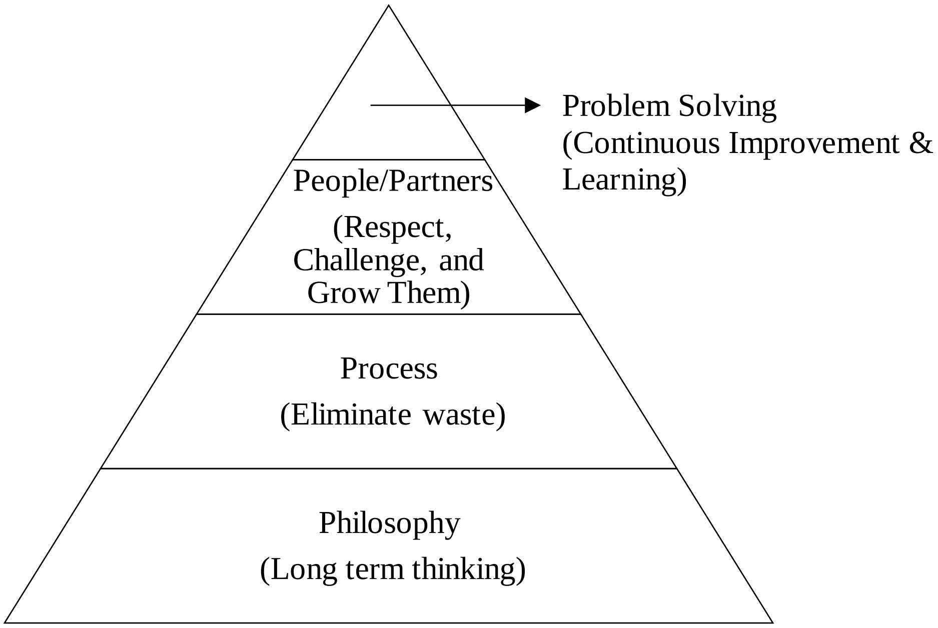


Figure (2.3): “4P” of the Toyota Way (adopted from Ballard et al., 2007)

2.2.4 Three stages of Lean Construction

Gambetese and Pestana (2014) argued that implementing LC requires a guidance on how to achieve it. LC implementation efforts can be divided into three different stages, with increasing degree of sophistication (Eriksson, 2010).

Stage 1 of Lean focuses on waste elimination from a technical and operational perspective (Ogunbiyi et al., 2014). The most important core element of LC is waste reduction (Ogunbiyi, 2014). Essential parts of this stage are: elimination of needless movements, cutting out unnecessary costs, optimizing workflow, and sharing the benefits from improved performance (Green and May, 2006).

Stage 2 focuses on eliminating adversarial relationships and enhancing cooperative relationships and teamwork among supply chain actors (Ogunbiyi et al., 2014). The essential parts are cooperation, long-term framework agreements, workshops, and facilitator (Green and May, 2006). The workshops and facilitator role are needed in order to enhance good communication among the project participants which in turn improves integration and coordination (Ogunbiyi, 2014). Lean stage two does not relate to concept of partnering since it is about eliminating waste derived from adversarial relationships by increasing integration and collaboration (Eriksson, 2010).

Stage 3 is identified as the most sophisticated stage because it involves a structural change of project governance (Ogunbiyi et al., 2014). Its essential parts are: information technology, pre-fabrication, last planner (LP), bottom-up activities and emphasis on individuals, a rethink of design and construction, decreased competitive forces, long-term contracts, training at all staff levels, and a systems perspective of both processes and the product (Green and May, 2006). Only when striving to achieve stage 3, a substantial change from other types of project governance is required (Eriksson, 2010).

2.3 Summary

Although the construction industry plays a vital role in the national economy, it remained one of the most hazardous industries around the world. It accounts high percentages of fatalities and injuries. Accidents and injuries do not affect human health only, but also have high social and economic costs. It acts as an obstacle to reliable workflow, as well. LC identified accidents as major source of waste of time, money and labor. Thus, the relationship between Lean and safety is clear.

The previous section presented an overview of safety on construction sites. It presented the records of accidents in many countries and determined the causes of accidents on construction sites. It classified the causes of accidents into onsite and offsite causes. As LC tools are used to reduce the onsite causes of accidents such as poor supervision, excessive stress and inappropriate planning. In addition, the previous section presented the history of Lean thinking, LC elements and LC principles. The stages could be followed to apply LC is also reviewed in this section.

This section formed a background of both safety and LC and how the researchers correlate between them based on the LC concept. Next section studies the applicability level of LC techniques to improve safety on construction sites. It presents the integration of LC tools and onsite causes of accidents to promote safety, too.

Objective 1

The first objective of the research is to investigate the applicability level of LC techniques to reduce the causes of accidents in construction projects. The interaction of Lean thinking principles generate Lean Construction tools. LC tools would be presented in this section to decrease the onsite causes of accidents are Last Planner System, Increased Visualization, 5S, Poka yoke, Daily Huddle Meetings, 5 whys, First Run Studies and Kaizen. The features or practices which are adopted in LC tools are formed LC techniques. This section critically review literatures relating to level of applicability of LC techniques to decrease the onsite causes of accidents in construction projects.

2.4 The applicability level of Lean Construction techniques to reduce the causes of accidents in construction projects

The awareness of LC implementation has been increasing (Ogunbiyi et al., 2011). The concept of LC is becoming a reality more and more present in construction industry. Its effectiveness in controlling and eliminating wastes are becoming more and more acknowledged (Vieira and Cachadinha, 2011). However, Ogunbiyi (2014) believed that currently LC is still in early stage of development (Ogunbiyi, 2014). Similarly, Sarhan et al. (2017) stated that the adoption of LC is still in a transition phase (Sarhan et al., 2017). Therefore, the introduction of LC, implementation of LC method, tools and thinking has been a challenge (Wandahl, 2014).

One of the major challenges to implement LC is lack of awareness of LC techniques (Sarhan et al, 2017, Cano et al., 2015, Sarhan and Fox, 2013, Ballard and Tommelein, 2012). As a result, supporting the LC techniques needs for more empirical evidence to maximize the benefits of LC techniques (Sarhan and Fox, 2013). Over the past years, many efforts have been made to raise awareness by providing guidance and sharing knowledge relating to LC by academics, researchers and practitioners (Bashir et al., 2015, Sarhan and Fox, 2013).

The establishment of the bodies has also helped to enhance awareness of LC techniques (Ogunbiyi et al., 2013). For instance, Lean Construction Institute (LCI), Construction Lean Implementation Program (CLIP) (Bashir et al., 2015, Ogunbiyi et al., 2013), International Group for Lean Construction (IGLC), British Research Establishment (BRE), Construction Excellence

(CE) (Bashir et al., 2015), The Construction Industry Research and Information Association (CIRIA) and Construction Productivity Network (CPN) (Ogunbiyi et al., 2013). Additionally, seminars and conferences have been organized to increase awareness of LC with real case studies of some construction organizations adopted LC (Ogunbiyi et al., 2013). According to Sarhan and Fox (2013), currently some organizations and universities offer LC education, which has been helpful in moving lean thinking into construction education.

Despite these continuous efforts (Ogunbiyi et al., 2013), lack of awareness is still one of the key challenges to implement LC. The bodies established to increase awareness of LC are operating in very few countries (Wandahl, 2014). Furthermore, Ogunbiyi et al. (2013) revealed that few studies have been carried out in order to establish the current levels of awareness and implementation of Lean thinking within the construction industry.

2.4.1 Lean Construction tools and techniques

The interaction of Lean thinking principles generate Lean Construction tools (Bashir, 2013). LC doesn’t imply the same techniques of Lean manufacturing. Construction industry is a unique and dynamic process while manufacturing industry is movable and produce products in a fixed workplace (Pestana and Gambatese, 2016). Owing to this, construction academics and professionals have developed the Lean tools and techniques to implement LC based on the LC principles (Bashir et al., 2011, Gambetese and Pestana, 2014, Vieira and Cachadinha, 2011).

LC techniques are the features or practices adopted in LC tools. In other words, A LC tool comprise of one, two or more Lean techniques except the tool of Daily Huddle Meeting (DHM). It has only one feature, therefore it’s considered as a LC tool and a LC technique (Bashir, 2013). While Last Planner System (LPS) comprises of many techniques like workers empowerment, workers involvement, pre task hazard analysis and weekly work plan.

Sarhan et al. (2017) presented many tools which are used to implement LC. These tools include 5S, 5 whys, first run study (FRS), just in time (JIT), pull approach (Kanban), last planner system (LPS), error proofing or fail safe for quality and safety (Poka yoke), standard work, value stream mapping (VSM), increased visualization, DHM, target value design (TVD), partnering, computer aided design (CAD), six sigma, total productive maintenance (TPM), total quality management (TQM) and concurrent engineering (CE).

Moreover, Gambatese et al. (2016) introduced the best tools applied in LC. These include 5 S's, 5Whys, Andon, FRS, Integrated Project Delivery (IPD), JIT, Continuous improvement (Kaizen), Kanban, Kitting, LPS, Lean Project Delivery System (LPDS), Poka yoke, Standard Work, VSM and Work Structuring Designing.

Meanwhile, Ogunbiyi et al. (2013) summarized many Lean tools that can be used to implement LC. These tools include 5S, VSM, JIT, visualization tool, LPS, value analysis, Kanban and Kaizen. Similarly, Salem et al. (2005), Aziz and Hafez (2013) and Bashir (2013) illustrated six LC tools which are LPS, increased visualization, 5s, FRS, DHM and Poka-yoke.

Moreover, Marhani et al. (2013) introduced nine primary tools of LC that could be implemented in the LC practice. They are LPS, productive meetings, increased visualization, off-site prefabrication, 5s, poka-yoke, root cause analysis/ five why's, FRS and JIT.

In addition to the previous tools, a variety of Lean tools are mentioned by several researchers such as, design for manufacturing and assembly (DFMA), supplier management, effective human resource management (Ogunbiyi, 2014), business process re-engineering (BPR), product circles (PCs), teamwork (Alinaitwe, 2009), value based management (Alinaitwe, 2009, Ogunbiyi et al., 2013), process redesign and employee involvement (Ogunbiyi et al., 2013). All tools are concluded in Table (2.5) with researchers who adopted them.

Table (2.5): LC Tools

LC Tools	Source
5S	Sarhan et al., 2017, Gambatese et al., 2016, Aziz and Hafez, 2013, Bashir, 2013, Marhani et al., 2013, Ogunbiyi et al., 2013, Salem et al., 2005,
5 Why's	Sarhan et al., 2017, Gambatese et al., 2016, Marhani et al., 2013
FRS	Sarhan et al., 2017, Gambatese et al., 2016, Aziz and Hafez, 2013, Bashir, 2013 , Marhani et al., 2013, Salem et al., 2005

Table (2.5): LC Tools

LC Tools	Source
JIT	Sarhan et al., 2017, Gambatese et al., 2016, Ogunbiyi, 2014, Ogunbiyi et al., 2014, , Aziz and Hafez, 2013, Ogunbiyi et al., 2013, Alinaitwe, 2009,
Kanban	Sarhan et al., 2017, Gambatese et al., 2016, Ogunbiyi et al., 2013
LPS	Sarhan et al., 2017, Gambatese et al., 2016, Marhani et al., 2013, Ogunbiyi et al., 2013, Aziz and Hafez, 2013, Bashir, 2013, Alinaitwe, 2009, Salem et al., 2005
Poka-yoke	Sarhan et al., 2017, Gambatese et al., 2016, Aziz and Hafez, 2013, Bashir, 2013, Marhani et al., 2013, Salem et al., 2005
Standard Work	Sarhan et al., 2017, Gambatese et al., 2016
VSM	Sarhan et al., 2017, Gambatese et al., 2016, Ogunbiyi et al., 2013
Increased visualization	Sarhan et al., 2017, Aziz and Hafez, 2013, Bashir, 2013, Marhani et al., 2013, Ogunbiyi et al., 2013, Salem et al., 2005
DHM	Sarhan et al., 2017, Aziz and Hafez, 2013, Bashir, 2013, Salem et al., 2005
TVD	Sarhan et al., 2017
Partnering	Sarhan et al., 2017
CAD	Sarhan et al., 2017
Six Sigma	Sarhan et al., 2017
TPM	Sarhan et al., 2017, Ogunbiyi, 2014, Ogunbiyi et al., 2013, Alinaitwe, 2009
TQM	Sarhan et al., 2017, Ogunbiyi, 2014, Ogunbiyi et al., 2013, Alinaitwe, 2009
CE	Sarhan et al., 2017, Ogunbiyi et al., 2013, Alinaitwe, 2009
Andon	Gambatese et al., 2016
IPD	Gambatese et al., 2016
Kaizen	Gambatese et al., 2016, Ogunbiyi et al., 2013, Ogunbiyi, 2014

Table (2.5): LC Tools

LC Tools	Source
Kitting	Gambatese et al., 2016
LPDS	Gambatese et al., 2016
Work Structuring Designing	Gambatese et al., 2016
Value analysis	Ogunbiyi et al., 2013
Productive meetings	Marhani et al., 2013
Off-site prefabrication	Marhani et al., 2013
DFMA	Ogunbiyi, 2014
Supplier management	Ogunbiyi, 2014
Effective human resource management	Ogunbiyi, 2014
BPR	Alinaitwe, 2009
PCs	Alinaitwe, 2009
Teamwork	Alinaitwe, 2009
Value based management	Ogunbiyi et al., 2013, Alinaitwe, 2009
Process redesign	Ogunbiyi et al., 2013
Employee involvement	Ogunbiyi et al., 2013

2.4.2 Lean Construction tools related to safety

LC tools positively impact safety practices (Losonci and Demeter, 2013). The relationship between LC and safety work focus on the implementation of LC tools as drivers of improving safety (Awada et al., 2016, Nahmens and Ikuma, 2009). The construction firm has to identify the appropriate LC tools to address certain form of safety issue (Bashir, 2013). LC tools and their techniques can be used to minimize accidents and promote safety on construction projects (Awada et al., 2016, Enshassi and Abu Zaiter, 2014, Bashir et al., 2011, Bashir et al., 2010, Nahmens and Ikuma, 2009, Mitropoulos et al, 2007). For instance, poorly organized workplace has been identified as one of the causes of accidents on construction sites (Khosravi et al., 2014, Bashir, 2013, Suraji et al., 2001). LC tools such as 5S (housekeeping) is used to solve the problem of poorly organized workplace by their techniques (Bashir et al., 2011)

Bashir et al. (2011) revealed that LPS, 5S and Poka-yoke have a significant effect on safety improvement. Continuous improvement (Kaizen) has positive effects on safety, as well (Cudney et al., 2015, Forman, 2013, Gnoni et al. 2013, Nahmens and Ikuma, 2009). Enshassi and Abu Zaiter (2014) and Bashir (2013) explained that LC tools of LPS, increased visualization, 5S, Poka Yoke, DHM and FRS can be used to promote safety in construction projects. In addition, 5 Why's is another tool can be used to improve safety in construction projects (Bashir, 2013).

Most of researcher adopted LPS as LC tool to reduce the onsite causes of accidents (Camuffo, et al., 2017, Awada et al., 2016, Gambatese et al., 2016, Pestana and Gambatese, 2016, Enshassi and Abu Zaiter, 2014, Gambetese and Pestana, 2014, Bashir, 2013, Forman, 2013, Bashir et al., 2011, Forman, 2010, Nahmens and Ikuma, 2009, Mitropoulos et al., 2007, Salem et al., 2005). Additionally, 5S is another tool studied by many researchers to improve safety in construction industry (Awada et al., 2016, Pestana and Gambatese, 2016, Cudney et al., 2015, Gambetese and Pestana, 2014, Enshassi and Abu Zaiter, 2014, Bashir, 2013, Bashir et al., 2011, Nahmens and Ikuma, 2009, Salem et al., 2005). LC tools which have a significant impact on safety are illustrated in table (2.6) with researchers adopted them.

Table (2.6): LC tools related to safety

LC Tools	Source
LPS	Camuffo, et al., 2017, Awada et al., 2016, Gambatese et al., 2016, Pestana and Gambatese, 2016, Enshassi and Abu Zaiter, 2014, Gambetese and Pestana, 2014, Bashir, 2013, Forman, 2013, Bashir et al., 2011, Forman, 2010, Nahmens and Ikuma, 2009, Mitropoulos et al., 2007, Salem et al., 2005
Increased visualization	Awada et al., 2016, Enshassi and Abu Zaiter, 2014, Bashir, 2013, Salem et al., 2005
5S	Awada et al., 2016, Pestana and Gambatese, 2016, Cudney et al., 2015, Gambetese and Pestana, 2014, Enshassi and Abu Zaiter, 2014, Bashir, 2013, Bashir et al., 2011, Nahmens and Ikuma, 2009 , Salem et al., 2005
Poka-yoke	Enshassi and Abu Zaiter, 2014, Bashir, 2013, Bashir et al., 2011, Mitropoulos et al., 2007, Salem et al., 2005

Table (2.6): LC tools related to safety

LC Tools	Source
DHM	Enshassi and Abu Zaiter, 2014, Bashir, 2013, Salem et al., 2005
5 Why's	Bashir, 2013, Saurin et al., 2006, Howell et al., 2002
FRS	Enshassi and Abu Zaiter, 2014, Bashir, 2013, Salem et al., 2005
Kaizen	Cudney et al., 2015, Forman, 2013, Gnoni et al. 2013, Nahmens and Ikuma, 2009.

Most of researchers revealed that the previous tools of LC (LPS, increased visualization, 5S, Poka yoke, DHM, 5 whys, FRS and Kaizen) are the best tools to promote safety in construction industry. Therefore, this study will discuss these tools broadly with their impact on the onsite causes of accidents.

2.4.2.1 Last Planner System (LPS)

LPS is a system of production control, introduced by Glenn Ballard since 1992, that emphasizes the relationship between scheduling and production control to create a reliable workflow (Sarhan et al., 2017, Awada et al., 2016, Enshassi and Abu Zaiter, 2014, Salem et al., 2014, Shang and Pheng, 2014, Ogunbiyi, 2014, Aziz and Hafez, 2013, Ogunbiyi et al., 2012, Bashir et al., 2011). The role of LPS is to replace optimistic planning with realistic planning by evaluating the workers' performance based on their ability to achieve their commitments (Salem et al., 2014, Enshassi and Abu Zaiter, 2014, Bashir et al., 2011).

LPS is similar to the Kanban (Pull system) in Lean Manufacturing (LM) (Salem et al., 2005). According to Chahal and Narwal (2017), the pull systems are a Lean approach developed in the automotive industry as a mechanism to pull materials and parts throughout the value stream on a JIT basis. Similarly, LPS is a pull controlling methodology which allows tasks to start only when all the constraints have been removed (Seppänen et al., 2010). LPS relied on Should Can Will Did analysis (Shang and Pheng, 2014). LPS analyzed what should be done, what can be done, what will be done and what has been done (Issa, 2013). Lean practitioners believed that implementation of the LPS is the most beneficial to the safety (Pestana and Gambetese, 2016, Gambetese and Pestana, 2014). Using LPS in construction works had about 45% lower accident rate than similar work without applying LPS (Thomassen et al., 2003).

Bashir et al. (2011) demonstrated that LPS could reduce the excessive stress, time pressure and organizational pressure which are considered to be among onsite causes of accidents. Risks and hazards caused by poor planning and control and unsafe acts of workers can be eliminated by LPS, too (Nahmens and Ikuma, 2009). LPS can treat other onsite causes of accidents like poor work methods, poor site supervision and physical and mental disability (Bashir, 2013).

Lean practitioners should work hand-in-hand with safety professionals to integrate safety in the planning process (Pestana and Gambatese, 2016). At the planning stages, the different risks and hazards can be identified in advance and effective decisions can be made to mitigate them (Pestana and Gambatese, 2016, Gnoni et al., 2013, Bashir et al., 2011, Nahmens and Ikuma, 2009). LPS is based on four planning stages: the master plan, the six week look ahead plan, weekly work plan (Ogunbiyi et al., 2012, Sacks et al., 2009) and percent plan complete (PPC) (Shang and Pheng, 2014, Issa, 2013). Safety is incorporated into the production planning and control processes at these stages as followed:

- **At the master plan stage**: what should be done (Issa, 2013). It represents the overall project schedule (Salem et al., 2014, Ogunbiyi et al., 2012). It captures the entire task to be executed throughout the project and shows the completion time and means required for each activity (Daniel et al., 2017). Safety could be incorporated by selecting appropriate work methods, make provision for safety equipment and develop a schedule of tasks based on workers' abilities and skills. This minimizes accidents caused by poor work methods, workers' inability and inadequate safety equipment (Bashir, 2013, Bashir et al., 2011).
- **At the six week look ahead stage**: what can be done (Issa, 2013). It reflects works to be completed for the next 6 to 8 weeks (Shang and Pheng, 2014, Forman, 2013, Ogunbiyi et al., 2012). Safety supervisors develop a plan for supervision schedules to avoid accidents due to poor supervision (Bashir, 2013, Bashir et al., 2011). Works are carefully reviewed to identify constraints, risks and hazards and removed before actual production takes place to promote safety (Salem et al., 2014, Forman, 2013, Ogunbiyi et al., 2012, Bashir et al., 2011, Seppänen et al., 2010).
- **At the Weekly Work Plan stage (WWP)**: what will be done (Issa, 2013). It is a detailed schedule for works to be carried out the following week (Daniel et al., 2017, Shang and Pheng, 2014, Bashir, 2013). It is prepared by the site managers along with the foreman (Dave et al.,

2015) based on worker's ability and commitments. This could prevent accidents caused by poor skills among workers and organizational pressure (Bashir, 2013, Bashir et al., 2011).

- **Percent Plan Complete (PPC):** what has been done (Issa, 2013). It is a measurement metric of the LPS which reflects the progress (Bashir, 2013). The quantity and reason for any variation of each tasks on the WWP would be reflected by PPC (Shang and Pheng, 2014). It summarized reasons for why activities are not executed as planned (Thomassen et al., 2003). It is calculated by dividing the number of completed assignments by the total number of assignments each week. A high PPC reflects a well-planned production process with high workflow reliability between production units (Shang and Pheng, 2014).

The LPS has certain features that are considered to be helpful in promoting safety (Forman, 2013). This can be by:

1. Empowering workers and correlating work methods with their skills (Camuffo et al., 2017, Awada et al., 2016, Bashir, 2013). Worker needs to be empowered to make his own commitment on what day-to-day or week-to-week tasks he can actually accomplish in a given time (Enshassi and Abu Zaiter, 2014, Gao and Low, 2014). This can minimize accidents caused by time pressure, organizational pressure and excessive stress (Bashir, 2013, Bashir et al., 2011).
2. High involvement of the workers in selecting work methods and correlating it with workers' abilities (Camuffo et al., 2017, Bashir, 2013, Bashir et al., 2011, Forman 2010). Workers' involvement practices like teamwork, job rotation and decision rights delegation increases the depth and breadth of worker's abilities (Camuffo et al., 2017). This could contribute to minimize accidents caused by physical and mental disability and poor work methods (Bashir et al., 2011).
3. Involvement of the all employees in safety planning. In construction, the working environment changes among projects, so safety performance depends on the avoidance of unsafe acts by workers. This could decrease the unsafe acts of workers which is one of the onsite causes of accidents (Forman 2010, Nahmens and Ikuma, 2009).
4. Pre-task hazard analysis which prepared before an assignment was released, both inspection and root cause analysis would be improved (Sacks et al., 2009, Howell et al., 2002). It could help in risk identification and reduction (Bashir, 2013, Sacks et al., 2009).

5. Weekly work planning which can minimize the effect of poor planning on safety (Awada et al., 2016, Bashir, 2013). Table (2.7) summarizes the LPS techniques with onsite causes of accidents that can be eliminated using them.

Table (2.7): LPS techniques and relevant onsite causes of accidents

LPS techniques	Onsite causes of accidents	Sources
Make provision for safety equipment	Inadequate safety equipment	Bashir, 2013, Bashir et al., 2011, Sack et al., 2005
Develop a plan for supervision	Poor supervision	Bashir, 2013, Bashir et al., 2011
Develop a schedule based on worker's abilities and commitments	High percentage of unskilled workers, Organizational pressure	Bashir, 2013, Bashir et al., 2011
Workers' empowerment in assignment scheduling	Time pressure, organizational pressure and excessive stress	Camuffo et al., 2017, Gao and Low, 2014, Bashir, 2013, Bashir et al., 2011, Hasle, 2011, Forman, 2010
Correlating work methods with worker's skills	Excessive stress	Camuffo et al., 2017, Bashir, 2013, Bashir et al., 2011, Mitropoulos et al., 2007
Worker involvement in task planning	Lack of motivation	Gambetese et al., 2016, Gambetese and Pestana, 2014, Bashir, 2013, Gnoni et al., 2013, Bashir et al., 2011, Hasle, 2011, Saurin et al., 2006
Correlating work method with worker's ability	Physical and mental disability	Bashir, 2013, Bashir et al., 2011
Involvement of all employees in safety planning	Unsafe acts of workers	Nahmens and Ikuma, 2009
Pre task hazard analysis	Risk identification and reduction	Gambetese et al., 2016, Pestana and Gambatese, 2016, Gambetese and Pestana, 2014, Bashir, 2013, Bashir et al., 2011, Sacks et al., 2009, Howell et al., 2002

Table (2.7): LPS techniques and relevant onsite causes of accidents

LPS techniques	Onsite causes of accidents	Sources
Weekly work planning	Poor planning, poor site management	Gambetese and Pestana, 2014, Bashir, 2013, Bashir et al., 2011

2.4.2.2 Increased visualization

The increased visualization is a LC tool about communicating key information to the workers using visual devices like various signs and labels around the construction site (Sarhan et al., 2017, Enshassi and Abu Zaiter, 2014, Ogunbiyi, 2014, Bashir, 2013, Salem et al., 2005). Visual devices enable someone to walk into the workplace and know within a short period of time what's happening regard some elements as workflow, performance targets, and specific required actions (Sarhan et al., 2017, Kilpatrick, 2003).

Visual devices includes signs related to safety, schedule, and quality (Bashir, 2013, Abdelhamid and Salem, 2005, Salem et al., 2005). It could be used to provide immediate and visual information that enables people to make correct decisions and manage their work and activities properly (Chahal and Narwal, 2017, Kilpatrick, 2003). Increased visualization can be identified as one of the key principles of promoting safety on the construction site (Enshassi and Abu Zaiter, 2014, Fewings, 2013). It is similar to the tool of visual controls used in Lean Manufacturing (LM) (Awada et al., 2016, Salem et al., 2005).

The visualization technique is used to monitor the construction workers and warn supervisor if they are not using hard hats, for instance. In this technique, camera are installed in the construction sites and real time images are transferred to the computers. These images are continuously displayed on an office computer. From the real time images, the algorithm will detect whether the construction workers are using hard hats. Once the algorithm identifies a worker working without hard hat, it automatically dispatches a warning message to the safety officer (Shrestha et al., 2011).

It can be extended to safety purposes using safety signs and visual demarcations and boards (Saurin et al., 2006). Safety signs and boards used to display current accident rates which allow all workers to identify issues, the boundaries for safe performance and compare the expected safety performance (Enshassi and Abu Zaiter, 2014). The boundary beyond works should be made very visible to the workers to prevent accidents caused by human error (Mitropoulos et al. 2007, Saurin et al., 2006). This can achieved by visual demarcations and boards (Bashir, 2013).

A major strength of visual devices is that the information is promptly available to a wide range of employees (Saurin et al., 2006). It could communicate vital information to workers with low levels of knowledge and poor site awareness which could reduce the likelihood of accidents occurring (Bashir, 2013). Safety signs and labels could potentially reduce accidents caused by poor communication (Aziz and Hafez, 2013, Bashir, 2013, Arleroth and Kristensson, 2011). Additionally, using safety signs and labels helps workers to identify workstations and pathways easily. It can assists in reducing chances of errors and mistakes which could lead to accidents (Sarhan et al., 2017, Sacks et al. 2009, Kilpatrick, 2003).

One of the major causes of accidents is unsafe site conditions, which basically is due to inadequate supervision with poor visualization (Awada et al., 2016, Enshassi and Abu Zaiter, 2014, Shrestha et al., 2011). By improving visibility, effective visual workplace will be produced which lead to effective work conditions (Anvari et al., 2011b) and reducing hazards such as chemical exposures and tripping/falling hazards (Bashir, 2013, Nahmens and Ikuma, 2009).

Although visual devices are beneficial to decrease different forms of hazards, many hazards can’t be easily and visually discriminated as workers fatigue (Bashir, 2013, Saurin et al., 2006). Moreover, using signs in large quantities could be distractive and impacting negatively on safety, so using signs on the construction sites should be in proper quantities to have positive outcome in safety improvement (Saurin et al., 2006). Table (2.8) summarizes the increased visualization techniques that can be used to minimize the onsite causes of accidents.

Table (2.8): Increased visualization techniques and relevant onsite causes of accidents

Increased visualization techniques	Onsite causes of accidents	Source
Camera connected with computer algorithm to warn safety officer	Safety violation	Shrestha et al., 2011
Visual demarcations and boards	Human error	Bashir, 2013

Table (2.8): Increased visualization techniques and relevant onsite causes of accidents

Increased visualization techniques	Onsite causes of accidents	Source
Safety signs and labels	High percentage of uneducated workers, poor site awareness	Sarhan et al., 2017, Bashir, 2013, Saurin et al., 2006
Safety signs and labels	Poor communication	Aziz and Hafez, 2013, Bashir, 2013, Arleroth and Kristensson, 2011
Safety signs and labels	Human error	Sarhan et al., 2017, Enshassi and Abu Zaiter, 2014, Sacks et al. 2009, Kilpatrick, 2003
Visibility improvement	Unsafe site conditions	Anvari et al., 2011b
Visibility improvement	Poor supervision	Awada et al., 2016, Enshassi and Abu Zaiter, 2014, Shrestha et al., 2011
Visibility improvement	Exposure to hazards as chemical exposure and tripping/falling hazards	Bashir, 2013, Nahmens and Ikuma, 2009

2.4.2.3 The 5S (House-keeping)

5S is a systematic method focuses on organizing and standardizing the workplace (Bashir, 2013, Bashir et al., 2011, Abdulmalek and Rajgopal, 2007, Kilpatrick, 2003). Sometimes, 5S referred to the visual work place. It is about a place for everything and everything in its place. (Anerao and Deshmukh, 2016, Ogunbiyi, 2014, Salem et al., 2005). It is one of the simplest Lean tools to implement (Kilpatrick, 2003). Because of that, it is considered as the first step should be taken by the organization to implement LC (Bashir et al., 2011). On the other hand, from a worker safety stand point, implementing 5S's can be viewed as less effective as incorporating safety into LPS (Pestana and Gambatese, 2016). This tool is similar to the 5S housekeeping system from LM (Abdelhamid and Salem, 2005, Salem et al., 2005).

5S focuses on establishing visual order, organization, cleanliness, and standardization which leads to improved safety, creation of space, improved teamwork, and continuous improvement (kaizen activities) (Cudney et al., 2015, Modi and Thakkar, 2014, Ogunbiyi, 2014, Ogunbiyi et al., 2014, Anvari et al., 2011b). Good housekeeping is a well-known practice that leads to safer jobsites (Pestana and Gambatese, 2016). Bashir et al. (2011) believed that adopting 5S improve ergonomics and reduces workers exposure to hazards which cause injuries. It reduces confusion, extra steps, and on-the-spot decisions, and therefore reduces motion and decreases trip and fall hazards (Pestana and Gambatese 2016, Nahmens and Ikuma, 2009)

5S is a Lean tool derived from five Japanese words: Seiso (shine), Seiton (straighten), Seiri (sort), Seiketsu (standardize) and Shitsuke (sustain), as a foundation for continuous improvement (Sarhan et al., 2017, Pestana and Gambatese 2016, Cudney et al., 2015, Modi and Thakkar, 2014, Bashir, 2013, Anvari et al., 2011b, Vieira and Cachadinha, 2011, Abdelhamid and Salem, 2005). These 5S practices are not independent but correlative. According to Bashir (2013), the components of 5S tool seems to have a potential for reducing accidents on construction sites. Which is explained below:

- **Seiso** (shine): it means to clean up the site (Cudney et al., 2015, Ogunbiyi, 2014, Vieira and Cachadinha, 2011, Abdelhamid and Salem, 2005, Salem et al., 2005). It involves removing all objects and materials from unwanted places and keeping away materials and machines/items that are not required to be used within that period. This could result in preventing accidents caused by site congestion and obstruction (Bashir, 2013, Bashir et al., 2011). Additionally, cleaning the workplace could potentially reduce accidents caused by site hazards like dust (Nahmens and Ikuma 2009) and untidy site (Bashir, 2013).
- **Seiton** (Straighten or set in order): it refers to arrange tools and materials for ease of use (Cudney et al., 2015, Abdelhamid and Salem, 2005, Salem et al., 2005). It involves placing all materials and plants at their optimal location for ease identification and promote orderliness in the workplace (Ogunbiyi, 2014, Bashir, 2013, Bashir et al., 2011, Vieira and Cachadinha, 2011). This reduces congestion, promotes convenience and eases movement and circulation on the site (Bashir, 2013). Hence, the chances of slipping and tripping are minimized (Bashir et al., 2011).
- **Seiri** (Sort): it refers to separate the needed tools and remove unneeded from the workplace (Anerao and Deshmukh, 2016, Cudney et al., 2015, Ogunbiyi, 2014, Bashir et al., 2011, Vieira and Cachadinha, 2011, Salem et al., 2005). As a result, cleanliness and safer working environment could be achieved (Salem et al., 2005). This could minimize accidents caused by

site congestion and makes circulation and movement safer on the site (Bashir et al., 2011). According to Nahmens and Ikuma (2009), clearing the unwanted materials resulted in a free flow of materials, circulation and safer movement. This could reduce chances of trips, falls and exposure to hazards.

- **Seiketsu** (standardize): is to maintain the first 3Ss. It is ensured that the workplace has common standards and ways of working (Tezel and Aziz, 2016, Abdelhamid and Salem, 2005). It seeks to define standard procedures to maintain the working environment clean and organized (Cudney et al., 2015, Ogunbiyi, 2014, Bashir, 2013, Bashir et al., 2011, Vieira and Cachadinha, 2011). A significant level of cleanliness and orderliness is required to achieve the maximum safety on construction sites (Bashir, 2013, Bashir et al., 2011). This could address poor safety culture among workers on construction sites, which is a determinant of accident (Bashir, 2013).
- **Shitsuk** (sustain): it refers to create the habit of conforming to the rules (Anerao and Deshmukh, 2016, Ogunbiyi, 2014, Abdelhamid and Salem, 2005, Salem et al., 2005). It is about ensuring that the company continue to continually improve using the previous stages of 5S, maintain housekeeping, and conduct audits and so forth (Tezel and Aziz, 2016). It also about implement methods to sustain the process (Cudney et al., 2015) and make 5S a way of life (Anvari et al., 2011b) and become part of the culture of the business and the responsibility of everyone in the organization (Tezel and Aziz, 2016). Shitsuke emphasizes a continuous improvement in safety culture among the workforce (Bashir, 2013). This would enable the workers to adopt orderliness and cleanliness as a continuous and permanent habit on site (Bashir et al., 2011). Table (2.9) summarizes the 5S techniques that can be used to minimize the onsite causes of accidents.

Recently, 5S was expanded to 6S by the addition of safety (Li et al., 2016, Anvari et al., 2011b, Nahmens and Ikuma 2009). 6S is a method used to create and maintain a clean, orderly and safe work environment. The first five of these elements were taken from the Toyota Management System (TMS) but the sixth ‘S’ was added by Universal Coordinated Time to emphasize safety in the workplace (Anvari et al., 2011b). They work together to support continuous improvement efforts in a company (Nahmens and Ikuma 2009).

Table (2.9): 5S (Housekeeping) techniques and relevant onsite causes of accidents

5S components	5S techniques	Onsite causes of accidents	Sources
Seiso (Shine)	Removing materials and machines that are not required to be used within that period	Site congestion	Bashir, 2013, Bashir et al., 2011
	Cleaning the workplace	Site hazards like dust, noise	Bashir, 2013, Nahmens and Ikuma, 2009
	Cleaning the workplace	Poorly organized site	Bashir, 2013
Seiton (Set in order)	Material and plant organization	Site congestion, Falling, slipping and tripping accidents	Bashir, 2013, Bashir et al., 2011
Seiri (Sort)	Separating needed tools from unneeded materials	Site congestion	Bashir et al., 2011
	Clearing the unwanted materials	Trips, falls and exposure to hazards	Nahmens and Ikuma, 2009
Seiketsu (Standardize)	Define standard procedures to maintain the working environment clean and organized	Poor safety culture	Bashir, 2013, Bashir et al., 2011
Seiketsu (Sustain)	Continuous improvement in safety culture among the workforce	Poor safety culture	Bashir, 2013, Bashir et al., 2011

2.4.2.4 Error-proofing (Poka-yoke)

Poka-yoke is a Japanese word for error proofing or fail-safe (Sarhan et al., 2017, Bashir, 2013). It is a Lean tool involves all measures taken to prevent an error from occurring (Sarhan et al., 2017, Ogunbiyi, 2014, Abdelhamid and Salem, 2005). It is a way of avoiding inadvertent errors in simple ways and cost effective (Anvari et al., 2011a). It is a concept that deals with basically what people can do to avoid errors in the workplace (Bashir et al., 2011). These errors could be quality problems, delays in delivering a mid-process product, safety issues and so on (Enshassi and Abu Zaiter, 2014, Anvari et al., 2011a). The concept of Poka-yoke relies on the generation of ideas that alert for potential defects (Abdelhamid and Salem, 2005, Salem et al., 2005).

This is similar to visual inspection tool (Poka- Yoke devices) from LM (Ogunbiyi, 2014, Abdelhamid and Salem, 2005, Salem et al., 2005). Poka-yoke can be extended to safety but there are potential hazards instead of potential defects (Ogunbiyi, 2014, Abdelhamid and Salem, 2005, Salem et al., 2005). In situations where an error occurs, the Poka-yoke could minimize or prevent its impacts on the workers, product or the environment (Bashir et al., 2011). Poka-yoke concentrates on all techniques that could contribute to reduction of accidents on construction sites. It is widely known to be very useful to deal with human errors which is one of the major causes of accidents. (Bashir, 2013). These technique include visual inspection and error-proofing devices such as gadgets alerts (Bashir et al., 2011, Saurin et al., 2006).

Visual inspection could potentially reduce accidents caused by poor supervision (Bashir, 2013). While gadgets warning raise alarms of the occurrence of an unwanted event or automatically shuts down to prevent errors and their impacts (Bashir et al., 2011, Saurin et al., 2006). For instance, equipment failure is a major cause of accident (Loughborough and UMIST, 2003). Poka yoke devices could be attached to the equipment to alert workers in case of faults or failures (Bashir et al., 2011). In some cases, alarms and warning gadgets used to prevent workers from approaching or crossing into unsafe boundaries on site (Saurin et al., 2006).

To promote safety, error-proofing devices could be used to prevent the occurrence of errors instead of protecting workers (Saurin et al. 2006). Even when errors or accidents occur, the techniques will prevent or minimize their impact (Bashir, 2013). For instance, the use of safe guards and PPE devices could protect workers from wide range of hazards and absorb several possible errors (e.g. a hard hat protects a construction workers head from being stuck by a falling object) (Bashir et al., 2011, Saurin et al., 2006). According to Saurin et al., (2006), these devices could also protect workers from excess heat, sound, noise, dust and some other site hazards. Table (2.10) summarizes the Poka yoke techniques with onsite causes of accidents that can be eliminated using them.

Table (2.10): Poka yoke techniques and relevant onsite causes of accidents

Poka yoke techniques	Onsite causes of accidents	Source
Visual inspection	Poor supervision	Bashir, 2013
Alarms and warning gadgets	Equipment failure	Bashir et al., 2011, Saurin et al., 2006
Alarms and warning gadgets	Crossing unsafe boundaries	Saurin et al., 2006
Safe guards and PPE	Falling objects	Bashir et al., 2011, Saurin et al., 2006
Safe guards and PPE	Site hazards: excess heat, sound, noise, dust	Saurin et al., 2006

2.4.2.5 Daily huddle meeting (DHM)

A 5 to 10 minute meeting at the beginning of a shift to focus the crew on that day’s expectation for safety and work to be accomplished (Mastroianni and Abdelhamid, 2003). DHM is a LC tool where a brief daily start-up meeting is conducted (Bashir, 2013). It allows the team members to present briefly of what they have been working on since the last meeting and discuss problem that prevent the completion of an assignment (Sarhan et al., 2017, Ogunbiyi, 2014, Aziz and Hafez, 2013, Salem et al., 2005). This is done to create a forum to develop a team and to have the team members feel like they part of something through the sharing of information (Mastroianni and Abdelhamid, 2003). The huddle meeting increases employee‘s job satisfaction, since it encourages two way communications between team and its leader (Ogunbiyi, 2014, Bashir, 2013, Ogunbiyi et al., 2013).

Two-way communication is the key of the DHM process in order to achieve employee involvement (Sarhan et al., 2017, Ogunbiyi, 2014, Ogunbiyi et al., 2013). During the meeting, workers being encouraged to discuss the good and bad aspects of their tasks and empowered to suggest ways to solve these problems together (Sarhan et al., 2017, Ogunbiyi, 2014, Bashir, 2013, Ogunbiyi et al., 2013). Therefore, the problem of poor communication and coordination could be reduced. Meetings are part of continuous improvement opportunities that could be used to identify and reduce safety hazards on construction sites. It also gives room for enlightening and educating the workers, which is vital to promote safety. As a result, the accidents caused by lack of safety awareness among worker would be decreased (Bashir, 2013). Table (2.11) summarizes the onsite causes of accidents that could be reduced by DHM.

Table (2.11): DHM and relevant onsite causes of accidents

LC tool	Onsite causes of accidents	Source
DHM	Poor communication and coordination	Bashir, 2013
	Risk identification and reduction	Bashir, 2013
	Lack of safety awareness	Bashir, 2013

2.4.2.6 First run studies (FRS)

In order to achieve continuous improvement in the production process. FRS are used to plan out the critical tasks (Sarhan et al., 2017, Bashir, 2013, Nahmens and Ikuma, 2009, Salem et al., 2005). The first run of a selected assignment should be examined in detail, bringing ideas and suggestions to explore alternative ways of doing the task (Sarhan et al., 2017, Ogunbiyi, 2014, Bashir, 2013, Salem et al., 2005). FRS include productivity studies and review work methods by redesigning and streamlining the different functions involved (Bashir, 2013).

The PDCA (plan, do, check, and act) cycle is used to develop the first-run study (Sarhan et al., 2017, Ogunbiyi, 2014, Nahmens and Ikuma, 2009, Salem et al., 2005). Plan refers to select work process to study, assemble people, analyze process steps, brainstorm how to eliminate steps, check for safety, quality and productivity (Salem et al., 2005). Do means to try out ideas on the first run. Check is to describe and measure what actually happens. Act refers to reconvene the team and communicate to improve method and performance as the standard (Abdelhamid and Salem, 2005).

FRS involves the practices of critical task planning which aims at studying the task, reviewing different work methods to identify the most appropriate method that matches the workers ability and convenience. This minimize the accidents caused by poor planning and the human errors (Bashir, 2013, Mitropoulos et al., 2007). Using video files, photos or illustrations to show the method or illustrate the work instruction is another practice of FRS (Salem et al., 2005). It can be used to reduce accidents caused by low level of knowledge and poor site awareness (Bashir, 2013). Table (2.12) summarizes techniques of FRS that can be used to reduce the onsite causes of accidents.

Table (2.12): FRS and relevant onsite causes of accidents

FRS techniques	Onsite causes of accidents	Sources
Critical task planning	Poor planning, human error, poor work methods	Bashir, 2013, Mitropoulos et al., 2007
Work methods illustration using videos, photos, etc.	High percentage of uneducated workers and poor site awareness	Bashir, 2013

2.4.2.7 Continuous improvement (Kaizen)

The Japanese word for continuous improvement (CI) is Kaizen (Sarhan et al., 2017, Vieira and Cachadinha, 2011, Senaratne and Wijesiri, 2008). Kaizen is a Lean tool used for rapid process improvement (Ikuma et al., 2011). It is based on the concept of a cyclical process which can involve people, materials or equipment which seeks to improve the processes performance involving all activities (Sarhan et al., 2017, Vieira and Cachadinha, 2011). Kaizen is a methodology that seeks to achieve perfection (Vieira and Cachadinha, 2011). Nahmens and Ikuma (2009) stated that there was a relationship between builders that use CI programs and safety outcomes. Accident rates were significantly lower among builders with a CI program.

The key features of a continuous improvement process are that everybody is involved in the improvement process and they should never accept the status quo (Bayfield and Roberts, 2005). Most notably, Kaizen involves line workers in decision processes for improvements and focuses on making quick and feasible changes (Ikuma et al., 2011). Decisions regarding the elimination and control of safety hazards can be incorporated into kaizen events (Ikuma et al., 2011, Nahmens and Ikuma, 2009). For addressing safety hazards in the workplace, the National Safety Council's Hierarchy of Controls should be followed:

1. Determine if the hazard can be eliminated completely or if it must be controlled.
2. If the hazard cannot be eliminated, the second step is to determine how the hazard can be controlled: through engineering controls using process design, administrative changes, personal protective equipment (PPE), or some combination of these three alternatives.
3. If any hazards cannot be completely resolved through process design, then it will be controlled by administrative changes or PPE, which may also be considered through continuous improvement activities (Nahmens and Ikuma, 2009). Table (2.13) summarizes techniques of Kaizen that can be used to reduce the onsite causes of accidents.

Table (2.13): Kaizen and relevant onsite causes of accidents

Kaizen techniques	Onsite causes of accidents	Sources
Involvement of all employees in improvement process	Poor communication and coordination	Bayfield and Roberts, 2005
Pre task hazard analysis	Risk identification and reduction	Nahmens and Ikuma, 2009

2.4.2.8 The Five Why's

The five why's tool is also known as accident investigation tool (Bashir, 2013, Razuri et al., 2007). The five times repetition of "why" (5 whys) when facing a problem helps to find the root cause of construction related problem (Sarhan et al., 2017, Bashir, 2013). The name originated from the fact that "why" needs to be asked at least five times to find the root cause of a problem. The tool simply requires the workforce and the management to ask "why?" over and over when a problem occurs (Gambetese and Pestana, 2014, Bashir, 2013).

Razuri et al. (2007) identified 5why's or accident investigation as a key technique in safety management. By conducting the accident investigation, the root causes of accidents could be identified as well as the ways to prevent them from reoccurrence (Bashir, 2013). Therefore, the number of accidents on construction sites can be reduced if the causes of those accidents can be identified and eliminated (Wong et al., 2016, Chi and Han, 2013, Enshassi, 2010). Table (2.14) summarizes techniques of 5why's that can be used to reduce the onsite causes of accidents.

Table (2.14): 5why's technique and relevant onsite causes of accidents

5why's techniques	Onsite causes of accidents	Sources
Accident investigation and root-cause analysis program	Risk identification and reduction	Wong et al., 2016, Bashir, 2013, Chi and Han, 2013, Enshassi, 2010, Razuri et al., 2007

2.4.3 Summary

The previous objective was to investigate the level of implementing LC techniques to improve safety in construction projects. This objective presented the LC tools that were adopted by many researchers. It is specialized to explain broadly of how LC tools and techniques could be used to reduce accidents and promote safety on construction sites. It also studied the integration of LC tools and onsite causes of accidents. The most important points could be concluded from this objective are:

- Despite the significant efforts and large number of publications on LC, Lack of awareness of LC is still one of the major challenges to implement LC.
- To implement Lean thinking in construction, researchers developed the LM tools and techniques that conform to LC concepts and principles.
- This research explained broadly the LC tools that can positively impact safety practice by their features which are LPS, increased visualization, 5S, DHM, Poka yoke, FRS, Kaizen and 5 whys.
- LPS and 5S are the most efficient tools to be implemented on construction sites to promote safety.
- Continuous improvement is a LC tool which is incorporated in all tools. It is always used to determine the most efficient tool to eliminate accidents on construction sites.
- The previous section explained the integration of LC tools to reduce the onsite causes of accidents. This can be summarized in Table (2.15) which provides a guide to investigate the correlation between LC and safety.

Table (2.15): Lean tools and techniques relevant to onsite causes of accidents

Onsite causes of accidents	LC techniques	LC tools
Inadequate safety equipment	Make provision for safety equipment	LPS
Poor supervision	Develop a plan for supervision	LPS
	Visibility improvement	Increased visualization
	Visual inspection	Poka yoke
High percentage of unskilled workers	Develop a schedule based on worker's abilities and commitments	LPS
High percentage of uneducated workers	Illustration of work methods using videos, photos, etc.	FRS
	Safety signs and labels	Increased visualization

Table (2.15): Lean tools and techniques relevant to onsite causes of accidents

Onsite causes of accidents	LC techniques	LC tools
Poor site awareness	Illustration of work methods using videos, photos, etc.	FRS
	Safety signs and labels	Increased visualization
	DHM	DHM
Organizational pressure	Develop a schedule based on worker's abilities and commitments	LPS
	Empowering workers	LPS
	Correlating work methods with worker's skills	LPS
Time pressure and excessive stress	Empowering workers	LPS
	Correlating work methods with worker's skills	LPS
Physical and mental disability	Worker involvement in selecting work methods	LPS
	Correlating work method with worker's ability	LPS
Poor work methods	Worker involvement in selecting work methods	LPS
Unsafe acts of workers	Involvement of all employees in safety planning	LPS
Risk identification and reduction	Pre task hazard analysis	LPS, Kaizen
	Accident investigation and root-cause analysis program	5 why
	DHM	DHM
Poor planning	Weekly work planning	LPS
	Critical task planning	FRS

Table (2.15): Lean tools and techniques relevant to onsite causes of accidents

Onsite causes of accidents	LC techniques	LC tools
Human error	Safety signs and boards	Increased visualization
	Visual demarcations and boards	Increased visualization
	Safety signs and labels	Increased visualization
	Critical task planning	FRS
Poor communication and coordination	Safety signs and labels	Increased visualization
	DHM	DHM
Unsafe site conditions	Visibility improvement	Increased visualization
Poorly organized site	Cleaning the workplace	5S
Exposure to hazards as chemical exposure, excess heat, sound, noise and dust	Visibility improvement	Increased visualization
	Cleaning the workplace	5S
	Safe guards and PPE	Poka yoke
	Clearing the unwanted materials	5S
Site congestion	Removing materials and machines that are not required to be used within that period	5S
	Material and plant organization	5S
	Separating needed tools from unneeded materials	5S
Falling, slipping and tripping accidents	Visibility improvement	Increased visualization
	Eases movement on the site	5S
	Clearing the unwanted materials	5S

Table (2.15): Lean tools and techniques relevant to onsite causes of accidents

Onsite causes of accidents	LC techniques	LC tools
Falling objects	Safe guards and PPE	Poka yoke
Poor safety culture	Define standard procedures to maintain the working environment clean and organized	5S
	Continuous improvement in safety culture among the workforce	5S
Equipment failure	Alarms and warning gadgets	Poka yoke
Crossing unsafe boundaries	Alarms and warning gadgets	Poka yoke

Objective 2

Lean Construction techniques and its application within construction industry is reported to have resulted in a lot of benefits. Safety can benefit from the application of LC tools and LC techniques. For this reason, the second objective is specialized to quantify benefits of implementing LC techniques which is related to safety improvement in construction projects which will encourage the construction participants to adopt LC techniques in their projects.

2.5 Benefits of implementing LC techniques related to safety improvement in construction projects

The introduction of the LC concept and its application within the construction industry is reported to have a lot of benefits (Oladiran, 2017, Adegbembo et al., 2016, Bashir, 2013, Fernandez-Solis et al., 2013, Ayarkwa et al., 2012a, b, Abdullah et al., 2009). There are many reasons to include LC techniques in construction projects (Anvari et al., 2011a, Mossman, 2009, Salem et al., 2006). Application of LC techniques resulted in better planning of works (Bashir, 2013, Fernandez-solis et al., 2013, AlSehaimi et al., 2009). Therefore, greater predictability to the hazards in tasks can be attained in construction projects (Adegbembo et al., 2016, AlSehaimi et al., 2009, Mossman, 2009).

In other words, proper planning allows employees to identify tasks in advance, look at potential safety hazards and establish a smoother schedule with fewer safety hazards (Pestana and Gambatese, 2016). Therefore, the workflow variation can be reduced and the rate of workflow on-site can be improved (Oladiran, 2017, Pestana and Gambatese, 2016, Dave et al., 2015, Fernandez-solis et al., 2013, Al-Aomar, 2012, Liu et al., 2011). Moreover, having a proper project planning shortens the duration of construction project (Adegbembo et al., 2016, Pestana and Gambatese, 2016, Modi and Thakkar, 2014, Ogunbiyi et al., 2014, Fernandez-solis et al., 2013, Issa, 2013, Marhani et al., 2013).

Application of LC techniques helped workers to submit their tasks with less defects at handover and with high quality (Oladiran, 2017, Chikhalikar and Sharma, 2015, Mehra et al., 2015, Modi and Thakkar, 2014). High quality and less defects mean that percentage of rework in construction projects will be reduced (Chikhalikar and Sharma, 2015, Ogunbiyi et al., 2012).

Therefore, workers can accomplish their tasks without excessive stress which improve safety (Bashir, 2013, Bashir et al., 2011). Additionally, less rework decrease the time pressure which helps in delivering the projects on time or in some cases ahead of schedule (Dave et al., 2015, Al-Aomar, 2012, Ayarkwa et al., 2012a, Ogunbiyi et al., 2012, Mossman, 2009).

Productivity losses are among the financial costs that can be reduced by implementing the LC techniques in safety improvement (Couto et al., 2017, Sarhan et al., 2017, Adegbembo et al., 2016, Mehra et al., 2015, Khosravi et al., 2014, Modi and Thakkar, 2014, Ogunbiyi et al., 2014). Using LC techniques reduced the additional costs resulting from accidents on construction sites like medical treatment, workers' compensation, litigation cost and insurance cost (Couto et al., 2017, Oladiran, 2017, Khosravi et al., 2014, Modi and Thakkar, 2014, Salem et al., 2014, Ahuja, 2013, Bashir, 2013, Ogunbiyi et al., 2013). Increasing profit is also proved to be a benefit resulted by LC techniques (Oladiran, 2017, Chikhalikar and Sharma, 2015, Modi and Thakkar, 2014, Mossman, 2013, Al-Aomar, 2012, Nesensohn et al., 2012, Zhou, 2012, Ogunbiyi et al., 2011, Mossman, 2009)

According to Bashir (2013), Al-Aomar (2012), Anvari et al. (2011a) and Zhou (2012), construction firms can be more competitive by improving work efficiency which are both recorded as benefits resulting from the implementation of LC techniques. Work efficiency can be promoted by reducing people's workload (Mehra et al., 2015, Ogunbiyi et al., 2014, Bashir, 2013, Ogunbiyi et al., 2012, Gapp et al., 2008, Salem et al., 2005).

Application of LC techniques led to reduce wastes on site which improve safety in construction projects (Oladiran, 2017, Chikhalikar and Sharma, 2015, Modi and Thakkar, 2014, Ahuja, 2013, Bashir, 2013, Ogunbiyi et al., 2013, Al-Aomar, 2012, Ayarkwa et al., 2012a). Moreover, site organization is also proved to be a benefit of LC techniques' application (Oladiran, 2017, Bashir, 2013). Construction site can be organized by removing clutter and reducing the congestion at workspace (Oladiran, 2017, Mehra et al., 2015, Bashir, 2013). Site organization also facilitate the coordination in tools handling (Oladiran, 2017). As a result, space can be created to increase the employees' convenience in workplace (Modi and Thakkar, 2014, Ogunbiyi et al., 2014, Bashir, 2013, Salem et al., 2005, Kilpatrick, 2003).

Tezel and Aziz (2016) stated that the implementation of LC techniques helped in distinguishing dangerous places from safe places which leads to zero injuries. While Oladiran (2017) and Ahuja (2013) found that reducing site hazards such as noise and dust; and control the construction site environmentally are benefits attained by application of LC techniques which resulted in making the workplace safety. Increased workplace safety is translated into safer work conditions for employees and exposure to risk can be reduced (Bashir, 2013, Vieira and Cachadinha, 2011). These procedures should lead to a decrease of number of accidents (Bashir, 2013, Vieira and Cachadinha, 2011).

Bashir (2013) stated that the application of LC techniques resulted in having a better safety management plan. LC techniques helped to promote better safety performance and maintain a standard safety culture which leads to improve the workers' safety (Oladiran, 2017, Sarhan et al., 2017, Adegbembo et al., 2016, Pestana and Gambatese, 2016, Gambetese and Pestana, 2014, Ogunbiyi et al., 2014, Singh et al., 2014). Employees can clearly know the critical work areas and events duration (Pestana and Gambatese, 2016, Cerveró-Romero et al., 2013).

As a result, project stakeholders will be satisfied about the completed project (Oladiran, 2017, Sarhan et al., 2017, Adegbembo et al., 2016, Singh et al., 2014, Bashir, 2013, Ogunbiyi et al., 2013). Stakeholders satisfaction create a trust bond and transparency between the parties (Sarhan et al., 2017, Adegbembo et al., 2016, Dave et al., 2015, Ogunbiyi et al., 2013, Ayarkwa et al., 2012a, Gapp et al., 2008).

LC techniques assist in increasing employee empowerment and involvement to discuss and resolve work place problems and increases their awareness to create and maintain a safer workplace (Mehra et al., 2015, Gambetese and Pestana, 2014, Bashir, 2013, Al-Aomar, 2012, Ogunbiyi et al., 2012, Salem et al., 2005). Engaging of all employees on a project improves their self- disciplined, gives everyone a sense of belonging and their problem-solving ability can be enhanced (Adegbembo et al., 2016, Ayarkwa et al., 2012a).

Fernandez-solis et al. (2013) in line with Mossman (2013) and Gapp et al. (2008) stated that implementing LC techniques resulted in employees' involvement which reduced stress level on management, reduce the conflicts in projects and improve collaboration between project participants. Increasing the communication among project participants is another benefit resulted by the application of LC techniques (Oladiran, 2017, Bashir, 2013, Fernandez-solis et al., 2013, Ogunbiyi et al., 2012, Green and May, 2006). Communication between project practitioners promoted the free flow of information on-site (Oladiran, 2017, Bashir, 2013, Ayarkwa et al., 2012a). Table (2.16) summarizes the benefits of implementing LC techniques which is related to safety improvement in construction projects

Table (2.16): Benefits of implementing LC techniques which is related to safety improvement in construction projects

Benefits	Sources
Better planning of works	Bashir, 2013, Fernandez-solis et al., 2013, AlSehaimi et al., 2009
Greater predictability	Adegbembo et al., 2016, AlSehaimi et al., 2009, Mossman, 2009
Identifying tasks in advance	Pestana and Gambatese, 2016
Looking at potential safety hazards	Pestana and Gambatese, 2016
Establishing a smoother schedule and fewer safety hazards	Pestana and Gambatese, 2016
Reducing the workflow variation	Pestana and Gambatese, 2016, Dave et al., 2015, Fernandez-solis et al., 2013, Liu et al., 2011
Improving the rate of workflow on-site	Oladiran, 2017, Al-Aomar, 2012,
Minimizing the project duration	Adegbembo et al., 2016, Pestana and Gambatese, 2016, Modi and Thakkar, 2014, Ogunbiyi et al., 2014, Fernandez-solis et al., 2013, Issa, 2013, Marhani et al., 2013, Al-Aomar, 2012, Anvari et al., 2011a, Ogunbiyi et al., 2011, Mossman, 2009, Salem et al., 2005, Kilpatrick, 2003
Submit work with high quality and less defects	Oladiran, 2017, Chikhalikar and Sharma, 2015, Mehra et al., 2015, Modi and Thakkar, 2014, Bashir, 2013, Fernandez-solis et al., 2013, Ogunbiyi et al., 2013, Pasale and Bagi, 2013, Ayarkwa et al., 2012a, Ogunbiyi et al., 2012, Zhou, 2012, Mossman, 2009, Salem et al., 2005, Kilpatrick, 2003

Table (2.16): Benefits of implementing LC techniques which is related to safety improvement in construction projects

Benefits	Sources
Less rework in construction projects	Chikhalikar and Sharma, 2015, Bashir, 2013, Ogunbiyi et al., 2012, Bashir et al., 2011
Delivering the projects on time or in some cases ahead of schedule	Dave et al., 2015, Bashir, 2013, Al-Aomar, 2012, Ayarkwa et al., 2012a, Ogunbiyi et al., 2012, Mossman 2009
Increasing productivity	Couto et al., 2017, Sarhan et al., 2017, Adegbembo et al., 2016, Mehra et al., 2015, Khosravi et al., 2014, Modi and Thakkar, 2014, Ogunbiyi et al., 2014, Ahuja, 2013, Bashir, 2013, Fernandez-solis et al., 2013, Issa, 2013, Marhani et al., 2013, Ogunbiyi et al., 2013, Pasale and Bagi, 2013, Marhani et al., 2012, Zhou, 2012, AlSehaimi et al., 2009, Mossman 2009, Salem et al., 2005, Kilpatrick, 2003
Reducing the additional costs	Couto et al., 2017, Oladiran, 2017, Khosravi et al., 2014, Modi and Thakkar, 2014, Salem et al. 2014, Ahuja, 2013, Bashir, 2013, Ogunbiyi et al., 2013, Ayarkwa et al., 2012a, Zhou, 2012, Anvari et al., 2011a, Mossman, 2009
Increasing profit	Oladiran, 2017, Chikhalikar and Sharma, 2015, Modi and Thakkar, 2014, Mossman, 2013, Al-Aomar, 2012, Nesensohn et al., 2012, Zhou, 2012, Ogunbiyi et al., 2011, Mossman, 2009
Construction firms become more competitive	Bashir, 2013, Al-Aomar, 2012, Zhou, 2012, Anvari et al., 2011a
Improving work efficiency by reducing people's workload	Mehra et al., 2015, Ogunbiyi et al., 2014, Bashir, 2013, Ogunbiyi et al., 2012, Gapp et al., 2008, Salem et al., 2005
Reducing wastes on site	Oladiran, 2017, Chikhalikar and Sharma, 2015, Modi and Thakkar, 2014, Ahuja, 2013, Bashir, 2013, Ogunbiyi et al., 2013, Al-Aomar, 2012, Ayarkwa et al., 2012a, Suresh

Table (2.16): Benefits of implementing LC techniques which is related to safety improvement in construction projects

Benefits	Sources
	et al., 2011, Mossman 2009, Green and May, 2006
Site organization	Oladiran, 2017, Pestana and Gambatese, 2016, Mehra et al., 2015, Bashir, 2013, Vieira and Cachadinha, 2011
Removing clutter from workspace	Mehra et al., 2015
Reducing congestion on sites	Oladiran, 2017, Bashir, 2013
Facilitate maximum coordination in the handling of tools	Oladiran, 2017
Creation of space and convenience in workplace for employees	Modi and Thakkar, 2014, Ogunbiyi et al., 2014, Bashir, 2013, Salem et al., 2005, Kilpatrick, 2003
Distinguishing dangerous places from safe ones	Tezel and Aziz, 2016
Reducing site hazards such as noise and dust	Oladiran, 2017, Ahuja, 2013
Control the construction site environmentally (less weather effects)	Oladiran, 2017, Ahuja, 2013, Bashir, 2013
Better safety management plan	Bashir, 2013
Improving workers' safety	Oladiran, 2017, Sarhan et al., 2017, Adegbembo et al., 2016, Pestana and Gambatese, 2016, Ogunbiyi et al., 2014, Singh et al., 2014, Ogunbiyi et al., 2013, Mossman, 2009, Gapp et al., 2008, Salem et al., 2005
Employees can clearly know the critical work areas and durations of these	Pestana and Gambatese, 2016, Cerveró-Romero et al., 2013
Stakeholders satisfaction	Oladiran, 2017, Sarhan et al., 2017, Adegbembo et al., 2016, Singh et al., 2014, Bashir, 2013, Ogunbiyi et al., 2013, Al-Aomar, 2012, Zhou, 2012, Anvari et al., 2011a, Mossman 2009, Gapp et al., 2008, Salem et al., 2005

Table (2.16): Benefits of implementing LC techniques which is related to safety improvement in construction projects

Benefits	Sources
Creating a trust bond and Enhancing transparency between the project parties	Sarhan et al., 2017, Adegbembo et al., 2016, Dave et al., 2015, Ogunbiyi et al., 2013, Ayarkwa et al., 2012a, Gapp et al., 2008
Increasing employee empowerment and involvement	Dave et al., 2015, Mehra et al., 2015, Gambetese and Pestana, 2014, Bashir, 2013, Cerveró-Romero et al., 2013, Ogunbiyi et al., 2013, Al-Aomar, 2012, Ogunbiyi et al., 2012, Green and May, 2006, Salem et al. 2005
Improving the employees' self- disciplined	Adegbembo et al., 2016, Pasale and Bagi, 2013, Ayarkwa et al., 2012a
Enhancing a sense of belonging among the employees and their problem-solving ability	Oladiran, 2017, Adegbembo et al., 2016, Mossman, 2013, Ayarkwa et al., 2012a
Reducing stress level on management and firefighting on projects	Fernandez-solis et al., 2013, Mossman, 2013, Gapp et al., 2008
Promoting the team collaboration among project practitioners	Oladiran, 2017, Dave et al., 2015, Ogunbiyi et al., 2014, Bashir, 2013, Fernandez-solis et al., 2013, Mossman, 2013, Al-Aomar, 2012, AlSehaimi et al., 2009, Gapp et al., 2008, Salem et al., 2005
Increasing communication among project practitioners	Oladiran, 2017, Bashir, 2013, Fernandez-solis et al., 2013, Ogunbiyi et al., 2012, Green and May, 2006
Promoting free flow of information on-site between project practitioners	Oladiran, 2017, Bashir, 2013, Ayarkwa et al., 2012a

2.5.1 Summary

This section is to identify the benefits of implementing LC techniques which is related to safety improvement in construction projects. The results of this section helps construction practitioners to be enlightened on the benefits of LC techniques to incorporate them in the safety improvement. A total of thirty seven benefits were identified through the critical review of previous studies.

Despite the significant benefits of LC techniques in terms of reducing waste, increasing productivity, costs cutting, increasing quality, improving workers' safety, increasing satisfaction promoting collaboration and minimizing duration, not every construction firm will be successful in its first attempt to get Lean. As with the application process of LC techniques is prevented by barriers. Therefore, the next section will identify the barriers prevented the application of LC techniques in safety improvement.

Objective 3

In order to achieve a successful application of the Lean Construction techniques in promoting construction safety, it is recommended to understand the barriers facing construction firms in the implementation of LC. A thorough investigation of the barriers facing LC implementation in construction firms including the implementation of LC techniques was carried out. LC techniques which are explained in section 2.4.2 in order to improve construction safety are then connected logically with the barriers of LC implementation to investigate the barriers to the application of LC techniques to improve safety in construction projects. Barriers to the application of LC techniques to improve safety are grouped into categories related to management issues, financial issues, educational issues, governmental issues, technical issues and human attitudinal issues.

2.6 Barriers to the application of Lean Construction techniques in safety improvement in construction projects

Lean Construction considers poor safety and accidents as potential wastes that should be eliminated (Bashir et al., 2010). LC techniques can be used to eliminate the onsite causes of accidents (Bashir et al., 2011). To integrate Lean philosophy in a construction organization, it is recommended to understand and anticipate the barriers that might hinder the proper implementation of LC in construction projects (Cano et al., 2015). Several studies have been carried out in different countries worldwide to identify the barriers to the successful implementation of LC in construction projects (Attri et al., 2017, Bashir et al., 2015, Cano et al., 2015, Singh et al., 2014, Wandahl, 2014, Fernandez-Solis et al., 2013). Generally, barrier is defined as ‘what prevents a step or an action to achieve the objectives’. It is also known as "obstacle", "difficulty", "hurdle" and "hindrance" (Cano et al., 2015, p.1).

Barriers to the successful implementation of LC in construction projects were classified into several groups. According to Bashir et al. (2015, 2010) and Bashir (2013), barriers to the successful implementation of LC in construction projects were classified into six groups which are management issues, financial issues, educational issues, governmental issues, technical issues and human attitudinal issues. While Cano et al. (2015) summarized the barriers to the successful implementation of LC in construction projects in six groups related to people, organizational structure, supply chain, internal value, external value chain, external management and value chain and externalities. Oladiran (2008) categorized the barriers to the implementation of LC in construction projects under seven subheadings which are skills and knowledge-related, management-related, government-related, attitude-related, resource-related, logistics-related and others.

2.6.1 Categories of the barriers to the application of Lean Construction techniques to improve construction safety

This research will classify the barriers to the application of LC techniques to improve safety in construction projects similarly to the classification of the barriers to the successful implementation of LC in construction projects which is adopted by Bashir et al. (2015, 2010) and Bashir (2013). Therefore, the barriers to the application of LC techniques to improve safety in construction projects will be categorized into management barriers, financial barriers, educational barriers, governmental barriers, technical barriers and human attitudinal barriers.

2.6.1.1 Management barriers

Management barriers are referred to various issues related to the support of the top management administers the construction firms (Abdullah et al., 2009). Since the successful implementation of LC or any new innovative strategy needs to be supported by top management (Attri et al., 2017, Small et al., 2017, Sandeep and Panwar, 2016, Bashir et al., 2015, Mehra et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013). The role of management is a key factor potentially enhancing or hindering the effect of Lean tools on safety improvement (Camuffo and Stefano, 2015).

Many barriers to the LC implementation in construction projects are identified in several studies and seemed to be related to management issues. Poor project definition is proved to be a management barrier prevented the successful implementation of LC in construction projects (Small et al., 2017, Ayarkwa et al., 2012b, Brady et al., 2011, Oladiran, 2008).

Many of LC techniques are used to promote safety in construction projects like conducting a pre task hazard analysis and defining standard procedures to maintain clean work environment (Cudney et al., 2015, Sacks et al., 2009). Conducting a critical task planning to study the task and review the work methods to identify the appropriate method that matches with workers abilities is also identified as LC technique to improve safety in construction projects (Bashir, 2013, Mitropoulos et al., 2007). Logically, to apply the previous LC techniques, the project should be defined clearly to explain the vision, mission and main objectives of the project and its stakeholders.

Moreover, decision making shouldn't be centralized under single authority. Delegation strategy should be adopted by top managers to allow workers to participate in decision making and enhance work flow, too (Camuffo et al., 2017, Brady et al., 2011, Alinaitwe, 2009, Oladiran, 2008). As a result, the approval procedure from top management can be shortened (Small et al., 2017, Fernandez-Solis et al., 2013, Porwal et al., 2010, Alinaitwe, 2009, AlSehaimi et al., 2009)

Furthermore, lack of time for innovation is identified as a management barrier faced some construction firms in implementation of LC in construction projects (Zhou, 2012, Brady et al., 2011, Abdullah et al., 2009, Alinaitwe, 2009, AlSehaimi et al., 2009, Mossman, 2009, Alarcon et al., 2002). Time pressure in construction projects returns to the organizational pressure which adversary affect the application of any innovative strategy (Tsang et al., 2017). Sometimes time pressure affect the application of safety itself based on the contractor's belief that safety implementation is time consuming (Abu-Alqumboz, 2007).

In addition, Awada et al. (2016), Alarcón et al. (2011) and Alinaitwe (2009) identified lack of transparency as a management barrier prevented the successful implementation of LC in construction projects. Transparency is operating in such a way that it is easy for others to see what actions are performed (Brady, 2014). In other words, when transparency is missed, by logic employees can't be involved in safety planning and selecting work methods which are main techniques of LC should be used to promote safety.

Lack of communication among participants of the production process (managers, administrators, foremen, etc.) is another barrier hindered the implementation of LC in construction projects (Attri et al., 2017, Small et al., 2017, Mehra et al., 2015, Singh et al., 2014, Sarhan and Fox, 2013, Zhou, 2012, Alarcón et al., 2011, Abdullah et al., 2009, Alinaitwe, 2009, Kilpatrick, 2003). Lack of communication can lead to lack of coordination, cooperation and team work which may hamper the LC implementation efforts in construction projects (Attri et al., 2017).

Poor coordination between the project parties is identified as a barrier to the implementation of LC in construction projects (Attri et al., 2017, Mehra et al., 2015, Gambetese and Pestana, 2014, Kilpatrick, 2003). Poor coordination is about inadequate involvement of employees in safety planning (Gambetese and Pestana, 2014). It doesn't allow the daily conduction of meetings with employees which encourages communication between team and its leader (Ogunbiyi, 2014). It becomes very difficult to implement any innovative program when the employees fail to work together as a team (Attri et al., 2017).

Moreover, absence of long term forecast and investment by the top management is one of the major barriers to the implementation of LC (Small et al., 2017, Bashir et al., 2015, Ogunbiyi, 2014, Shang and Pheng, 2014, Bashir, 2013, Fernandez-Solis et al., 2013, Al-Aomar, 2012, Bashir et al., 2010, AlSehaimi et al., 2009, Mossman, 2009). The poor or negative long term forecast of LC implementation could contribute to inadequate support and commitment from the management to full investment in implementing LC (Bashir et al., 2015, Bashir, 2013).

Inadequate planning to implement LC is another barrier hindered the implementation of LC in construction projects (Attri et al., 2017, Small et al., 2017, Sandeep and Panwar, 2016, Cano et al., 2015, Dave et al., 2015, Mehra et al., 2015, Alinaitwe, 2009, Salem et al., 2005, Alarcon et al., 2002). One of the most important LC tools is LPS which mainly aimed to replace the optimistic planning with realistic planning based on workers abilities (Enshassi and Abu Zaiter, 2014, Salem et al., 2014, Bashir et al., 2011). Inadequate planning will impede the application of LPS to replace the optimistic planning with the realistic planning (Salem et al., 2014).

Logistics' problems like poor management of materials, equipment and tools and short supply of material are identified as barriers to the LC implementation in construction projects (Small et al., 2017, Sundquist et al., 2017, Alinaitwe, 2009). For instance, some building materials may be purchased too late to the process that result in delays and time pressure while others are bought in large quantities that might lead to site congestion (Small et al., 2017, Sundquist et al., 2017). As a result, poor management of material resulted in hindering the application of 5S tool which focused on organizing the workplace (Bashir, 2013, Bashir et al., 2011, Abdulmalek and Rajgopal, 2007, Kilpatrick, 2003). Table (2.17) summarizes the management barriers to the application of LC techniques to improve safety in construction projects.

Table (2.17): Management barriers to the application of LC techniques to improve safety in construction projects

Management barriers	Sources
Top management support and commitment	Attri et al., 2017, Small et al., 2017, Sandeep and Panwar, 2016, Bashir et al., 2015, Mehra et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Ayarkwa et al., 2012a, Ayarkwa et al., 2012b, Zhou, 2012, Bashir et al., 2010, Porwal et al., 2010, Abdullah et al., 2009, Alinaitwe, 2009, Mossman, 2009, Oladiran, 2008, Kim and Park, 2006, Salem et al., 2005, Kilpatrick, 2003
Poor project definition	Small et al., 2017, Ayarkwa et al., 2012b, Brady et al., 2011, Oladiran, 2008
Centralization of decision under single authority	Camuffo et al., 2017, Brady et al., 2011, Alinaitwe, 2009, Oladiran, 2008
Lengthy approval procedure from top management	Small et al., 2017, Fernandez-Solis et al., 2013, Porwal et al., 2010, Alinaitwe, 2009, AlSehaimi et al., 2009
Lack of time for innovation	Zhou, 2012, Brady et al., 2011, Abdullah et al., 2009, Alinaitwe, 2009, AlSehaimi et al., 2009, Mossman, 2009, Alarcon et al., 2002
Lack of transparency	Awada et al., 2016, Alarcón et al., 2011, Alinaitwe, 2009
Poor communication among participants of the production process (managers, administrators, foremen, etc.)	Attri et al., 2017, Small et al., 2017, Mehra et al., 2015, Singh et al., 2014, Sarhan and Fox, 2013, Zhou, 2012, Alarcón et al., 2011, Abdullah et al., 2009, Alinaitwe, 2009, Kilpatrick, 2003
Poor coordination between the project parties	Attri et al., 2017, Mehra et al., 2015, Gambetese and Pestana, 2014, Kilpatrick, 2003
Absence of long term forecast and investment by the top management	Small et al., 2017, Bashir et al., 2015, Ogunbiyi, 2014, Shang and Pheng, 2014, Bashir, 2013, Fernandez-Solis et al., 2013, Al-Aomar, 2012, Bashir et al.,

Table (2.17): Management barriers to the application of LC techniques to improve safety in construction projects

Management barriers	Sources
	2010, AlSehaimi et al., 2009, Mossman, 2009
Inadequate planning	Attri et al., 2017, Small et al., 2017, Sandeep and Panwar, 2016, Cano et al., 2015, Dave et al., 2015, Mehra et al., 2015, Alinaitwe, 2009, Salem et al., 2005, Alarcon et al., 2002
Logistics’ problems	Small et al., 2017, Sundquist et al., 2017, Alinaitwe, 2009

2.6.1.2 Financial barriers

Financial issues are among the most common barriers to LC practice across different organizations in various countries but it varies across countries (Bashir et al., 2015, Wandahl, 2014, Bashir, 2013, Sarhan and Fox, 2013). The successful implementation of LC requires adequate fund to provide relevant resources, incentives and reward systems and sometimes to employ Lean specialist in the early stages to guide the organization in implementing the concept of Lean in safety improvement (Small et al., 2017, Bashir et al., 2015, Cano et al., 2015, Enshassi and Abu Zaiter, 2014, Bashir, 2013, Ayarkwa et al., 2012b, Zhou, 2012, Bashir et al., 2010, Porwal et al., 2010). Inadequate resources hindered developing and implementing an effective plan, and dealing with changes arising during the implementation of LC (Bashir et al., 2015, Bashir, 2013, Bashir et al., 2010, Alinaitwe, 2009, Oladiran, 2008). Inadequate fund of project can be traced to the low tender prices (Small et al., 2017).

Cost of training, consultancy fees and cost to conduct workshops are considered as implementation cost of LC in construction projects (Bashir, 2013). Implementation cost of LC is proved to be a financial barrier impeded the implementation of LC in construction projects (Sandeep and Panwar, 2016, Bashir et al., 2015, Bashir, 2013, Al-Aomar, 2012, Alarcón et al., 2011, Oladiran, 2008). Moreover, poor salaries of professionals do not encourage them to apply any innovative strategies (Small et al., 2017, Bashir et al., 2015, Marhani et al., 2013, Ayarkwa et al., 2012b, Oladiran, 2008).

Lack of incentives and motivation is identified as financial barrier hindered the implementation of LC in construction projects (Attri et al., 2017, Sandeep and Panwar, 2016, Mehra et al., 2015, Bashir, 2013, Alinaitwe, 2009, Oladiran, 2008). Sometimes incentives encourage a worker to put greater efforts in carrying out a new innovative strategies (Attri et al., 2017, Bashir, 2013). This can affect the application of LC techniques like workers empowerment in tasks scheduling to make their commitment on their productivity (Enshassi and Abu Zaiter, 2014). It also affects the involvement of workers in selecting work methods based on their skills and abilities (Camuffo et al., 2017, Gambetese et al., 2016). Incentives and motivation can change the traditional working behavior and enhance their concern about housekeeping, too. Since workers are used to being messy and throwing garbage on the ground (Salem et al., 2005).

Moreover, Oladiran (2008) identified corruption and inflation as barriers to implement LC. Corruption, which includes bribery, extortion and fraud, may damage the implementation of LC by resulting in overpricing of projects, using of inferior materials and poor workmanship (Ayarkwa et al., 2012b, Oladiran, 2008). On the other hand, inflation in material prices due to unsafe markets condition for construction is one of the major causes for the increased budget cost of the project which is opposed to the main benefits of LC in reducing cost (Gade, 2016, Alinaitwe, 2009, Oladiran, 2008). Table (2.18) summarizes the financial barriers to the application of LC techniques to improve safety in construction projects.

Table (2.18): Financial barriers to the application of LC techniques to improve safety in construction projects

Financial barriers	Sources
Inadequate funding of the project to provide the required resources and training	Small et al., 2017, Bashir et al., 2015, Cano et al., 2015, Enshassi and Abu Zaiter, 2014, Bashir, 2013, Ayarkwa et al., 2012b, Zhou, 2012, Bashir et al., 2010, Porwal et al., 2010, Alinaitwe, 2009, Mossman, 2009, Oladiran, 2008, Salem et al., 2005
Low tender prices	Small et al., 2017
Implementation cost of LC	Sandeep and Panwar, 2016, Bashir et al., 2015, Bashir, 2013, Al-Aomar, 2012, Alarcón et al., 2011, Oladiran, 2008

Table (2.18): Financial barriers to the application of LC techniques to improve safety in construction projects

Financial barriers	Sources
Poor salaries of professionals	Small et al., 2017, Ayarkwa et al., 2012b, Oladiran, 2008
Lack of incentives and motivation	Attri et al., 2017, Sandeep and Panwar, 2016, Mehra et al., 2015, Bashir, 2013, Alinaitwe, 2009, Oladiran, 2008
Corruption due to bribery, extortion and fraud	Ayarkwa et al., 2012b, Oladiran, 2008
Inflation in material prices due to unsafe markets condition for construction	Gade, 2016, Alinaitwe, 2009, Oladiran, 2008

2.6.1.3 Educational barriers

Over the past years, many efforts have been made to increase awareness of LC by providing guidance and sharing knowledge relating to LC by academics, researchers and practitioners. (Bashir et al., 2015, Bashir, 2013, Sarhan and Fox, 2013, Bashir et al., 2010). The establishment of bodies like Lean Construction Institute (LCI), Construction Lean Implementation Program (CLIP) has also helped to raise awareness of LC (Bashir et al., 2015, Ogunbiyi et al., 2013). Despite these continuous efforts, it seems that educational barriers could pose a great threat to the implementation of LC (Bashir et al., 2015, Bashir, 2013, Wandahl, 2014, Ogunbiyi et al., 2013, Bashir et al., 2010). Abdullah et al. (2009) stated that it is essential to have a full comprehension of Lean manufacturing concepts to understand the concept of LC clearly.

Educational barriers included lack of understanding of Lean concept and inadequate knowledge of LC (Awada et al., 2016, Shang and Pheng, 2014, Bashir, 2013, Sarhan and Fox, 2013, Bashir et al., 2010, Oladiran, 2008, Salem et al., 2005, Alarcon et al., 2002). This can be traced to the fact that LC is a concept evolved from the manufacturing industry (Abdullah et al., 2009). Lack of technical skills is another barrier impede the implementation of LC in construction projects (Small et al., 2017, Bashir, 2013, Fernandez-Solis et al., 2013, Bashir et al., 2010, Porwal et al., 2010, Abdullah et al., 2009). Lack of technical skills hindered the conduction of pre task hazards analysis and accidents investigation program which are LC techniques used to promote safety (Sacks et al., 2009). Moreover, technical skills of safety supervisors enabled them to define a standard procedure in order to maintain a clean work environment (Cudney et al., 2015).

Furthermore, lack of education and training; and lack of awareness programs are reported as educational barriers to the successful implementation of LC in construction projects (Attri et al., 2017, Bashir et al., 2015, Mehra et al., 2015, Singh et al., 2014, Sarhan and Fox, 2013, Al-Aomar, 2012). Without proper education and training, employees will not be able to know the basic concepts and benefits of implementing the LC techniques (Attri et al., 2017). Employee working in the construction firms should have adequate knowledge about the program to be implemented (Sandeep and Panwar, 2016). If the employees working in construction firms do not know the basic concepts of LC, then full commitment will not be seen from the employees (Attri et al., 2017)

Lack of experiences and information sharing is another educational barrier to the implementation of LC in construction projects (Bashir et al., 2015, Dave et al., 2015, Bashir, 2013, Fernandez-Solis et al., 2013, Alarcon et al., 2011, Brady et al., 2011, Bashir et al., 2010, Alarcon et al., 2002). Sharing experiences and information among the construction firms leads to generate a "learning cycle" which produce fast learning from successes and failures (Alarcón et al., 2011, Alarcon et al., 2002). For instance, companies that fail in their first experience to implement an innovative strategy tend to understand the reasons of their failure and to improve their implementation process. They realize that implementation of any innovative strategy is possible because there is always a project successfully implement this innovative strategy and they can learn how to do it better next time (Alarcón et al., 2011). Table (2.19) summarizes the educational barriers to the application of LC techniques to improve safety in construction projects.

Table (2.19): Educational barriers to the application of LC techniques to improve safety in construction projects

Educational barriers	Sources
Lack of LC concept understanding	Small et al., 2017, Awada et al., 2016, Shang and Pheng, 2014, Bashir, 2013, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Sarhan and Fox, 2012, Alarcón et al., 2011, Bashir et al., 2010, Porwal et al., 2010, Abdullah et al., 2009, Mossman, 2009, Oladiran, 2008, Salem et al., 2005, Alarcon et al., 2002

Table (2.19): Educational barriers to the application of LC techniques to improve safety in construction projects

Educational barriers	Sources
Lack of knowledge	Awada et al., 2016, Sandeep and Panwar, 2016, Shang and Pheng, 2014, Bashir, 2013, Sarhan and Fox, 2013, Ayarkwa et al., 2012a, Zhou, 2012, Bashir et al., 2010, Alinaitwe, 2009, Oladiran, 2008, Salem et al., 2005, Alarcon et al., 2002
Lack of technical skills	Small et al., 2017, Bashir, 2013, Fernandez-Solis et al., 2013, Bashir et al., 2010, Porwal et al., 2010, Abdullah et al., 2009, Alinaitwe, 2009, and Mossman, 2009, Oladiran, 2008, Kim and Park, 2006, Alarcon et al., 2002
Lack of education and training	Attri et al., 2017, Small et al., 2017, Sandeep and Panwar, 2016, Bashir et al., 2015, Cano et al., 2015, Mehra et al., 2015, Shang and Pheng, 2014, Singh et al., 2014, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Al-Aomar, 2012, Ayarkwa et al., 2012b, Sarhan and Fox, 2012, Brady et al., 2011, Porwal et al. 2010, Abdullah et al., 2009, Alinaitwe, 2009, Mossman, 2009, Oladiran, 2008, Kim and Park, 2006, Salem et al., 2005, Kilpatrick, 2003, Alarcon et al., 2002
Lack of awareness programs	Attri et al., 2017, Bashir et al., 2015, Mehra et al., 2015, Singh et al., 2014, Sarhan and Fox, 2013, Al-Aomar, 2012, Sarhan and Fox, 2012, Abdullah et al., 2009, Alinaitwe, 2009, Mossman, 2009, Oladiran, 2008, Kim and Park, 2006, Mastroianni and Abdelhamid, 2003, Alarcon et al., 2002
Lack of experiences and information sharing	Bashir et al., 2015, Dave et al., 2015, Bashir, 2013, Fernandez-Solis et al., 2013, Alarcon et al., 2011, Brady et al., 2011, Bashir et al., 2010, Alarcon et al., 2002

2.6.1.4 Governmental barriers

Some studies stated that some of the barriers of LC implementation are due to government attitudes and support towards the construction industry in some countries (Bashir et al., 2015, Bashir, 2013, Bashir et al., 2010). Government aspects that affect the project's development and the LC's implementation are considered as external barrier in construction projects (Cano et al., 2015, Shang and Pheng, 2014). Governmental barriers are related to the government bureaucracy and instability (Small et al., 2017, Oladiran, 2008). Moreover, inconsistency in policies was identified as government barriers to the implementation of LC which has a major effects on the plans of construction firms (Small et al., 2017, Bashir et al., 2015, Bashir, 2013, Ayarkwa et al., 2012b, Alinaitwe, 2009, Oladiran, 2008).

Additionally, unsteady price of commodities is another barrier prevented the implementation of LC in construction projects (Bashir et al., 2015, Bashir, 2013, Bashir et al., 2010, Alinaitwe, 2009, Oladiran, 2008). Commodities needed in construction projects to improve safety are safety equipment as PPE, signs, boards, demarcations and alarms which are considered as LC techniques to promote safety (Sarhan et al., 2017, Bashir, 2013, Bashir et al., 2011). The unsteady price of these commodities will affect the application of LC techniques to improve construction safety. Furthermore, some of the financial barriers like inflation, professional wages, and corruption practices could also be related to government issues (Bashir, 2013, Bashir et al., 2010).

Government barriers have minor effects on the application of LC techniques to improve safety (Cano et al., 2015, Bashir, 2013). According to the findings of Bashir (2013), none of the barriers to the application of LC techniques to improve safety related to the government. Table (2.20) summarizes the governmental barriers to the application of LC techniques to improve safety in construction projects.

Table (2.20): Governmental barriers to the application of LC techniques to improve safety in construction projects

Governmental barriers	Sources
Lack of government support towards the construction industry	Bashir et al., 2015, Cano et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Bashir et al., 2010
Government bureaucracy and instability	Small et al., 2017, Oladiran, 2008

Table (2.20): Governmental barriers to the application of LC techniques to improve safety in construction projects

Governmental barriers	Sources
Inconsistency in the government policies	Small et al., 2017, Bashir et al., 2015, Bashir, 2013, Ayarkwa et al., 2012b, Alinaitwe, 2009, Oladiran, 2008
Unsteady price of commodities	Bashir et al., 2015, Bashir, 2013, Bashir et al., 2010, Alinaitwe, 2009, Oladiran, 2008

2.6.1.5 Technical barriers

Technical barriers have a direct impact on the application of certain LC principle and tools such as reliability, simplicity, flexibility and benchmarking (Koskela, 1992). Lack of agreed implementation methodology to implement LC is identified as technical barrier prevented the successful implementation of LC in construction projects (Small et al., 2017, Alinaitwe, 2009). Moreover, complexity of LC implementation is another barrier to implement LC in construction projects (Gade, 2016, Bashir et al., 2015, Singh et al., 2014, Bashir, 2013, Alarcon et al., 2002). Since, LC does not just involve applying LC techniques on site, but also involves developing a culture among the staff for a continuous improvement across all units of the construction firm (Bashir et al., 2015, Bashir, 2013).

Similarly, the barrier of long implementation period is considered as one of the major barriers to the implementation of LC in construction projects (Small et al., 2017, Adegbembo et al., 2016, Sandeep and Panwar, 2016, Bashir et al., 2015, Bashir, 2013, Marhani et al., 2013, Ayarkwa et al., 2012b, Bashir et al., 2010). Kim and Park (2006) was discovered that the implementation of LC in construction projects had resulted in too many meetings and these meetings had to be held repeatedly and took time when poorly managed. Furthermore, time is needed to train the workers on LC, apply its principles, select the appropriate LC techniques to use and implement them on site, manage change to working culture, and carry out an evaluation to identify areas for improvement (Bashir et al., 2015).

Design related barriers to implement LC successfully in construction projects include incomplete designs (Bashir et al., 2015, Bashir, 2013, Ayarkwa et al., 2012, Alinaitwe, 2009, Koskela, 1999). Incomplete designs is significant in projects which are undertaken and initiated before the design is complete. This leads to increases the probability of re-work while reducing the potential for Lean planning and scheduling due to time constraints and unrealistic completion dates (Small et al., 2017).

Additionally, poor performance measurement strategies and fragmented nature of the construction industry are technical barriers hindered the implementation of LC in construction projects (Small et al., 2017, Bashir et al., 2015). Lack of integrity of the production chain including client, materials' suppliers and subcontractors is a barrier to the implementation of LC in construction projects, as well (Cano et al., 2015, Marhani et al., 2013, Ayarkwa et al., 2012b, Zhou, 2012, Alarcón et al., 2011, Alinaitwe, 2009). Table (2.21) summarizes the technical barriers to the application of LC techniques to improve safety in construction projects.

Table (2.21): Technical barriers to the application of LC techniques to improve safety in construction projects

Technical barriers	Sources
Lack of agreed implementation methodology	Small et al., 2017, Alinaitwe, 2009
Complexity of LC implementation	Gade, 2016, Bashir et al., 2015, Singh et al., 2014, Bashir, 2013, Alarcon et al., 2002
Long implementation period	Small et al., 2017, Adegbembo et al., 2016, Sandeep and Panwar, 2016, Bashir et al., 2015, Bashir, 2013, Marhani et al., 2013, Ayarkwa et al., 2012b, Bashir et al., 2010, Abdullah et al., 2009, Mossman, 2009, Kim and Park, 2006, Kilpatrick, 2003, Alarcon et al., 2002
Incomplete designs	Bashir et al., 2015, Bashir, 2013, Ayarkwa et al., 2012, Alinaitwe 2009, Koskela 1999
Poor performance measurement strategies	Small et al., 2017, Bashir et al., 2015, Bashir, 2013
Fragmented nature of the construction industry	Small et al., 2017, Adegbembo et al., 2016, Ogunbiyi, 2014, Ayarkwa et al., 2012b, Pheng and Shang, 2011, Porwal et al., 2010, Alinaitwe, 2009

Table (2.21): Technical barriers to the application of LC techniques to improve safety in construction projects

Technical barriers	Sources
Lack of integrity of the production chain including client, materials' suppliers and subcontractors	Cano et al., 2015, Marhani et al., 2013, Ayarkwa et al., 2012b, Zhou, 2012, Alarcón et al., 2011, Alinaitwe, 2009

2.6.1.6 Human attitudinal barriers

Attitude refers to the trend regarding intent, commitment and cooperation that need to be presented within the parties to successfully implement LC in construction projects. This attitude will consequently influence their capacity to work as a team (Abdullah et al., 2009). According to Bygballe and Swärd (2014), human attitude is one of the major factors affecting the implementation of LC in various construction industries.

Mossman (2009) and Oladiran (2008) identified selfishness among professionals to provide their experience of the LC implementation as a human barrier prevented the successful implementation of LC in construction projects. Moreover, poor leadership is proved to be among the human barriers to LC implementation in construction projects (Attri et al., 2017, Bashir et al., 2015, Mehra et al., 2015, Bashir et al., 2010, Porwal et al., 2010, Alinaitwe, 2009, Mossman, 2009, Alarcon et al., 2002). Lack of leadership may result into introduction of other barriers like employee resistance to change, inability to change the organizational culture and poor communication (Attri et al., 2017, Sandeep and Panwar, 2016, Mehra et al., 2015, Sarhan and Fox, 2013, Ayarkwa et al., 2012b, Zhou, 2012, Oladiran, 2008).

LC needs a fundamental change in the mind of the employees to manage their resistance to change (Attri et al., 2017, Awada et al., 2016, Sandeep and Panwar, 2016, Mehra et al., 2015, Shang and Pheng, 2014, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Al-Aomar, 2012). Since employee support is very necessary for successfully implementing LC in construction projects (Sandeep and Panwar, 2016).

In addition, cultural issues are also mentioned as barriers to the successful implementation of LC in construction projects (Sandeep and Panwar, 2016, Cano et al., 2015, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Ayarkwa et al., 2012a, b, Sarhan and Fox, 2012, Zhou, 2012). The successful implementation of LC is also required a radical change in the prevailing culture of the organization (Attri et al., 2017, Sandeep and Panwar, 2016, Cano et al., 2015, Mehra et al., 2015, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013).

Moreover, lack of self-criticism limited the capacity to learn from errors which hindered the successful implementation of LC in construction projects (Alinaitwe, 2009, Alarcon et al., 2002). Fear of unfamiliar practices is another barrier to the implementation of LC due to the misconceptions and misunderstandings of workers and some clients about LC (Bashir et al., 2015, Bashir, 2013, Al-Aomar, 2012, Sarhan and Fox, 2012, Bashir et al., 2010, Mossman, 2009, Alarcon et al., 2002). Additionally, lack of teamwork is proved to be a barrier impede the successful implementation of LC in construction projects (Bashir et al., 2015, Cano et al., 2015, Fernandez-Solis et al., 2013, Al-Aomar, 2012, Ayarkwa et al., 2012b, Bashir et al., 2010, Porwal et al., 2010). Table (2.22) summarizes the attitudinal barriers to the application of LC techniques to improve safety in construction projects.

Table (2.22): Human attitudinal barriers to the application of LC techniques to improve safety in construction projects

Human attitudinal barriers	Sources
Selfishness among professionals	Mossman, 2009, Oladiran, 2008
Poor leadership	Attri et al., 2017, Bashir et al., 2015, Mehra et al., 2015, Bashir et al., 2010, Porwal et al., 2010, Alinaitwe, 2009, Mossman, 2009, Alarcon et al., 2002
Employees' resistance to change	Attri et al., 2017, Awada et al., 2016, Sandeep and Panwar, 2016, Mehra et al., 2015, Shang and Pheng, 2014, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Al-Aomar, 2012, Ayarkwa et al., 2012b, Zhou, 2012, Porwal et al., 2010, Oladiran, 2008, Kilpatrick, 2003, Mastroianni and Abdelhamid, 2003
Cultural issues	Sandeep and Panwar, 2016, Cano et al., 2015, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Ayarkwa et al., 2012a, Ayarkwa et al., 2012b, Sarhan and Fox, 2012, Zhou, 2012, AlSehaimi et al. 2009, Alinaitwe, 2009, Nesensohn et al. 2012, Mossman,

Table (2.22): Human attitudinal barriers to the application of LC techniques to improve safety in construction projects

Human attitudinal barriers	Sources
	2009, Oladiran, 2008, Kim and Park, 2006, Salem et al., 2005
Inability to change the organizational culture	Attri et al., 2017, Sandeep and Panwar, 2016, Cano et al., 2015, Mehra et al., 2015, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Ayarkwa et al., 2012a, Nesensohn et al., 2012, Sarhan and Fox, 2012, Zhou, 2012, AlSehaimi et al. 2009, Alinaitwe, 2009, Mossman, 2009, Oladiran, 2008, Kim and Park, 2006, Salem et al., 2005
Lack of self-criticism	Alinaitwe, 2009, Alarcon et al., 2002
Fear of unfamiliar practices	Bashir et al., 2015, Bashir, 2013, Al-Aomar, 2012, Sarhan and Fox, 2012, Bashir et al., 2010, Mossman, 2009, Alarcon et al., 2002
Lack of teamwork	Bashir et al., 2015, Cano et al., 2015, Fernandez-Solis et al., 2013, Al-Aomar, 2012, Ayarkwa et al., 2012b, Bashir et al., 2010, Porwal et al., 2010, Abdullah et al., 2009, Alinaitwe, 2009, Mossman, 2009, Oladiran, 2008, Kim and Park, 2006, Salem et al., 2005

2.6.2 Summary

Prior to the application of LC techniques in safety improvement, it is advisable to identify the wide set of barriers which hindered the application of LC techniques. This section identified the barriers to the application of LC techniques in safety improvement in construction projects through critical review of previous studies. Barriers to the application of LC techniques in safety improvement in construction projects are categorized into six groups including management, financial, educational, government, technical and human attitudinal barriers. A total of forty three barriers were identified through the critical review of previous studies.

Previous studies showed that most of barriers are related to human issues, financial, technical, educational and management while none are related to the government. The critical barriers mentioned in this section and identified by several researchers are lack of management commitment and support, lack of LC concept understanding, lack of education and training, long implementation period, lack of awareness programs, employees' resistance to change and inability to change the organizational culture,

By understanding these barriers which affect the successful application of LC techniques, researchers, practitioners and companies in construction industry can focus their attention and resources on the significant barriers and to identify strategies can be taken to address the barriers and facilitate the application of LC techniques to improve safety.

Objective 4

In order to apply LC techniques in safety improvement successfully, it is advisable to provide ways prevented the occurrence of barriers to the application of LC techniques which are mentioned in the previous section. This section is specialized to identify the critical success factors that should be taken by construction firms to overcome or mitigate the impact of the barriers on the successful application of LC techniques to improve safety in construction projects. According to the previous researched, success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects were categorized into groups related to management, education and skills improvement, government and operation.

2.7 Critical Success Factors (CSF) to overcome the barriers to the application of LC techniques to improve safety in construction projects

The barriers to the application of LC techniques to improve safety in construction projects have to be addressed in order to realize the targeted benefits (Cano et al., 2015, Bashir, 2013). A set of Critical Success Factors (CSFs) is used as elements which are opposed to the identified barriers as an efficient method to overcome or minimize their impact on the LC's implementation in construction projects (Bashir et al., 2015, Cano et al., 2015, Ogunbiyi et al., 2013). A success factor is something that must occur or that must not happen to achieve the objectives, this factor becomes critical if its compliance is absolutely necessary for achieving those objectives (Cano et al., 2015).

Cano et al. (2015) classified the CSFs to overcome the barriers of LC implementation into groups related to people, organizational structure, supply chain, internal value chain, external value chain and externalities. While, Oladiran (2008) summarized the CSFs into groups related to management, education and skill development, government, operation, attitudinal change and others.

2.7.1 Categories of CSFs to overcome barriers to the application of LC techniques to improve safety in construction projects

This study will classify the CSFs to overcome the barriers to the application of LC techniques to improve safety in construction projects similar to the classification of Oladiran (2008). Therefore, CSF to overcome the barriers to the application of LC techniques to improve safety in construction projects will be categorized into categories related to management, education and skill development, government and operation success factors.

2.7.1.1 Management success factors

Management of construction firms has the main role to promote or hinder the implementation of LC in construction projects (Bashir et al., 2015, Bashir, 2013). The successful application of LC techniques lies on the support and commitment of top management (Azyan et al., 2017, Oladiran, 2017, Netland, 2016, Sandeep and Panwar, 2016, Sarhan et al., 2016, Bashir et al., 2015, Cano et al., 2015, Bashir, 2013, Antony et al., 2012). Construction managers should develop and implement an effective plan to implement LC techniques successfully in safety improvement (Cano et al., 2015, Bashir, 2013, Bashir et al., 2010).

Construction managers should ensure the continuous improvement in construction projects and thus reduction of costs, increase quality and productivity can be attained (Nasrollahzadeh et al., 2016, Sarhan et al., 2016, Ayarkwa et al., 2012b). Top managers should clearly define the roles, responsibilities, functions and levels of authority, too (Sarhan et al., 2016, Cano et al., 2015, Oladiran, 2008, Achanga et al., 2006). Moreover, decentralization of construction management and reduction of hierarchical levels are required to enhance workflow and apply LC techniques successfully to improve safety in construction projects (Cano et al., 2015, Oladiran, 2008, Achanga et al., 2006).

Good leadership is another important factor needed to overcome barriers to the application of LC techniques to improve safety in construction projects (Azyan et al., 2017, Cano et al., 2015, Shang and Pheng, 2014, Antony et al., 2012, Brady et al., 2011, Porwal et al., 2010). Leaders fosters effective skills and knowledge enhancement amongst its workforce (Achanga et al., 2006). Leaders must also know how and when to apply their knowledge and oversight (Ballard et al., 2007). Construction managers should construct honesty and trust between project participants (transparency) and be proactive in decision-making to apply LC techniques successfully in safety improvement (Cano et al., 2015, Shang and Pheng, 2014, Ayarkwa et al., 2012b). The concept of transparency leads to minimize the hierarchical structure of order giving (Brady, 2014).

In order to achieve successful application of LC techniques in safety improvement, it is highly desirable to improve communication skills among construction stakeholders either horizontally or vertically (Oladiran, 2017, Small et al., 2017, Cano et al., 2015, Antony et al., 2012, Ayarkwa et al., 2012b, Achanga et al., 2006). Moreover, the application of LC techniques in safety improvement needs to enhance the cooperation, coordination and promoting integration between stakeholders (Cano et al., 2015, AlSehaimi et al., 2009, Oladiran, 2008). Furthermore, supporting the development of team work is also proved to be a success factor to successfully implement LC techniques in safety improvement in construction projects (Small et al., 2017, Nasrollahzadeh et al., 2016, Netland, 2016, Ayarkwa et al., 2012b, AlSehaimi et al., 2009, Oladiran, 2008).

Construction managers should develop a proper strategic plan for applying LC techniques in order to communicate the objectives of their application to all employees to participate heartily in the application program (Small et al., 2017, Netland, 2016, Sandeep and Panwar, 2016, Bashir et al., 2015, Cano et al., 2015, Antony et al., 2012, Ayarkwa et al., 2012b, AlSehaimi et al., 2009, Achanga et al., 2006). Therefore, resistance of employees to change and their fear to adopt unfamiliar practices can be removed and will be encouraged to participate heartily in the application program (Bashir et al., 2015, Cano et al., 2015, Ayarkwa et al., 2012 b, AlSehaimi et al., 2009).

All team members, from the highest to the lowest level, must be vested in success and must be focused on process and customer satisfaction. This is a difficult cultural change to enact in the highly multicultural environment of construction site but the rewards are worthwhile (Small et al., 2017). Due to the fact that rewards make changes, construction managers should establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety (Netland, 2016, Cano et al., 2015, Antony et al., 2012, Salem et al., 2005).

Adequate funding of projects is also proved to be a critical factor to overcome the barriers to the application of LC techniques to improve safety (Azyan et al., 2017, Antony et al., 2012, Oladiran, 2008, Achanga et al., 2006). Since, finance covers useful provisions like consultancy and training can be made (Achanga et al., 2006). For the any innovative strategy, commitment of both financial and personnel resources is a crucial factor to apply the strategy successfully (Netland, 2016, Achanga et al., 2006). Moreover, it is important to invest time as much as money to successfully apply LC techniques (Antony et al., 2012).

Furthermore, management should monitor inflation risks, pricing levels and the stability of construction markets that could provide the stability which is needed in construction firms to make Lean methods feasible (Ayarkwa et al., 2012 b, Oladiran, 2008). Table (2.23) summarizes the management success factors to overcome barriers to the application of LC techniques to improve safety in construction projects.

Table (2.23): Management success factors to overcome barriers to the application of LC techniques to improve safety in construction projects

Management success factors	Sources
Management support and commitment	Azyan et al., 2017, Oladiran, 2017, Netland, 2016, Sandeep and Panwar, 2016, Sarhan et al., 2016, Bashir et al., 2015, Cano et al., 2015, Bashir, 2013, Antony et al., 2012, Bashir et al., 2010, Porwal et al., 2010, AlSehaimi et al., 2009, Oladiran, 2008, Salem et al., 2005
Developing and implementing an effective plan	Cano et al., 2015, Bashir, 2013, Bashir et al., 2010
Ensuring continuous improvement in construction projects to obtain the reduction of costs, increase quality and productivity	Nasrollahzadeh et al., 2016, Sarhan et al., 2016, Ayarkwa et al., 2012b
A clear definition of roles, responsibilities, functions and levels of authority	Sarhan et al., 2016, Cano et al., 2015, Oladiran, 2008, Achanga et al., 2006
Decentralization of construction management and reduction of hierarchical levels	Cano et al., 2015, Oladiran, 2008, Achanga et al., 2006
Good leadership	Azyan et al., 2017, Sarhan et al., 2016, Cano et al., 2015, Shang and

Table (2.23): Management success factors to overcome barriers to the application of LC techniques to improve safety in construction projects

Management success factors	Sources
	Pheng, 2014, Antony et al., 2012, Brady et al., 2011, Porwal et al., 2010, Ballard et al., 2007, Achanga et al., 2006
Constructing transparency among project participants	Cano et al., 2015, Brady, 2014, Shang and Pheng, 2014, Ayarkwa et al., 2012b
Construction managers should be proactive in decision-making	Cano et al., 2015, Brady, 2014, Shang and Pheng, 2014, Ayarkwa et al., 2012b
Improving the communication among construction stakeholders either horizontally or vertically	Oladiran, 2017, Small et al., 2017, Cano et al., 2015, Antony et al., 2012, Ayarkwa et al., 2012 b, Achanga et al., 2006
Enhancing the cooperation, coordination and promoting integration between stakeholders	Cano et al., 2015, AlSehaimi et al., 2009, Oladiran, 2008
Supporting the development of team work	Small et al., 2017, Nasrollahzadeh et al., 2016, Netland, 2016, Ayarkwa et al., 2012b, AlSehaimi et al., 2009, Oladiran, 2008
Developing a strategic plan for applying LC techniques and communicate the objectives of its application to all employee	Small et al., 2017, Netland, 2016, Sandeep and Panwar, 2016, Bashir et al., 2015, Cano et al., 2015, Antony et al., 2012, Ayarkwa et al., 2012b, AlSehaimi et al., 2009, Achanga et al., 2006
Establishing a recognition and reward system	Netland, 2016, Cano et al., 2015, Antony et al., 2012, Salem et al., 2005
Adequate funding of projects	Azyan et al., 2017, Netland, 2016, Antony et al., 2012, Oladiran, 2008, Achanga et al., 2006
Invest time as much as money to successfully apply LC techniques	Antony et al., 2012

Table (2.23): Management success factors to overcome barriers to the application of LC techniques to improve safety in construction projects

Management success factors	Sources
Monitoring inflation risks, pricing levels and the stability of construction markets to make Lean methods feasible	Ayarkwa et al., 2012b, Oladiran, 2008

2.7.1.2 Education and skill development success factors

Education and skills improvement is about building human by providing education and training for the employees at all levels on the Lean concept and tools (Azyan et al., 2017, Oladiran, 2017, Small et al., 2017, Netland, 2016, Sandeep and Panwar, 2016, Sarhan et al., 2016, Bashir et al., 2015, Cano et al., 2015, Shang and Pheng, 2014, Singh et al., 2014). It is believed that continuous training is the key to change the organization culture and employees resistance to change during LC implementation (Azyan et al., 2017, Small et al., 2017, Shang and Pheng, 2014, Antony et al., 2012, Ayarkwa et al., 2012a, b, Achanga et al., 2006).

The language of LC should be simplified (Bashir et al., 2015, Bashir, 2013, Ogunbiyi et al., 2011). All the instructions, directive and terms in the application of LC techniques should be simplified in order to achieve compliance and successful execution of the assigned tasks (Bashir et al., 2015, Bashir, 2013). Furthermore, construction firms should enlighten their employees on the benefits of LC by engaging them in meetings, workshops and other events on the benefits of LC techniques (Bashir et al., 2015, Bashir, 2013, Ogunbiyi et al., 2011).

Comprehensive understanding of the Lean philosophy should be enhanced through awareness programs in order to overcome the barriers to the application of LC techniques to improve safety (Oladiran, 2017, Bashir et al., 2015, Cano et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Ayarkwa et al., 2012a). Awareness programs could involve organizing a workshop or a training session with Lean consultants to train the employees adequately to fully understand LC techniques (Bashir et al., 2015, Bashir, 2013)

Moreover, awareness can be increased through research conferences to generate active, basic and applied research on LC to guide the application of LC techniques in order to improve safety (Bashir et al., 2015, Bashir, 2013, Ayarkwa et al., 2012a). Therefore, the Lean concept can be promoted to the stakeholders of construction projects (Bashir et al., 2015, Bashir, 2013, Oladiran, 2008). Moreover, construction firms could engage skillful site operatives and competent/skillful professionals to guide the application of LC techniques in order to improve safety (Bashir et al., 2015, Bashir, 2013, Oladiran, 2008, Achanga et al., 2006). Table (2.24) summarizes the education and skill development success factors to overcome barriers to the application of LC techniques to improve safety in construction projects.

Table (2.24): Education and skill development success factors to overcome barriers to the application of LC techniques to improve safety in construction projects

Education and skill development success factors	Sources
Providing education and training	Azyan et al., 2017, Oladiran, 2017, Small et al., 2017, Netland, 2016, Sandeep and Panwar, 2016, Sarhan et al., 2016, Bashir et al., 2015, Cano et al., 2015, Shang and Pheng, 2014, Singh et al., 2014, Antony et al., 2012, Ayarkwa et al., 2012 a, b, Zhou, 2012, Brady et al., 2011, Bashir et al., 2010, Porwal et al., 2010, Abdullah et al., 2009, Alinaitwe, 2009 and Mossman, 2009, Oladiran, 2008, Ballard et al., 2007, Salem et al., 2005,
The language of Lean should be simplified	Bashir et al., 2015, Bashir, 2013, Ogunbiyi et al., 2011
Enlighten the employees on the benefits of LC by meetings, workshops and other events	Bashir et al., 2015, Bashir, 2013, Ogunbiyi et al., 2011
Establishing awareness programs	Oladiran, 2017, Bashir et al., 2015, Cano et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Ayarkwa et al., 2012a
Promotion of the LC concept to the stakeholders of construction projects	Bashir et al., 2015, Bashir, 2013, Oladiran, 2008
Engagement of skillful site operatives	Bashir et al., 2015, Bashir, 2013, Oladiran, 2008, Achanga et al., 2006
Engagement of competent/skillful professionals	Netland, 2016, Bashir et al., 2015, Cano et al., 2015, Bashir, 2013, Oladiran, 2008, Achanga et al., 2006

2.7.1.3 Government success factors

The success of Lean application rests partly on the shoulders of the government (Shang and Pheng, 2014). Government should make reorientation in their approach to projects' execution (Oladiran, 2008). They should prioritize Lean in their national agenda and provide a clear direction for the construction firms to apply LC techniques (Shang and Pheng, 2014). Government agencies should introduce policies to encourage construction firms to engage in the application of LC techniques to improve safety in construction projects (Oladiran, 2017, Small et al., 2017, Suresh et al., 2017, Bashir et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Ayarkwa et al., 2012b, Oladiran, 2008).

The introduction of laws by the legislature, which is an arm of the government, is seen as another way of facilitating the full application of LC techniques among construction firms (Oladiran, 2017, Bashir et al., 2015, Bashir, 2013). Government should provide the basic infrastructure to apply Lean tools, establish standards for construction to eliminate government bureaucracy; and professional bodies should work closely with the government to introduce Lean in order to improve construction safety (Oladiran, 2008). Table (2.25) summarizes the government success factors to overcome barriers to the application of LC techniques to improve safety in construction projects.

Table (2.25): Government success factors to overcome barriers to the application of LC techniques to improve safety in construction projects

Government success factors	Sources
Government should provide a clear direction to apply LC techniques	Shang and Pheng, 2014
Government agencies should introduce policies	Oladiran, 2017, Small et al., 2017, Suresh et al., 2017, Bashir et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Ayarkwa et al., 2012b, Oladiran, 2008
Introduction of laws by the legislature	Oladiran, 2017, Bashir et al., 2015, Bashir, 2013
Government should provide the basic infrastructure	Oladiran, 2008
Government should establish standards for construction	Oladiran, 2008

Table (2.25): Government success factors to overcome barriers to the application of LC techniques to improve safety in construction projects

Government success factors	Sources
Government should work closely with professional bodies	Oladiran, 2008

2.7.1.4 Operation success factors

Operation success factors are needed to be considered during the application of LC techniques in safety improvement like standardizing and ensuring complete designs to apply LC techniques in safety improvement successfully (Cano et al., 2015). Additionally, workers should be involved and empowered to participate in the application of LC techniques in safety improvement (Azyan et al., 2017, Small et al., 2017, Netland, 2016, Bashir et al., 2015, Cano et al., 2015, Bashir, 2013, Ayarkwa et al., 2012 b, Brady et al., 2011, AlSehaimi et al., 2009).

Additionally, LC techniques should be applied gradually step-by-step in improving safety (Bashir et al., 2015, Bashir, 2013). Bashir (2013) stated that when the construction firms identify the tools that are relevant in achieving their targets, they should apply the tools in stages or one after the other, rather than many tools at a time. This strategy could help in addressing challenges like difficulties in changing working culture and complexity of Lean implementation.

Moreover, establishing an improvement committee is important to be responsible for the application of LC techniques in safety improvement (Cano et al., 2015). Construction firms should establish appropriate performance measurement approaches to measure the effectiveness of implemented LC techniques in safety improvement (Netland, 2016, Sandeep and Panwar, 2016, Ogunbiyi, 2014, Brady et al., 2011). If construction firm doesn’t measure the performance of LC techniques, then they will not be able to learn from mistakes and improve their weak links (Sandeep and Panwar, 2016, Cano et al., 2015, Ballard et al., 2007). Table (2.26) summarizes the Operation success factors to overcome barriers to the application of LC techniques to improve safety in construction projects.

Table (2.26): Operation success factors to overcome barriers to the application of LC techniques to improve safety in construction projects

Operation success factors	Sources
Standardize and ensure complete designs	Cano et al., 2015, Oladiran, 2008

Table (2.26): Operation success factors to overcome barriers to the application of LC techniques to improve safety in construction projects

Operation success factors	Sources
Workers empowerment and involvement	Azyan et al., 2017, Small et al., 2017, Netland, 2016, Bashir et al., 2015, Cano et al., 2015, Bashir, 2013, Ayarkwa et al., 2012 b, Brady et al., 2011, AlSehaimi et al., 2009
Application of LC techniques gradually step-by-step	Bashir et al., 2015, Bashir, 2013
Constitution of an improvement committee	Cano et al., 2015
Establishing appropriate performance measurement approaches	Netland, 2016, Sandeep and Panwar, 2016, Cano et al., 2015, Ogunbiyi, 2014, Brady et al., 2011, Ballard et al., 2007

2.7.2 Summary

This section identified a set of critical success factors which provided a useful insight for the construction practitioners to facilitate the application of LC techniques in safety improvement. After a thorough review, success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects are categorized into management, education and skill development, government and operation success factors.

A total of thirty four success factors were identified through the critical review of previous studies. Sixteen factors are considered as management success factors, seven as educational success factors, six as government success factors and five as operation success factors. The critical success factors which are identified to ensure the successful implementation of LC techniques to improve construction safety are providing the adequate education and training, management support and commitment; and developing a strategic plan, workers empowerment and involvement and good leadership.

Chapter 3

Research Methodology

Chapter 3

Research Methodology

This research was designed to develop a clear understanding of the relation between LC techniques and safety improvement and explore the current state of using Lean Construction (LC) techniques to promote safety in construction projects in Gaza Stip. This chapter presents the research methodology adopted to achieve the aims and objectives of this research. The methodology used in this research including: reviewing literatures related to Lean Construction and safety as well in order to collect factors; and collecting date from the respondents using a questionnaire as a quantitative. This chapter summarizes the research approach, research framework, target population and sampling methods, questionnaire design and development; and the methods used to analyze data collected quantitatively.

3.1 Research approach

In research, two broad methods of reasoning typically used are inductive and deductive approaches (Soiferman, 2010). The main difference between inductive and deductive approaches is the point that the inductive approach suggests applying old solutions to new problems, while the deductive approach has a tendency to apply new solutions to old problems (Graham and Carmichael, 2012).

Inductive approach begins with specific observations and the conclusions are generalized (Zalaghi and Khazaei, 2016, Neuman, 2013, Soiferman, 2010). It generally moves from specific to general, since the researcher generalizes his limited observations of specific circumstances to general conditions (Zalaghi and Khazaei, 2016, Soiferman, 2010). These generalizations need to be tested, some of which might be verified and some rejected (Zalaghi and Khazaei, 2016). In inductive approach, there is no theory at the beginning of the research, and theories would be developed and evolved as a result of research (Zalaghi and Khazaei, 2016, Babbie, 2014). Inductive researcher is known as someone who works from the “bottom-up, using the participants’ views to build broader themes and generate a theory interconnecting the themes” (Soiferman, 2010).

In contrast, in the deductive approach, arguments based on a well-established role for existing theory (Soiferman, 2010, Ali and Birley, 1999). The deductive approach constitutes developing of an assumption based on the existing theories and forming a research plan to test the assumption. When a deductive method is applied for a research project, the author formulates a set of hypotheses that need to be tested and next, using a relevant methodology, tests the hypothesis (Ashley and Boyd, 2006). Deductive approach can be described as a general to specific reasoning process (Zalaghi and Khazaei, 2016, Soiferman, 2010, Ali and Birley, 1999). Deductive researcher "works from the 'top down', from a theory to hypotheses to data to add to or contradict the theory" (Zalaghi and Khazaei, 2016, Creswell and Plano Clark, 2007, Ali and Birley, 1999).

The choice of research approach is usually a challenge, due largely to the debate over years on the best research approach. However, it has been established that no one research approach is better than the other because all the approaches have their own merits and demerits (Bashir, 2013). Generally, applying the inductive approach is usually related to qualitative researches of collecting and analyzing the data, while the deductive approach is usually related to quantitative researches (Marzano et al., 2015, Neuman, 2013, Soiferman, 2010). Many researchers have made the choice of a single method approach either qualitative or quantitative approach while some have used a mixed method approach for their research studies (Ogunbiyi, 2014).

The following sections examines the three approaches that can be adopted in the research studies:

3.1.1 Quantitative research

In quantitative research, the intent is usually to test theories deductively searching for evidence to either support or to refute the hypothesis (McCusker and Gunaydin, 2015, Terrell, 2012, Soiferman, 2010, Creswell and Plano Clark, 2007, Mack et al., 2005). The quantitative research in the context of social- science is normally used to investigate a social or human problem (Terrell, 2012). All aspects of the study in the quantitative research are carefully designed before data is collected. A hypothesis is proposed before the beginning of quantitative research (McCusker and Gunaydin, 2015, Ogunbiyi, 2014). The hypotheses and the questions to be asked in quantitative researches can be identified by the literature review (Soiferman, 2010). For quantitative researchers the literature review plays a major role in justifying the research and identifying the purpose of the study (Soiferman, 2010). Since the quality of all statistical calculations is relied on the quality of raw data (McCusker and Gunaydin, 2015).

There are different ways of collecting data in quantitative research approach (Denscombe, 2010). Researcher uses high structured methods such as questionnaires, and structured observation (McCusker and Gunaydin, 2015, Bashir, 2013, Mack et al., 2005). However, questionnaires are predominantly used in conducting surveys to find out facts, opinions and views of participants (Bashir, 2013).

With quantitative methods such as surveys and questionnaires, for example, researchers ask all participants identical questions in the same order (Marzano et al., 2015, Ogunbiyi, 2014). Generally, quantitative instruments use more rigid style of eliciting and categorizing responses to questions (Marzano et al., 2015, Ogunbiyi, 2014, Mack et al., 2005). It focuses on pointed, close-ended questions that test specific variables that derive from the hypotheses (Ogunbiyi, 2014, Soiferman, 2010). Quantitative methods answered questions about the ‘how many’ or ‘how much’ (McCusker and Gunaydin, 2015, Terrell, 2012).

Quantitative research is measured with numbers which can be statistically analyzed to answer research questions or to test hypotheses (McCusker and Gunaydin, 2015, Ogunbiyi, 2014, Soiferman, 2010, Ballard et al., 2007, Mack et al., 2005). Because quantitative research is numeric, the collection and analysis of data from representative samples is more commonly used (Ogunbiyi, 2014, Assessment Capacities Project, 2012). Quantitative research is characterized that data are obtained from large samples and can be easily generalized (Ogunbiyi, 2014). With quantitative analysis, it is possible to get visual representations for the data using graphs, plots, charts, and tables. In addition, the conclusions are drawn from logic, evidence, and argument (Soiferman, 2010).

3.1.2 Qualitative research

Qualitative research is often said to employ inductive thinking since it moves from specific observations about individual occurrences to broader generalizations and theories (Naoum, 2007, Creswell, 2006). Qualitative research involves exploring to understand a social or human problem (Creswell, 2006). The results of the exploration may later lead to general conclusions or theories

(Naoum, 2007, Ospina, 2004). It involves spending an extensive amount of time in the field because conclusions change and evolve continuously as more data is collected (Ogunbiyi, 2014, Soiferman, 2010). In qualitative research, the literature review is used to provide evidence for the purpose of the study and to identify the problem that will be addressed by the inquiry (Creswell and Plano Clark, 2007).

Qualitative research methods typically include case studies, surveys; and historical and document content analyses (Ogunbiyi, 2014). Qualitative research methods also include interviews with its main types of unstructured, structured or semi structured format (Bashir, 2013, Denscombe, 2010). Qualitative methods are typically more flexible, they allow greater interaction between the researcher and the study participant (Mack et al., 2005, Ospina, 2004). It consists of open-ended questions (Ogunbiyi, 2014, Soiferman, 2010, Creswell and Plano Clark, 2007, Creswell, 2006, Mack et al., 2005). As a result, it provides understanding and description of people‘s personal experiences of phenomena and issues can be examined in detail and in-depth (Ogunbiyi, 2014). Questions about the ‘what’, ‘how’ or ‘why’ of a phenomenon can be answered using qualitative methods (McCusker and Gunaydin, 2015, Terrell, 2012).

Qualitative research methods generates textual data obtained from audiotapes, videotapes, and field notes (McCusker and Gunaydin, 2015, Ballard et al., 2007, Mack et al., 2005). The words and images of participants collected are recorded by the researcher (Creswell and Plano Clark, 2007). The analysis of the qualitative data (words or text or images) typically follows the path of aggregating the words or images into categories of information and presenting the diversity of ideas gathered during data collection (Creswell, 2006). In qualitative research, the researcher is the instrument for data collection (Soiferman, 2010). The researcher is important to ensure the quality of the process (McCusker and Gunaydin, 2015). However, qualitative research is easily influenced by the researcher's personal biases (Ogunbiyi, 2014).

3.1.3 Mixed research

The mixed approach is a relatively new research approach which is also known as multi-methodology (Creswell, 2006). Mixed approach is a combination of both qualitative and quantitative approaches in in the same study (Halcomb and Hickman, 2015, Creswell, 2014, Ogunbiyi, 2014, Bashir, 2013, Terrell, 2012, Creswell, 2006). Mixing refers to the process of interlinking the qualitative and quantitative elements to produce a fuller account of the research problem (Zhang and Creswell, 2013). Mixed approach is practical because it tend to solve problems using both numbers and words; and combine inductive and deductive thinking (Creswell, 2006).

Mixed methods research provide the strengths of both quantitative and qualitative research, while offset their weaknesses (Ogunbiyi, 2014, Wisdom and Creswell, 2013, Halcomb and Andrew, 2009, Creswell, 2006). The use of quantitative and qualitative approaches in combination provides an integrated comprehensive understanding of research problems than either approach alone (Halcomb and Andrew, 2009, Creswell, 2006). It is considered as a viable option to obtain complementary findings and strengthen research results (Ogunbiyi, 2014). Despite the value of mixed approach, conducting it is not easy. It takes time and resources to collect and analyze both quantitative and qualitative data (Creswell, 2006).

In this research on “safety improvement through the application of Lean Construction techniques in construction projects”, the deductive approach will be adopted in order to achieve the research objectives. According to some researchers, deductive approach is considered as quantitative approach. Therefore, the quantitative approach will be used to collect data of this research. The questionnaire will be used as a method to collect the quantitative data.

3.1.4 Choice of research approach and research methods

The choice of research approach is usually a challenge (Bashir, 2013). Many researchers have made the choice of a single method approach either qualitative or quantitative approach while some have used a mixed method approach for their research studies (Ogunbiyi, 2014). The selection of research methods should be made in relation to the research objectives (McCusker and Gunaydin, 2015, Denscombe, 2010). Ogunbiyi (2014) stated that the not only the choice of research methods is important but also the method chosen should be appropriate to achieve the objectives of the study.

This research investigate the use of LC techniques in safety improvement among the construction projects. Many research methods are used by researchers to collect data in order to achieve the objectives of their studies which is related to Lean Construction. Enshassi and Abu

Zaiter (2014) used the quantitative approach to investigate the Lean tools' implementation in construction project and its impact on safety conditions through a questionnaire. While Forman (2013) have adopted the qualitative approach to investigate how organizations implement the change programs and what new forms of practice they stabilize as a result of the implementation process. On the other hand, Sarhan and Fox (2013) adopt the mixed method approach involving a questionnaire survey and semi-structured interviews to investigate the barriers of implementing LC in construction projects. Table (3.1) summarizes the research methods adopted by some researchers to conduct their studies.

Table 3.1): Research methods for previous studies

Author	Country	Research method
Azyan et al., 2017	Malaysia	Case study
Bajjou et al., 2017	Morocco	Comprehensive literature review
Couto et al., 2017	Brazil	Questionnaire survey
Daniel et al., 2017	United Kingdom (UK)	Semi-structured interviews, document analysis and structured observation
Oladiran, 2017	Nigeria	Structured interviews
Sarhan et al., 2017	Kingdom of Saudi Arabia (KSA)	Questionnaire survey
Small et al., 2017	United of Arabs Emirates (UAE)	Literature reviews
Adegbembo et al., 2016	Nigeria	Questionnaire survey
Awada et al., 2016	Lebanon	Questionnaire survey
Gambatese et al., 2016	USA	Comprehensive literature review, document content analyses and questionnaire survey
Li et al., 2016	China	Case study
Nasrollahzadeh et al., 2016	Malaysia	Questionnaire survey
Saunders et al., 2016	USA	Case study

Table 3.1): Research methods for previous studies

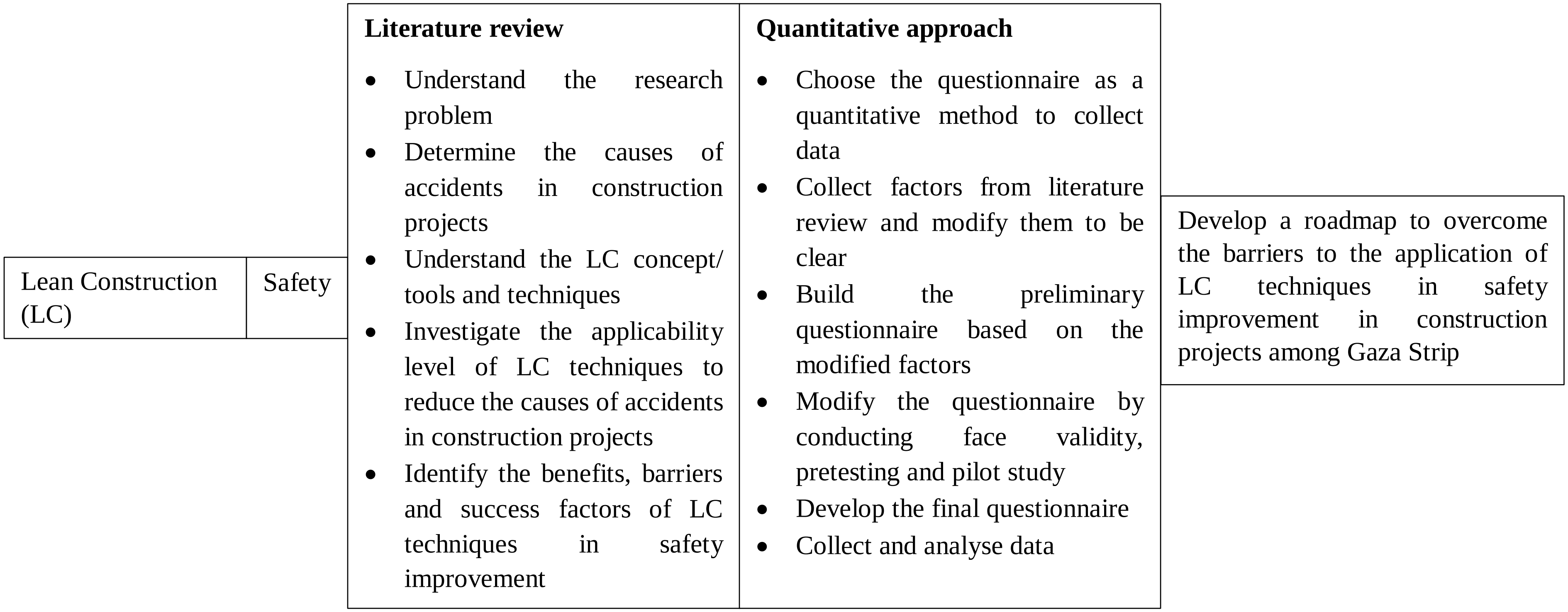
Author	Country	Research method
Bashir et al., 2015	UK	Semi-structured interview
Cano et al., 2015	Colombia	Analytical literature review
Cudney et al., 2015	USA	Questionnaire survey
Fang et al., 2015	Hong Kong	Questionnaire survey
Nikakhtar et al., 2015	Malaysia	Case study and simulation and process modelling
Pradeepkumar and Loganathan, 2015	India	Case study
Bygballe and Swärd, 2014	Scandinavia	Case study
Enshassi and Abu Zaiter, 2014	Palestine	Questionnaire survey
Gambetese and Pestana, 2014	USA	Case study and questionnaire survey
Ogunbiyi et al., 2014	UK	Questionnaire survey
Shang and Pheng, 2014	China	Questionnaire
Wandahl, 2014	Denmark	Questionnaire survey
Al- Najem et al., 2013	Al-Kuwait	Comprehensive literature review, questionnaire, Semi-structured interviews
Aziz and Hafez, 2013	Egypt	Case study
Cerveró-Romero et al., 2013	Mexico	Interview, questionnaire survey, observation and case study
Forman, 2013	Denmark	Case study
Ogunbiyi et al., 2013	UK	Comprehensive literature review
Sarhan and Fox, 2013	UK	Questionnaire survey and semi-structured interviews
Ayarkwa et al., 2012a	Ghana	Questionnaire survey

Table 3.1): Research methods for previous studies

Author	Country	Research method
Ayarkwa et al., 2012b	Ghana	Questionnaire survey
Marhani et al., 2012	Malaysia	An extensive literature review
Zhou, 2012	USA	Questionnaire survey
Bashir et al., 2011	United Kingdom	Comprehensive literature review
Ikuma et al., 2011	USA	Case study
Vieira and Cachadinha, 2011	Portugal	Case study
Forman, 2010	Denmark	Case study
Porwal et al., 2010	USA	Comprehensive literature review
Alinaitwe, 2009	Uganda	Questionnaire survey
AlSehaimi et al., 2009	KSA	Interview, observation and questionnaire survey
Ghosh and Young-Corbett, 2009	USA	Comprehensive literature review
Nahmens and Ikuma, 2009	USA	Survey
Olatunji, 2008	Nigeria	Interview
Mitropoulos et al., 2007	USA	Case study
Razuri et al., 2007	Chile	Questionnaire survey
Achanga et al., 2006	UK	Comprehensive literature review, observation, interview
Kim and Park, 2006	USA	Case study
Bayfield and Roberts, 2005	UK	Case study

3.2 Research Framework

The research process followed in this study can be summarized using a research framework consisting of four key stages as shown in Figure (3.1). The following sections explained broadly the process followed in this research.



Lean Construction (LC)

Safety

Literature review

- Understand the research problem
- Determine the causes of accidents in construction projects
- Understand the LC concept/ tools and techniques
- Investigate the applicability level of LC techniques to reduce the causes of accidents in construction projects
- Identify the benefits, barriers and success factors of LC techniques in safety improvement

Quantitative approach

- Choose the questionnaire as a quantitative method to collect data
- Collect factors from literature review and modify them to be clear
- Build the preliminary questionnaire based on the modified factors
- Modify the questionnaire by conducting face validity, pretesting and pilot study
- Develop the final questionnaire
- Collect and analyse data

Develop a roadmap to overcome the barriers to the application of LC techniques in safety improvement in construction projects among Gaza Strip

Figure (3.1): Research Framework

3.2.1 Literature review

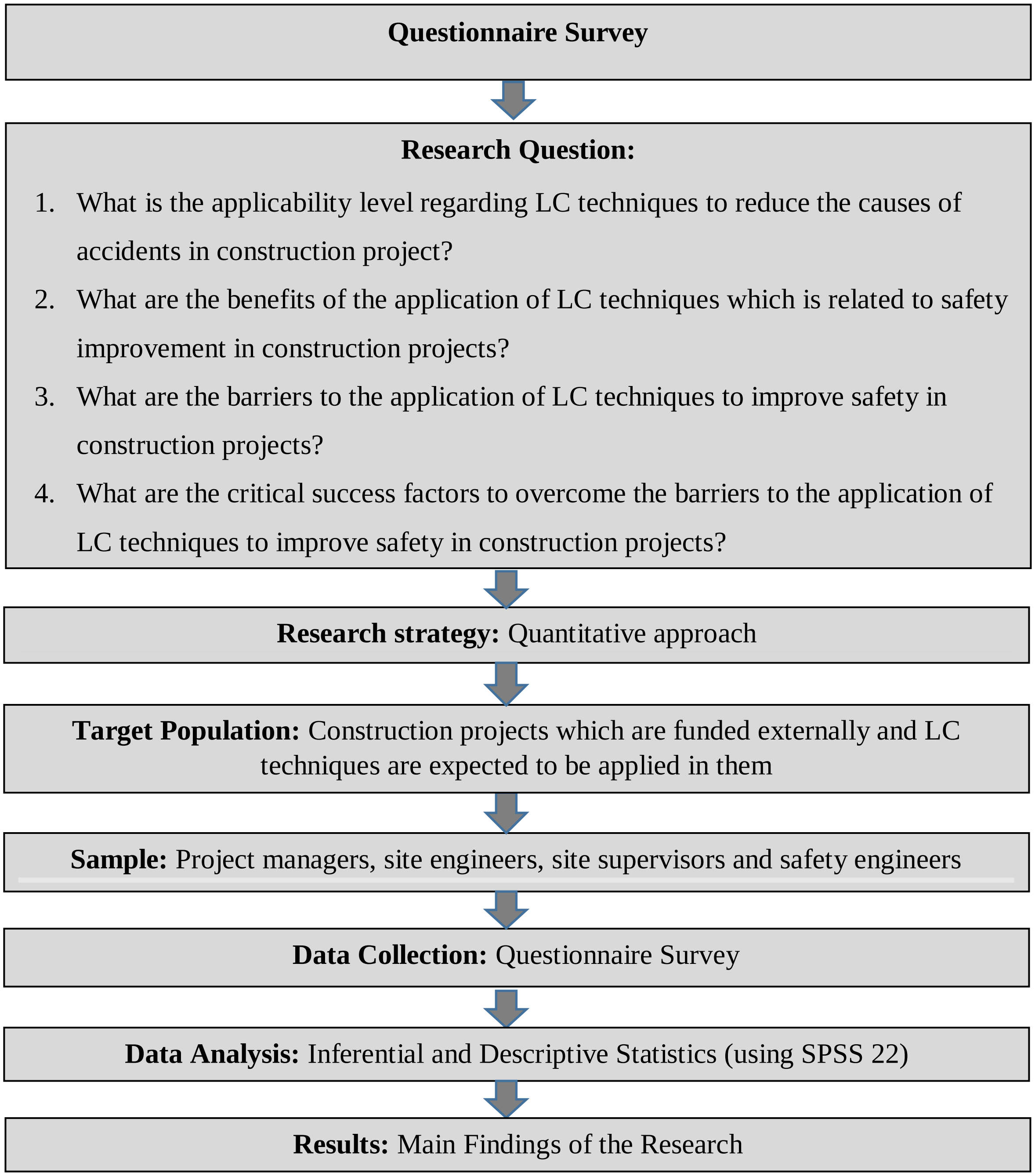
The literature review is an early and essential stage in conducting a research project to review the accumulated knowledge on the research questions (Neuman, 2013, Naoum, 2007). Starting the literature review process involves the identification of appropriate literature. There are three sources of literatures which are primary sources, secondary sources and reference guides. Primary sources include academic research journals, refereed conferences, theses, and reports. While secondary sources are textbooks, trade journals and newspapers. Dictionaries and glossaries; and encyclopedias are considered as reference guides (Naoum, 2007).

In relation to this research, literature was collected from academic research journals, refereed conferences, theses, reports and text books. The review of literature was extensively and critically undertaken at the initial stage of the study to identify the relation between LC techniques and safety improvement in construction projects, benefits, barriers and the success factors. The first part of literature focused on studying safety in construction industry including safety records, causes of accidents and the onsite causes of accidents. This part is followed by the application of Lean thinking in the construction sector which begins with understanding the concept of Lean thinking, the key characteristics of Lean Construction and its elements; and LC principles and its stages.

The remained parts of literature review were divided regard the objectives of this research sequentially. Firstly, investigating the applicability level of LC techniques to reduce the causes of accidents. This is followed by benefits of the application LC techniques which is related to safety improvement in construction projects and barriers to the application of LC techniques in safety improvement in construction projects. Finally, to identify the success factors which encourage the application of LC techniques in safety improvement in construction projects. The factors collected from literatures related to the research objectives composed a base to develop the preliminary questionnaire.

3.2.2 The Questionnaire Survey

The questionnaire survey is considered as the second stage of this research. The process followed in this stage is summarized in Figure (3.2). It focused on the development of the questionnaire survey and the results analysis. The main purpose of this stage was to identify the applicability level of LC techniques in reducing the causes of accidents, benefits of LC related to safety improvement, barriers prevented the application of LC in safety improvement and success factors encourage the application of LC in safety improvement. In addition, this stage of the study was carried out to verify the findings from the literature review.



Questionnaire Survey

Research Question:

1. What is the applicability level regarding LC techniques to reduce the causes of accidents in construction project?
2. What are the benefits of the application of LC techniques which is related to safety improvement in construction projects?
3. What are the barriers to the application of LC techniques to improve safety in construction projects?
4. What are the critical success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects?

Research strategy: Quantitative approach

Target Population: Construction projects which are funded externally and LC techniques are expected to be applied in them

Sample: Project managers, site engineers, site supervisors and safety engineers

Data Collection: Questionnaire Survey

Data Analysis: Inferential and Descriptive Statistics (using SPSS 22)

Results: Main Findings of the Research

Figure (3.2): Research process of second stage: Questionnaire survey

3.2.3 Research strategy for the questionnaire survey of the study

As shown in Figure (3.1), the second stage of research adopted the quantitative approach. In quantitative approach, researcher uses questionnaires, surveys, and structured observation to collect data (McCusker and Gunaydin, 2015, Bashir, 2013, Mack et al., 2005). However, questionnaires are predominantly used in conducting surveys to find out facts, opinions and views of participants (Bashir, 2013). Almost all questionnaires have ‘closed-ended’ questions that require a specific response such as ‘yes’ or ‘no’ or ranking the importance of factors (Naoum, 2007).

The main advantages of questionnaires are quick of conducting a survey, it is more suited to assembling a mass of information at a minimum expense in terms of finance, human and other resources (Mathers et al., 2007). On the other hand, the main limitation of questionnaire are inflexibility since most of questionnaires depends on close ended questions and there is no control over respondents which means that any person complete the questionnaire even though the specification of a particular persons (Naoum, 2007).

In this research, the questionnaire will be used as a tool to collect data regard the four objectives, since most of researches related to the research topic used questionnaires as seen in Table (3.1). The following section will clarify the target population and sampling methods in order to identify the target population and the sample who will fill the questionnaires.

3.3 Target population and sampling methods

Target population refers to all the members who meet the particular criterion specified for a research investigation (Alvi, 2016). A sample can be defined as a group of relatively smaller number of people selected from a population for investigation purpose (Alvi, 2016, Neuman, 2013). The process through which a sample is extracted from a population is called as sampling (Alvi, 2016). The members of the sample are called as participants (Alvi, 2016). Sample is used to fairly represent the target population (Denscombe, 2010). It is said to be representative when the characteristics of elements selected are similar to that of entire target population (Alvi, 2016, Neuman, 2013, Creswell, 2007). The more the sample is representative of the target population, the higher is the accuracy of the inferences and better are the results generalizable (Alvi, 2016, Neuman, 2013).

3.3.1 Sampling methods

Selecting the research sample is very important and great care must be taken when choosing the type of sample (Naoum, 2007). The study's research objectives and the characteristics of the study population (such as size and diversity) determine which and how many people to select (Mack et al., 2005, Bazeley, 2004). Sampling methods are broadly categorized into two major types which are probability and non- probability sampling (Alvi, 2016, Ogunbiyi, 2014, Naoum, 2007).

3.3.1.1 Probability Sampling

Probability sampling is also called as random sampling or representative sampling (Alvi, 2016, Neuman, 2013). In probability sampling, every member of the population is known before a sample is drawn and each member has a known chance of being selected as a sample (Alvi, 2016, Bryman, 2008). Probability sampling can be done as the population is precisely defined and limited to an infinite number of elements (Alvi, 2016). There are four types of probability sampling techniques including simple random sampling, stratified random sampling, systematic sampling; and cluster sampling.

1. Simple Random Sampling

A random sample in which a researcher creates a sampling frame and uses a pure random process to select cases (Neuman, 2013). In this type of sampling, each member of the population has an equal opportunity of being included in the sample (Alvi, 2016, Ogunbiyi, 2014, Bashir, 2013, Neuman, 2013). For instance, a researcher may put the names of all the members of a population in a hat, waddles the hat and thoughtlessly picks a portion of the names to form members of the sample (Bashir, 2013). Simple random sampling is the most commonly used method of selecting a probability sample (Ogunbiyi, 2014). A major disadvantage is that it may be very costly and time consuming especially in those cases when the participants are widely spread geographically and difficult to approach; and it needs a lot of efforts especially for a large population (Alvi, 2016).

2. Stratified Random Sampling

A random sample in which the researcher first divides the population into certain categories based on different features which is called strata (Alvi, 2016, Ogunbiyi, 2014, Bryman, 2008). Every element of population does not matches all the characteristics of the predefined criteria (Alvi, 2016). After dividing the population into strata, a random sample from each strata is drawn (Alvi, 2016, Bashir, 2013). This reduces the chances that the sample may not be a true representative of the population (Ogunbiyi, 2014, Bashir, 2013). For instance, if a class is stratified based on gender into 60 males and 40 females, 6 males and 4 females can be chosen to represent the class, as a sample (Bashir, 2013). The main disadvantages of it are that it needs a lot of efforts, it is costly and time consuming and if the criterion characteristic used for classification is not selected correctly, the whole research may be useless (Alvi, 2016).

3. Systematic Samples

A simple random sampling with a shortcut selection procedure (Neuman, 2013). In this type of sampling, the elements are selected at a regular interval (Alvi, 2016). A researcher first makes an ordered list of all the members of the population (Alvi, 2016, Bashir, 2013). The first member, starting point, is determined by a random selection (Bashir, 2013). The size of the sample to be formed and the total number of the members will determine how many members of the population will be skipped (Bashir, 2013, Neuman, 2013). For example, if 10 samples are to be selected from a population of 100 members, every 9 or 10 members will be skipped i.e. every 10th member will be selected (Bashir, 2013). The main disadvantages of systematic sampling are that it may be very costly and time consuming especially in those cases when the participants are widely spread geographically and difficult to approach, it needs a lot of efforts especially for a large population; and if the order of the list is biased in some way, systematic error may occur (Alvi, 2016).

4. Cluster Sampling

The group of elements residing in one geographical region is called as cluster and sampling of clusters is called as cluster sampling (Alvi, 2016). Cluster sampling is a type of random sample that uses multiple stages and is often used to cover wide geographic areas (Alvi, 2016, Ogunbiyi, 2014, Neuman, 2013). A sample of the clusters is then randomly selected (Bashir, 2013, Neuman, 2013). In other words, a random selection is made from the members of the clusters and data is then collected from these randomly selected members (Bashir, 2013). The main disadvantages of cluster sampling are that it may sometimes lead to sampling biases and systematic errors; and if clusters are not homogeneous among them, the final sample may not be representative of the population (Alvi, 2016).

3.3.1.2 Non-probability Sampling

Non probability sampling is also called as judgment or non-random sampling (Alvi, 2016). In nonprobability samples, you do not have to determine the sample size in advance and have limited knowledge about the population from which the sample is taken (Neuman, 2013). The researcher does not have a population where the total number of the members is known (Bryman, 2008). Non probability techniques make it possible to take a sample of population the elements of which are infinite in number (Alvi, 2016). None of the members has a known probability chance of being selected as a sample. Samples are selected based on their convenience and availability (Creswell, 2006). In this case, extreme care is needed in generalizing the findings from samples to the population (Bashir, 2013). The different types of non-probability sampling techniques are convenience sampling, purposive sampling, quota sampling; and snowballing sampling.

1. Convenience sampling

Convenience sampling is also called as accidental sampling or opportunity sampling (Alvi, 2016, Neuman, 2013). It is a non- random sample in which the researcher selects anyone he or she happens to come across (Neuman, 2013). The researcher includes those participants who are easy or convenient to approach (Alvi, 2016, Neuman, 2013, Bryman, 2008). The main disadvantages are that it is subjected to sampling biases and systematic errors; and when the cases are selected based on convenience, the sample can seriously misrepresent features in the entire population. However convenience samples are easy, cheap, and quick to obtain (Alvi, 2016, Neuman, 2013).

2. Purposive sampling

Purposive sampling is also known as judgment, expert, selective or subjective sampling (Battaglia, 2011, Black, 2010, Guarte and Barrios, 2006). It is strategic technique where samples are selected based on their relevance to the research question (Alvi, 2016, Denscombe, 2010). Purposive sampling is a sampling technique in which researcher relies on his or her own judgment when choosing members of population to participate in the study and provide the best information to achieve the objectives of the study (Ogunbiyi, 2014, Battaglia, 2011, Black, 2010). The main objective of purposive sampling is to produce a sample that can be considered ‘‘representative’’ of the population (Battaglia, 2011).

Purposive sampling is one of the most common sampling strategies in the social sciences (Guarte and Barrios, 2006, Mack et al., 2005). Purposive sampling is a technique widely used in qualitative research for the identification and selection of information-rich cases for the most effective use of limited resources (Palinkas et al., 2015, Ogunbiyi, 2014, Neuman, 2013, Black, 2010, Bryman 2008). Researchers often believe that they can obtain a representative sample by using a sound judgment, which will result in saving time and money (Black, 2010).

3. Quota sampling

A nonrandom sample in which the researcher first identifies general categories into which cases or people will be placed and then selects cases to reach a predetermined number in each category (Neuman, 2013). Quota sampling, sometimes considered a type of purposive sampling. As its criteria focus on people would be most likely to experience, know about, or have insights into the research topic (Mack et al., 2005). However, quota sampling is more specific with respect to sizes and proportions of subsamples, with subgroups chosen to reflect corresponding proportions in the population (Mack et al., 2005).

This is a technique where the sample should be composed of certain number of objects of different features. Then the researcher simply continues to search for enough participants within each category until the set number or quantity is attained (Bashir, 2013, Neuman, 2013). For instance, a researcher may decide that his/her research require 30 primary school teachers, 30 secondary school teachers and 30 university lecturers (Bashir, 2013).

4. Snowballing sampling

Snowballing is also known as chain sampling (Alvi, 2016, Neuman, 2013, Mack et al., 2005). The method uses an analogy to a snowball, which begins small but becomes larger as we roll it on wet snow and it picks up additional snow (Neuman, 2013). Snowball sampling is a multistage technique. It begins with one or a few people or cases and spreads out based on links to the initial cases (Ogunbiyi, 2014, Bashir, 2013, Neuman, 2013). Snowball sampling can be used when the populations are quite hard to find (Ogunbiyi, 2014).

Sampling issues must be resolved with respect to the purpose of the research, and in particular how the results are to be generalized to a population beyond the sample (Bazeley, 2004). ***In this research*** on "Improving safety using Lean Construction techniques in construction projects", the target population will be taken is "The construction projects which are externally funded and LC techniques are expected to be applied in them". As the number of the target population is not known, the sampling method will be adopted is a non- probability sampling. In order to achieve the research objectives, the purposive sample will be taken in this research. The target sample respondents include engineers who work in the field of construction supervision (Project manager, site engineers, site supervisors and safety engineers).

3.3.2 Sample size

One crucial aspect of study is deciding the size of sample. If the sample size is increased, the precision of estimates will be increased. In other words, the greater the sample size, the more statistically significant the result will be (Cornish, 2006). There are different formulae that can be used for the determination of appropriate sample sizes (Ogunbiyi, 2014, Sarmah et al., 2013). The researchers should choose the formula according to their needs and convenience. Using an adequate sample along with high quality data collection will result in more reliable and valid results (Sarmah et al., 2013). Determination of proper sample is vital to truly represent the target population and lead to reliable conclusions (Sarmah et al., 2013).

As previously mentioned, the purposive sampling is adopted in this research as sampling method. In purposive sample, Battaglia (2011) stated that the sample size might involve selecting large (1,000+ respondents), medium (100–999 respondents), and small (<100 respondents). On the other hand, Easterby-Smith et al. (2002), presented a rough formula for calculating the sample size (n) in terms of the maximum error required (E), as shown in Equation 3.1

$$n= \frac{2500}{E^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation 3.1}$$

According to equation 3.1, it is clear that the standard error is inversely proportional to the sample size. The standard error is a measure of the expected dispersion of sample estimates around the true population parameter. The larger the sample size, the smaller the standard error. The smaller the standard error, the more representative the sample will be of the target population (Ogunbiyi, 2014).

In relation to this research, the standard error taken is less than 5% to make the sample more representative. Therefore, the sample size would be at least 100 respondents. Actually, the sample size was 107, which is according to Battaglia (2011) considered as medium sample size and resulted in an error of 4.83% according to equation 3.1.

3.3.3 Response rate

Another aspect of sampling in a survey is the response rate (Ogunbiyi, 2014). Response rate is the number of participants who completed a questionnaire divided by the total number of participants who were asked to participate as shown in equation (3.2) (Central for disease control and prevention, 2010).

$$\text{Response rate} = \frac{\text{number of completed questionnaires} * 100}{\text{total number of sample}} \quad \ldots\ldots\ldots\ldots\ldots \quad \text{Equation 3.2}$$

In this research, 120 questionnaires were distributed and 106 were completed. Therefore, the response rate is 88.3 according to equation 3.2 which is considered as very good according to Saldivar (2012). The response rate of 88.33% is very good in comparison with the previous studies of Adegbembo et al. (2016) who recorded a response rate of 79.57%. On the other hand, Enshassi and Abu Zaiter (2014) recorded a response rate of 77.7% and 74.5% is the response rate which is recorded by Sarhan and Fox (2013).

3.4 Questionnaire design and development

The questionnaire design started with identifying a list of factors relating to the aims and objectives of the research. These factors were mainly obtained from the literature review and composed a base to develop the questionnaire. The questionnaire was provided with a covering letter explaining the aims of the research and the required accuracy to increase the answers' validity. The questionnaire included close-ended questions with multiple-choice to avoid any complications. The questionnaire (refer to Appendix C) was refined into six main sections as follows:

- Section A : Profile of respondent
- Section B: Awareness level of Lean Construction (LC) tools
- Section C: Application of LC techniques to reduce the causes of accidents on the construction sites
- Section D: Benefits of LC techniques related to safety improvement in construction projects
- Section E: Barriers to the application of LC techniques regarding safety improvement
- Section F: Success factors to apply LC techniques in safety improvement successfully.

Level of measurement or scale of measure in the questionnaire is a system for organizing information in the measurement of variables into four levels, from nominal level to ratio level (Neuman, 2013). There are four levels of measurement: nominal, ordinal, interval, and ratio scales (Patel, 2009, Naoum, 2007). Each level provides a different type of information:

- **Nominal-level measurement:** A level of measurement that has qualitative categories and cannot be ranked in a meaningful way in terms of degree or magnitude (Patel, 2009). Nominal measurement does not imply any idea of rank or priority (Naoum, 2007). It implies belonging to a classification or having a particular property and a label (Naoum, 2007). It is considered as the lowest and least precise level of measurement (Neuman, 2013, Patel, 2009). Nominal measurement indicates that a difference exists among categories (e.g., religion: Protestant, Catholic, Jew, Muslim; racial heritage: African, Asian, Caucasian, Hispanic, other) (Neuman, 2013)
- **Ordinal-level measurement:** A level of measurement that has qualitative categories and are ordered in terms of degree or magnitude (Patel, 2009). Ordinal measurement indicates a difference among categories of a variable and allows the categories to be rank ordered as well (e.g., opinion measures: strongly agree, agree, disagree, strongly disagree) (Neuman, 2013). It uses integers in ascending or descending order (Naoum, 2007).
- **Interval-level measurement:** A level of measurement that has quantitative values (or numbers) (Patel, 2009). It identifies differences among variable attributes, ranks categories, and measures distance between categories but has no true zero (Neuman, 2013). Often used examples are minutes, kilograms, number of words recalled in a memory test or percentage

marks in the exam (Naoum, 2007). This is most powerful type of variable because you can do the most with it statistically. (Patel, 2009).

- **Ratio-level measurement:** The ratio scale is similar to the interval scale except it involves the kind of numerical scale which has a true zero such as age, salary, time and distance (Neuman, 2013, Naoum, 2007). The variable attributes can be rank ordered and the distance between them precisely measured. It is considered as the highest, most precise level of measurement (Neuman, 2013).

In this research, three types of measurement levels were used in the questionnaire. Nominal level measurement was used in the first four questions in section (A) of the questionnaire (Profile of respondent). While ratio scale was used in section (A) to answer the last question about experience years. Finally, ordinal scale was used in all other sections of the questionnaire which is specialized to measure the respondents' opinions.

Likert scales fall within the ordinal level of measurement (Jamieson, 2004). Likert scales are commonly used to measure attitude, providing a range of responses to a given question or statement and resulting data are usually analyzed using the relative importance index (RII) method (Holt, 2014, Jamieson, 2004). As far as Likert was concerned, attitudes towards any object or on any issue varied along the same underlying negative-to-positive dimension (Johns, 2010). Typically, there are five response categories, although, there are scales with between four and seven response categories (Jamieson, 2004). Odd numbered scales have a "middle" category which allow respondents to represents neither a negative or positive response (Holt, 2014). Conversely, even-numbered scales is without mid or neutral response to force either a negative or positive response attitude (Johns, 2010).

In this research, a five-point Likert scale which varies from (0 or 1 = lowest scale to 4 or 5 = highest scale) was used for all the questions except the questions in section (A). The reason why five has become the norm is because it strikes a neutral point between the conflicting goals which offer enough choice and making things manageable for respondents (Johns, 2010). The response categories of such questions are called quantifiers which reflect the intensity of the particular judgement involved (Naoum, 2007). Table (3.2) summarized the quantifiers used for the five-point Likert scale in the questionnaire of this research.

Table 3.2): The quantifiers used for the five-point Likert scale

Sections	Quantifiers				
Awareness level of Lean Construction tools	Never 1	Little 2	Somewhat 3	Much 4	Very much 5
Application of LC techniques to reduce the causes of accidents on the construction sites	Never 1	Seldom 2	Often 3	Frequent 4	Always 5
Benefits of LC techniques related to safety improvement in construction projects	Not important 1	Slightly important 2	Important 3	Very important 4	Extremely important 5
Barriers to the application of LC techniques regarding safety improvement	No effect 0	Slight effect 1	Moderate effect 2	Strong effect 3	Extreme effect 4
Success factors to apply LC techniques in safety improvement successfully	Not influential 1	Slightly influential 2	Influential 3	Very influential 4	Extremely influential 5

Factors obtained from literature review composed a base to build a preliminary questionnaire (A). The researcher modified the preliminary questionnaire to clarify the factors to come out with questionnaire (B) before the amendment process. Then questionnaire (B) was revised through amendment process in order to maximize the response rate and to minimize misunderstanding errors. Amendment process was necessary to develop the final questionnaire that was surveyed to the target sample. ***In this research,*** the amendment process consisted of three stages:

1. **Face validity:** It is a subjective judgment by experts in the LC and safety to assess the clarity of the items, to remove the items far from the relation between LC and safety improvement; and to generate new items, if any.
2. **Pre testing:** It is needed to test the survey questionnaire (Arabic questionnaire) before using it to collect data in order to identify questions that don't make sense to participants or can't be understood.
3. **Pilot study:** Thirty completed questionnaires were entered into the SPSS to check their validity and reliability to delete any item that has a value less than the minimum ranges of both validity and reliability.

With each stage, the questionnaire was revised and refined more and more. The stages of the amendment process will be discussed at the following sections:

3.4.1 Modification by researcher

In the preliminary questionnaire (A), some of the items were repetitive and needed to be merged as the items in section (C) which is related to the using LC techniques in safety improvement. Some factors as benefits, barriers and success factors were related to LC only. The researcher summarized the benefits of LC which are related to safety and simplified these benefits to make respondents easily understand the safety benefits achieved by applying LC techniques.

Similarly, previous studies summarized the barriers and success factors of LC. The researcher modified these barriers and success factors of LC to be correlated with safety improvement to introduce barriers and success factors affect the application of LC techniques in safety improvement. Moreover, the researcher clarified and simplified these factors to help respondents recognize the relation between the LC and safety improvement. Those modifications have been explained in Table (3.3).

Table (3.3): Results of researcher modifications

#	Items before modifications	Researcher modifications
Section C: Application of LC tools and techniques to reduce the causes of accidents on the construction sites		
1.	Safety signs and labels to reduce accidents caused by high percentage of uneducated workers, poor site awareness	Merge 1, 2, 3 in one item: Using safety signs and labels on site to reduce accidents caused by high percentage of uneducated workers, poor site awareness, poor communication and human error
2.	Safety signs and labels to reduce accidents caused by poor communication	
3.	Safety signs and labels to reduce accidents caused by human error	
4.	Visibility improvement to reduce accidents caused by unsafe site conditions	Merge 4, 5, 6 in one item: Improving visibility to enhance site conditions, increase supervision, reduce exposure to hazards as chemical exposure, tripping, falling hazards; and reduce human error
5.	Visibility improvement to reduce accidents caused by poor supervision	

Table (3.3): Results of researcher modifications

#	Items before modifications	Researcher modifications
6.	Visibility improvement to reduce accidents caused by exposure to hazards as chemical exposure and tripping/falling hazards	
7.	Removing materials and machines that are not required to be used within that period to reduce accidents caused by Site congestion	Merge 7, 8, 9 in one item: Cleaning the workplace and removing materials and machines that are not required to reduce site congestion and reduce site hazards like dust
8.	Cleaning the workplace to reduce accidents caused by site hazards like dust, noise	
9.	Cleaning the workplace to reduce accidents caused by Poorly organized site	
10.	Separating needed tools from unneeded materials to reduce accidents caused by Site congestion	Merge 10, 11 in one item: Separating needed tools from unneeded materials and clearing the unwanted materials to reduce site congestion and trips, falls and exposure to hazards
11.	Clearing the unwanted materials to reduce accidents caused by Trips, falls and exposure to hazards	
12.	Alarms and warning gadgets to reduce accidents caused by Equipment failure	Merge 12, 13 in one item: Using Alarms and warning gadgets to reduce accidents caused by equipment failure and to warn workers from crossing the unsafe boundaries
13.	Alarms and warning gadgets to reduce accidents caused by Crossing unsafe boundaries	
14.	Safe guards and PPE to reduce accidents caused by Falling objects	Merge 14, 15 in one item: Using safe guards and PPE to reduce accidents caused by falling objects and site hazards like (excess heat, sound, noise, dust)
15.	Safe guards and PPE to reduce accidents caused by Site hazards: excess heat, sound, noise, dust	
16.	Conducting daily meeting to reduce accidents caused by Poor communication and coordination	Merge 16, 17, 18 in one item: Conducting daily meeting to increase communication between teamwork, increase workers

Table (3.3): Results of researcher modifications

#	Items before modifications	Researcher modifications
17.	Conducting daily meeting to reduce accidents caused by poor risk identification and reduction	awareness of safety to make them identify risks and reduce it
18.	Conducting daily meeting to reduce accidents caused by Lack of safety awareness	
Section D: Benefits of LC techniques related to safety improvement in construction projects		
1.	Reducing the additional costs	Reducing the additional costs resulting from accidents on construction sites (Ex. medical treatment, workers' compensation, etc.)
2.	Increasing productivity	Maximizing the workers productivity
3.	Construction firms become more competitive	Construction firms become more competitive by improving efficiency
4.	Submit work with high quality and less defects	Merge 4, 5 in one item: submit work with high quality and less defects to minimize the rework
5.	Less rework in construction projects	
6.	Improving workers' safety	Improving workers' safety by reducing site accidents, ensure safety and maintain a standard safety culture
7.	Increasing employee empowerment and involvement	Increasing employees' empowerment and involvement to discuss and resolve work place problems
Section E: Barriers to the application of LC techniques regarding safety improvement		
1.	Top management support and commitment	Lack of management support and commitment to the application of LC techniques in safety improvement
2.	Poor project definition	Poor project definition which explain the vision, mission and main objectives of the project and its stakeholders
3.	Lengthy approval procedure from top management	Lengthy approval procedure from top management to take any step
4.	Lack of time for innovation	Lack of time in construction firms for innovation and apply any innovative strategy

Table (3.3): Results of researcher modifications

#	Items before modifications	Researcher modifications
5.	Absence of long term forecast and investment by the top management	Absence of long term forecast of safety improvement
6.	Inadequate planning	Inadequate planning to apply LC techniques in safety improvement
7.	Logistics' problems	Logistics' problems (Ex. poor management of materials, equipment and tools and short supply of material)
8.	Implementation cost of LC	High cost of LC implementation including cost of training, consultancy fees and cost to conduct workshops
9.	Poor salaries of professionals	Poor salaries do not encourage employees to apply any innovative strategies
10.	Lack of knowledge and skills	Inadequate knowledge to apply LC techniques in safety improvement
11.	Lack of technical skills	Lack of technical skills to apply LC techniques in safety improvement
12.	Lack of education and training	Lack of education and training needed to apply LC techniques in safety improvement
13.	Lack of awareness programs	Lack of awareness programs to increase knowledge about LC
14.	Lack of experiences and information sharing	Lack of information and experiences sharing among construction firms
15.	Lack of government support towards the construction industry	Lack of government support towards the construction projects to apply any innovative strategy
16.	Lack of agreed implementation methodology	Lack of agreed implementation methodology to implement LC techniques
17.	Complexity of LC implementation	Complexity of LC implementation since LC does not just involve applying LC techniques on site, but also involves

Table (3.3): Results of researcher modifications

#	Items before modifications	Researcher modifications
		developing a culture among the staff for a continuous improvement
18.	Long implementation period	Long implementation period needed for LC techniques application in safety improvement
19.	Incomplete designs	Incomplete designs which leads to increases the probability of re-work
20.	Selfishness among professionals	Selfishness among professionals to provide their experience in using LC techniques to improve safety
21.	Lack of self-criticism	Lack of self-criticism which limited the capacity to learn from errors
22.	Fear of unfamiliar practices	Fear of unfamiliar practices due to the misconceptions and misunderstandings of LC
Section E: Success factors to apply LC techniques in safety improvement successfully		
1.	Management support and commitment	Management support and commitment to the application of LC techniques in safety improvement
2.	Developing and implementing an effective plan	Developing and implementing an effective plan to apply LC techniques in safety improvement
3.	A clear definition of roles, responsibilities, functions and levels of authority	A clear definition of roles, responsibilities, functions and levels of authority before the application of LC techniques
4.	Decentralization of construction management and reduction of hierarchical levels	Decentralization of construction management and reduction of hierarchical levels during the application of LC techniques
5.	Good leadership	Good leadership which foster effective skills and knowledge enhancement amongst workforce
6.	Establishing a recognition and reward system	Establish a recognition and reward system to encourage employees to

Table (3.3): Results of researcher modifications

#	Items before modifications	Researcher modifications
		participate in the application of LC techniques to improve safety
7.	Adequate funding of projects	Adequate funding of projects to cover the provisions of consultancy and training
8.	Providing education and training	Providing adequate education and training for employees at all levels on the LC concept and techniques
9.	The language of Lean should be simplified	Merge 9, 10 in one item: simplifying the language of Lean to enlighten the employees on the benefits of LC techniques application to achieve their compliance to the LC application
10.	Enlighten the employees on the benefits of LC by meetings, workshops and other events	
11.	Establishing awareness programs	Establishing awareness programs to increase the understanding of the LC using workshops and research conferences to guide the application of LC techniques in safety improvement
12.	Engagement of skillful site operatives	Merge 12, 13 in one item: Engagement of skillful site operatives and skillful professionals to guide the application of LC techniques in safety improvement
13.	Engagement of competent/skillful professionals	
14.	Government should provide a clear direction to apply LC techniques	Government should prioritize Lean in their national agenda and provide a clear direction for the construction firms to apply LC techniques in safety improvement
15.	Government agencies should introduce policies	Government agencies should introduce policies to encourage construction firms to engage in the application of LC techniques to improve construction safety
16.	Legislation bodies should introduce laws	Legislation bodies should introduce laws to facilitate the full application of LC techniques among construction firms

Table (3.3): Results of researcher modifications

#	Items before modifications	Researcher modifications
17.	Government should establish standards for construction	Government should establish standards for construction to eliminate government bureaucracy
18.	Government should work closely with professional bodies	Government should work closely with professional bodies to introduce LC to improve construction safety
19.	Workers empowerment and involvement	Workers empowerment and involvement in the application of LC techniques in safety improvement
20.	Application of LC techniques gradually step-by-step	Application of LC techniques gradually step-by-step in improving safety to decrease the complexity of LC implementation
21.	Constitution of an improvement committee	Constitution of an improvement committee to be responsible for the application of LC techniques in safety improvement
22.	Establishing appropriate performance measurement approaches	Establishing appropriate performance measurement approaches to measure the effectiveness of implemented LC techniques in safety improvement and identifying the mistakes to improve their weak links

3.4.2 Face validity

Face validity is a subset of content validity which is one of validity types. In face validity, experts are asked their opinion about whether an instrument measures the concept intended (Heale and Twycross, 2015, Drost, 2011). It is essential to see whether the questionnaire appears to be a valid or not. Questionnaire (B) was sent to six experts by hand delivery to assess the validity of the questionnaire and obtain suggestions for any modification. Many useful and important modifications have been made for the questionnaire. Those modifications have been explained in Table (3.4).

Table (3.4): Results of the face validity

#	Experience	Specialization	Modifications
A	27 years' experience in construction field	Assistant Professor of civil engineering, Faculty of Engineering, The Islamic University of Gaza, Gaza Strip	• In section D: ✓ Delete item ‘Construction firms become more competitive by improving efficiency’, because it’s more indirect. ✓ Delete item ‘Identifying tasks in advance’, ‘Looking at potential safety hazards’ and ‘Establishing a smoother schedule and fewer safety hazards’ because it is involved in item ‘ Better safety management plan’ ✓ Delete item ‘Increasing employees empowerment and involvement to discuss and resolve work place problems’ ✓ Delete item ‘Reducing the workflow variation’ ✓ Delete item ‘Minimizing the project duration’. • In section F: ✓ Merge item ‘Effective communication among construction stakeholders either horizontally or vertically’, ‘Enhancing the cooperation, coordination and promoting integration between stakeholders’ and ‘Establishing closer and collaborative relations with suppliers, customers and consultants’ in the management success factors • Had advised to shorten the questionnaire.
B	24 years' experience in construction field	Bachelor in civil engineering	• In section A: Add others in the question regard experience • In section C: Replace ‘5whys’ with accident investigation, because it caused misleading to the respondent • In section D: ✓ Merge items ‘Site organization’, ‘Removing clutter from workspace’ and ‘Creating of space and convenience in workplace for employees’ ✓ Delete item ‘Construction firms become more competitive by improving efficiency’, because it’s more indirect. • In section E: ✓ Delete item ‘Lack of integrity of the production chain including client, materials’ suppliers and subcontractors’ in the technical barriers ✓ Delete item ‘Inability to change the organizational culture’ in the human attitudinal barriers • In section F:

Table (3.4): Results of the face validity

#	Experience	Specialization	Modifications
			✓ Delete item ‘Support the team work development’ • Had advised to shortcut the questionnaire.
C	15 years' experience in construction field	Assistant Professor of civil engineering, Faculty of Engineering, The Islamic University of Gaza, Gaza Strip.	• Suggested adding a definition of LC in the cover letter of the questionnaire and its relation with safety improvement. • In section C: Define the abbreviation of PPE at the item of ‘Using safe guards and PPE to reduce accidents caused by falling objects and site hazards like (excess heat, sound, noise, dust)’ in Poke Yoke tool • In section D: ✓ Deleted item ‘Construction firms become more competitive by improving efficiency’, because it’s more indirect. ✓ Delete item ‘Minimizing the project duration’, because it is same as ‘Delivering the projects on time or in some cases ahead of schedule’ ✓ Delete items ‘Greater predictability to look at potential safety hazards’, ‘Identifying tasks in advance’, ‘Looking at potential safety hazards’ and ‘Establishing a smoother schedule and fewer safety hazards’, because it is included in item ‘Better safety management plan’. • In section E: ✓ Delete item ‘Inflation in material prices due to unsafe markets condition for construction’ in the financial barriers • Had advised to shortcut the questionnaire.
D	15 years' experience in construction field	M.Sc. in Infrastructure	• In section D: ✓ Merge items ‘Site organization’, ‘Removing clutter from workspace’ and ‘Creating of space and convenience in workplace for employees’ ✓ Merge items ‘Maximizing the workers productivity’ and ‘Improving work efficiency’ ✓ Delete item ‘Increasing employees empowerment and involvement to discuss and resolve work place problems’ ✓ Replace the word of firefighting in the item ‘Reducing stress level on management and firefighting in projects’ with conflicts

Table (3.4): Results of the face validity

#	Experience	Specialization	Modifications
			✓ Merge items ‘Promoting team collaboration among project practitioners’ and ‘Increasing communication among project participants’ ✓ Merge items ‘Greater predictability to look at potential safety hazards’, ‘Identifying tasks in advance’, ‘Looking at potential safety hazards’ and ‘Establishing a smoother schedule and fewer safety hazards’ ✓ Delete item ‘Reducing the workflow variation’ ✓ Delete item ‘Minimizing the project duration’. • In section E: ✓ Delete items ‘Corruption due to bribery, extortion and fraud’ and ‘Inflation in material prices due to unsafe markets condition for construction’ in the financial barriers ✓ Delete item ‘Inability to change the organizational culture’ in the human attitudinal barriers, because it is the same as ‘Resistance to change by employees’ • In section F: ✓ Merge item ‘Effective communication among construction stakeholders either horizontally or vertically’, ‘Enhancing the cooperation, coordination and promoting integration between stakeholders’ and ‘Establishing closer and collaborative relations with suppliers, customers and consultants’ in the management success factors ✓ Delete item ‘Support the team work development’ in the management success factors ✓ Delete item ‘Monitoring inflation risks, pricing levels and the stability of construction markets to make LC techniques feasible’ in the management success factors ✓ Merge items ‘Government should provide a clear direction for the construction firms to apply LC techniques in safety improvement’ and ‘Government agencies should introduce policies to encourage construction firms to engage in the application of LC techniques to improve construction safety’ in the governmental success factors ✓ Merge items ‘Government should provide the basic infrastructure to apply LC techniques’ and

Table (3.4): Results of the face validity

#	Experience	Specialization	Modifications
			‘Government should establish standards for construction to eliminate government bureaucracy’ in the governmental success factors ✓ Start with item ‘Standardize and ensure complete designs’ in the operation success factors • Had advised to shortcut the questionnaire
E	10 years in Lean industry	Professor of Industrial engineering, Faculty of Engineering, The Islamic University of Gaza, Gaza Strip.	• Modified the research subject from ‘Safety and health improvement using LC techniques in construction projects’ to ‘Safety improvement using LC techniques in construction projects’ • Audited the English language of the cover page of the questionnaire • In section D: ✓ Merge items ‘Site organization’, ‘Removing clutter from workspace’ and ‘Creating of space and convenience in workplace for employees’ ✓ Deleted item ‘Construction firms become more competitive by improving efficiency’ in section D, because it’s more indirect. ✓ Delete item ‘Greater predictability to look at potential safety hazards’ ✓ Delete item ‘Reducing the workflow variation’ ✓ Delete item ‘Minimizing the project duration’. • In section E: ✓ Delete item ‘Inability to change the organizational culture’ in the human attitudinal barriers, because it is the same as ‘Resistance to change by employees’ • Had advised to shortcut the questionnaire.
F	7 years' experience in construction field	M.Sc. in construction management	• Add the abbreviation of ‘Increased visualization’ (IV) in Section (B) and add the other name of ‘5 whys’ tool • In section C: ✓ Delete ‘to reduce accidents caused by….’ in all items to shorten the sentences and put it in the subject of section. For instance, the item ‘Providing employees with safety equipment to reduce accidents caused by inadequate safety equipment’ will be ‘Providing employees with safety equipment’ ✓ Merge items ‘Correlating work methods with worker’s skills to reduce the excessive stress’ and

Table (3.4): Results of the face validity

#	Experience	Specialization	Modifications
			‘Correlating work methods with worker’s ability to reduce accidents caused by physical and mental disability’ ✓ Merge items ‘Worker’s empowerment in assignment scheduling to reduce time pressure, organizational pressure and excessive stress’ and ‘Workers’ involvement in task planning to reduce accidents caused by lack of motivation’ ✓ Delete item ‘Improving visibility to enhance site conditions, increase supervision and reduce exposure to hazards’ ✓ Replace ‘Poka yoke’ with ‘Fail safe for quality and safety’ ✓ Replace ‘5whys’ with accident investigation, because it caused misleading to the respondent • In section D: ✓ Modify item ‘Reducing the additional costs resulting from accidents on construction sites (Ex. medical treatment, workers’ compensation, etc.)’ to be ‘Reducing the additional costs resulting from accidents on construction sites’ ✓ Modify item ‘Improving work efficiency by reducing people’s workload’ to be ‘Improving work efficiency’ ✓ Merge items ‘Promoting team collaboration among project practitioners’ and ‘Increasing communication among project participants’ ✓ Delete item ‘Identifying tasks in advance’, ‘Looking at potential safety hazards’ and ‘Establishing a smoother schedule and fewer safety hazards’ because it is involved in item ‘ Better safety management plan’ ✓ Merge ‘Reducing the workflow variation’ and ‘Improving the rate of workflow on-site’ ✓ Delete item ‘Minimizing the project duration’ • In section E: ✓ Delete item ‘Corruption due to bribery, extortion and fraud’ in the financial barriers ✓ Delete item ‘Lack of integrity of the production chain including client, materials’ suppliers and subcontractors’ in the technical barriers ✓ Delete item ‘Inability to change the organizational culture’ in the human attitudinal barriers • In section F:

Table (3.4): Results of the face validity

#	Experience	Specialization	Modifications
			✓ Modify item ‘Good leadership which foster effective skills and knowledge enhancement amongst workforce’ to be ‘Good leadership’ ✓ Modify item ‘Constructing transparency between project participants to reduce the hierarchical structure of order giving’ to be ‘Constructing transparency between project participants’ ✓ Delete item ‘Support the team work development’ ✓ Merge items ‘Government should provide the basic infrastructure to apply LC techniques’ and ‘Government should establish standards for construction to eliminate government bureaucracy’ in the governmental success factors ✓ Start with item ‘Standardize and ensure complete designs’ in the operation success factors

All results of face validity were taken in review. Questionnaire (A and B) were modified based on face validity results as shown in the appendices (A and B). Questionnaire (B) was translated into Arabic after modification and pretested as shown in the following section.

3.4.3 Pretesting the questionnaire

Pretesting questionnaire is an essential step in the questionnaire development process. Pretesting increases the validity and reliability of the questionnaire. It helps to determine if respondents understand the questions or have information that questions require to be understandable (GAO, 2017). Pretesting is conducted on a small number of people from the target population which is between 5 and 10 respondents. Once all the tests have been completed, notes on the questionnaire items should be reviewed and modified. If major changes are needed to the questions or structure, it might be necessary to repeat the pretesting exercise with different people before starting the survey (Tools for international development, 2014).

In this research, the questionnaire was pretested in the Arabic Language before surveying. It was sent to ten engineers who works in projects funded from external parties and LC techniques are expected to be applied there. Once all tests have been completed, notes on the questionnaire items were reviewed and modified. Most of pretesting results were on the Arabic language wording. As a result, the questionnaire was pretested through one phase to be understood.

3.4.4 Pilot study

For large or complex surveys it's a good idea to do a full pilot before starting actual data collection. Piloting identify practical problems with implementation, rather than problems with the survey design. To do a pilot, the questionnaire should be tested with a reasonably large sample. The size of the pilot sample depends on how big your actual sample is, and how many data collectors you have. For a typical survey a sample of around 30-50 people is usually enough to pilot the questionnaire. After questionnaire distribution and collection, the completed questionnaires should be entered into the database that planned to be used and then tested the analysis that planned to be performed (Tools for international development, 2014).

In this research, thirty questionnaires were distributed purposively to respondents from the target sample (Engineers who work in the field of construction supervision). All copies were collected and analyzed through statistical Package for the social science IBM (SPSS) version 22. The tests that conducted were statistical validity of the questionnaire/ criterion related validity; and reliability of the questionnaire by Half Split method and the Cronbach's coefficient Alpha method.

3.4.5 Statistical validity of the questionnaire

In a quantitative study, validity is defined as the extent to which a concept is accurately measured (Heale and Twycross, 2015). To insure the validity of the questionnaire, two substantial tests are applied. The first is criterion-related/internal validity test (Pearson test) which measures the correlation coefficient between each item in the section and whole section. The second is structure validity test (Pearson test) that shows "the degree to which scores of a questionnaire are an adequate reflection of the dimensionality of the construct to be measured" (Elbers et al., 2012).

3.4.5.1 Internal validity

Internal validity of the questionnaire is the first statistical test that used to test. It is measured with the Pearson correlation and the strength of the relationship is measured on a scale that varies from -1 through +1 (Naoum, 2007). ***In this research,*** internal validity was measured by pilot study sample which consisted of (30) questionnaires through measuring the Pearson correlation coefficients between each item in the section and whole section. Internal validity test applied on sections B, C, D, E and F which are sequentially including awareness level of Lean Construction

(LC) tools, application of LC techniques to reduce the causes of accidents on the construction sites, benefits of LC techniques related to safety improvement in construction projects, barriers to the application of LC techniques regarding safety improvement; and success factors to apply LC techniques in safety improvement successfully.

Tables from D1 to D5 at Appendix (D) summarizes the internal validity results. As shown in the tables, all of the Pearson correlation are between 1 and -1 and *p*-values are less than 0.05, so the correlation coefficients of each field are significant at α= 0.05. Thus, it can be said that the items of each field are consistent and valid to be measured what it were set for.

3.4.5.2 Structure validity

Structure validity is the second statistical test that used to test the validity of the questionnaire's structure. It measures the correlation coefficient between one section and all of the other sections of the questionnaire that have the same level of rating scale (five-point Likert scale) (Garson, 2013). As shown in Table (3.5), the *p*-values of all sections are less than 0.05. Thus it can be said that the sections are valid to be measured what it were set for to achieve the main aim of the study.

Table (3.5): Structure validity of the questionnaire

Sections	Pearson correlation	*p*-value	Significant (Sig.) at
Awareness level of Lean Construction (LC) tools	0.372*	0.043	Sig. at 0.05
Application of LC techniques to reduce the causes of accidents on the construction sites	0.575**	0.001	Sig. at 0.01
Benefits of LC techniques related to safety improvement in construction projects	0.734**	0.000	Sig. at 0.01
Barriers to the application of LC techniques regarding safety improvement	0.728**	0.000	Sig. at 0.01
Success factors to apply LC techniques in safety improvement successfully	0.673**	0.000	Sig. at 0.01

3.4.6 Reliability

The second measure of quality in a quantitative study is reliability, or the accuracy of an instrument. In other words, the degree to which a research instrument produce the same results under the same conditions (Heale and Twycross, 2015, Field, 2009, Saunders et al., 2009). In statistical terms, the usual way to look at reliability is based on the idea that individual items should produce results consistent with the overall questionnaire (Field, 2009).

Saunders et al. (2009) outlines three common approaches to assessing reliability, in addition to comparing the data collected with other data from a variety of sources. They are test re-test; internal consistency and alternative form. Test re- test is done by repeating the questionnaire to the same sample of the target group in a different time and comparing the scores that obtained in the first time and in the second time by computing a reliability coefficient. For the most purposes, it can be considered satisfactory if the reliability coefficient is above (0.7). A period from two weeks to a month is recommended for distributing the questionnaires for the second time (Field, 2009). This may create difficulties, as it is often difficult to persuade respondents to answer the same questionnaire twice (Field, 2009, Saunders et al., 2009). In addition, the longer the time interval between the two questionnaires, the lower the likelihood that respondents will answer the same way. Therefore, it recommended to use this method only as a supplement to other methods (Saunders et al., 2009).

Internal consistency involves correlating the responses to each question in the questionnaire with those to other questions in the questionnaire. There are a variety of methods for calculating internal consistency, of which one of the most frequently used is Cronbach’s alpha (Field, 2009, Saunders et al., 2009). The final approach to testing for reliability is ‘alternative form’. This offers some sense of the reliability within your questionnaire through comparing responses to alternative forms of the same question or groups of questions. Where questions are included for this purpose, usually in longer questionnaires, they are often called ‘check questions’. Respondents may suffer from fatigue owing to the need to increase the length of the questionnaire, and they may spot the similar question and just refer back to their previous answer (Saunders et al., 2009).

In this research, because of the previous limitations in using both of test re- test and alternative form approaches, internal consistency approach was used to measure the reliability of questionnaire. Internal consistency was measured using both of split half coefficient and Cronbach's alpha coefficient through the SPSS software to achieve that.

3.4.6.1 Spilt half

It is considered as the simplest method to test the internal consistency of a questionnaire (Field, 2009). It involves dividing the scores a participant received on a questionnaire into two groups with an equal amount of scores and determining whether both halves give the same results (Neuman, 2013). The split-half method splits the questions of a dimension in two, for example odd-numbered questions versus even numbered questions, or just randomly split (Neuman, 2013). The correlation between the two halves tests must be corrected to obtain the reliability coefficient for the whole test (Drost, 2011, Field, 2009).

This method depends on finding Pearson correlation coefficient between the means of questions with odd rank and questions with even rank of each field of the questionnaire and corrected by Spearman Brown correlation coefficient. The corrected correlation coefficient (consistency coefficient) is computed according to the following equation: Consistency coefficient =2r/(r+1), where r is the Pearson correlation coefficient. The normal range of corrected correlation coefficient 2r/(r+1) is between 0.0 and +1.0 (Garson, 2013). As shown in Table (3.6), results of Spearman Brown correlation coefficient for all questionnaire sections were between 0 and 1 which is in the normal range.

Table (3.6): Reliability test by Half-Split coefficient method

Sections	Pearson correlation	Guttman Split-Half coefficient	Sig. (2-tailed)
Awareness level of Lean Construction (LC) tools	0.964	0.982	Sig. at 0.01
Application of LC techniques to reduce the causes of accidents on the construction sites	0.780	0.877	Sig. at 0.01
Benefits of LC techniques related to safety improvement in construction projects	0.664	0.798	Sig. at 0.01
Barriers to the application of LC techniques regarding safety improvement	0.622	0.763	Sig. at 0.01

Table (3.6): Reliability test by Half-Split coefficient method

Sections	Pearson correlation	Guttman Split-Half coefficient	Sig. (2-tailed)
Success factors to apply LC techniques in safety improvement successfully	0.674	0.792	Sig. at 0.01

3.4.6.2 Cronbach's Coefficient Alpha (Cα)

Cronbach's Alpha is one of the most frequently used methods for calculating internal consistency (Field, 2009, Saunders et al., 2009). This method is used to measure the reliability of the questionnaire between each field and the mean of the whole fields of the questionnaire (Field, 2009, Saunders et al., 2009). The normal range of Cronbach's coefficient alpha (Cα) value is between 0.0 and +1 and the higher value reflects a higher degree of internal consistency (Field, 2009). Table (3.7) summarizes the results of Cronbach's coefficient alpha for questionnaire which are between the normal range (0 and 1).

Table 3.7): Reliability test by Cronbach's coefficient alpha

Sections	Cronbach's alpha (Cα)
Awareness level of Lean Construction (LC) tools	0.955
Application of LC techniques to reduce the causes of accidents on the construction sites	0.888
Benefits of LC techniques related to safety improvement in construction projects	0.917
Barriers to the application of LC techniques regarding safety improvement	0.859
Success factors to apply LC techniques in safety improvement successfully	0.909

3.4.7 Final amendment to the questionnaire

The original questionnaire was developed in English language based on factors exactly as devised from literature review which is attached in Appendix (A). The English questionnaire was modified by the researcher and through amendment process. Its questions were being formulated in a way that introduces the concept to the participants simply and smoothly in order to gain the needed responses to answer the main research questions and to achieve the research objectives. The questionnaire items in each section of this study was coded in a systemic format that is easy to analyze using statistics software on computers. An English modified version of the questionnaire is attached in Appendix (B). Based on the belief of the researcher that the questionnaire would be more effective and easier to be understood for all respondents if it is in Arabic (native language), the questionnaire B was translated into Arabic language after final modification, which is attached in Appendix C.

Regarding the final content of the questionnaire, the researcher elicited a set of factors that is related to awareness level of LC tools, application of LC tools and techniques to reduce the causes of accidents on the construction sites, benefits of LC techniques related to safety improvement, barriers; and success factors affect the application of LC techniques in safety improvement. Based on literature review (Chapter 2), the researcher has summarized 8 tools of LC, 39 techniques to reduce the causes of accidents on the construction sites, 37 benefits of LC techniques related to safety improvement in construction projects, 43 barriers to the application of LC techniques regarding safety improvement and 34 success factors to apply LC techniques in safety improvement successfully. While, factors of the section (A) were designed by the researcher.

In the questionnaire design, some items have been modified, while others have been merged, as well as others have been deleted. Table (3.8) shows how items were obtained for each section in the questionnaire. Tables from (D6) to Table (D10) in Appendix D provide a clear description of all changes in questionnaire items. Based on that, the final questionnaire contains:

- Section A: requests information on the respondent and the organization’s profile (consist of 5 questions, Q1 to Q5)
- Section B: To investigate the awareness level of Lean Construction (LC) tools (consist of 8 questions from, AL1 to AL8)
- Section C: To investigate the applicability of LC techniques to reduce the causes of accidents on the construction sites (consist of 25 questions from, App1 to App25)
- Section D: To investigate the benefits of LC techniques related to safety improvement in construction projects (consist of 22 questions from, Ben1 to Ben22)

- Section E: To investigate the barriers to the application of LC techniques regarding safety improvement (consist of 39 questions from, Bar1 to Bar39)
- Section F: To investigate the success factors to apply LC techniques in safety improvement successfully (consist of 26 questions from, SF1 to SF26)

Table (3.8): A summary illustrates how factors were obtained for each field in the questionnaire

Section	From literature review	Deleted items	Modified items	Merged and modified items	Final used items
Awareness level of Lean Construction tools	8	-	-	-	8
Application of LC techniques to reduce the causes of accidents on the construction sites	3	3	14	8	25
Benefits of LC techniques related to safety improvement in construction projects	16	9	2	4	22
Barriers to the application of LC techniques regarding safety improvement	20	4	19	-	39
Success factors to apply LC techniques in safety improvement successfully	7	3	14	5	26

3.5 Data analysis

Once the data is collected through questionnaires, the results of will be ready to be analyzed to determine the direction of the study (Field, 2009, Naoum, 2007). Quantitative analysis techniques such as graphs, charts and statistics allow to make data collected useful and turn them into information to conclude a general understanding of the phenomenon under study (Saunders et al., 2009). Quantitative results can be presented in charts or graphs to summarize their features, and interpret or give theoretical meaning to the results (Neuman, 2013). Data can be analyzed by computer-based analysis software such as Excel to more advanced data management and statistical analysis software packages such as Minitab, SAS, SPSS for Windows and Statview (Saunders et al., 2009). ***In this research,*** the computerized tool IBM SPSS (Statistical Program for Social

Sciences) version 22 was used as the data analysis tool to help tabulate data and establish relationships between variables.

Prior to data analysis, the accuracy of data coding must be checked, or data should be cleaned. Errors in coding or entering data into a computer threaten the validity of the measures and cause misleading results. If you have a perfect sample, perfect measures, and no errors in gathering data but make errors in the coding process or in entering data into a computer, an entire research project can ruined (Neuman, 2013).

Data analysis classified into descriptive analysis and inferential analysis (Naoum, 2007). When the data are quantitative this involves both looking at data to see what the general trends in the data are, and also fitting statistical models to the data (Field, 2009). The word statistics can refer to a set of collected numbers as well as a branch of applied mathematics we use to manipulate and summarize the features of numbers (Neuman, 2013). To select the most appropriate statistics, researcher need to know which type of question they are asking and the level of measurement being used for the variables (Thompson, 2009)

This research on safety improvement using Lean Construction techniques in construction projects. There are various methods used by researchers to analyze data in their studies which are related to Lean Construction. Oladiran (2017) analyzed the data regard the usage of LC techniques in Nigeria using descriptive statistics tools namely frequencies, percentages, means and modes. While Cano et al. (2015) analyzed data collected about the barriers and success factors in LC implementation using a cause-effect matrix and a structural analysis with MIC MAC method. On the other hand Gambetese and Pestana (2014) used the methods of content analyses, mean rating and frequency distribution to analyze data collected to connect between Lean Design/Construction and construction worker safety. Table (3.9) summarizes some of data analysis methods for previous studies which are used in this research.

Table 3.9): Data analysis methods for previous studies

Author	Country	Analysis
Azyan et al., 2017	Malaysia	Exploratory analysis
Couto et al., 2017	Portugal	Comparative analysis

Table 3.9): Data analysis methods for previous studies

Author	Country	Analysis
Daniel et al., 2017	UK	Content analysis and coding process
Oladiran, 2017	Nigeria	Frequency distribution, means and modes analysis
Sarhan et al., 2017	KSA	Mean score and ANOVA test
Adegbembo et al., 2016	Nigerian	Mean Item Score (MIS)
Awada et al., 2016	Lebanon	Frequency distribution
Gambatese et al., 2016	USA	Content analyses, mean score and median score
Li et al., 2016	China	Correlation Coefficient Tests
Nasrollahzadeh et al., 2016	Malaysia	Analytic Hierarchy Process (AHP)
Saunders et al., 2016	USA	ANOVA analysis
Bashir et al., 2015	UK	Thematic analysis approach
Cano et al., 2015	Colombia	Cause-effect matrix and a structural analysis with MIC MAC method
Cudney et al., 2015	USA	Frequency distribution
Fang et al., 2015	Hong Kong	Confirmatory factor analysis and structural equation modeling
Nikakhtar et al., 2015	Malaysia	Computer simulation
Bygballe and Swärd, 2014	UK	Abductive research logic analysis
Enshassi and Abu Zaiter, 2014	Palestine	Frequency distribution, mean score, standard deviation and weighted rank
Gambetese and Pestana, 2014	USA	Content analyses, mean rating and frequency distribution

Table 3.9): Data analysis methods for previous studies

Author	Country	Analysis
Ogunbiyi et al., 2014	UK	Mean scores percentile method, Cronbach's a reliability test, Kruskal Wallis test, Kendall's coefficient of concordance and *t*-test
Shang and Pheng, 2014	China	Mean, standard deviation and principal component analysis
Wandahl, 2014	Denmark	Frequency distribution
Al- Najem et al., 2013	Al-Kuwait	Alpha Cronbach's, *t*-test and mean score
Ogunbiyi et al., 2013	UK	Mean score
Sarhan and Fox, 2013	UK	Mean score, SD and rank analysis
Ayarkwa et al., 2012a	Ghana	Mean scores
Ayarkwa et al., 2012b	Ghana	Mean scores and factor analysis
Zhou, 2012	U.S	Alpha Cronbach, Kaiser Meyer Olkin (KMO) and Mean score
Ikuma et al., 2011	USA	Comparative Analysis
Alinaitwe, 2009	Uganda's	Mean and variance scores
Nahmens and Ikuma, 2009	USA	Descriptive analysis, normality test and Mann Whitney Test
Mitropoulos et al., 2007	USA	Comparative Analysis
Razuri et al., 2007	Chile	Kendall's Correlation Coefficient, effectiveness index (EI) and incremental analysis
Achanga et al., 2006	UK	Delphi techniques

3.5.1 Descriptive statistics analysis

Descriptive statistics are the basic statistics that describe what is going on in a population or data set (Crossman, 2018, Neuman, 2013, Thompson, 2009). They are important and useful because they allow us to see patterns among our data, and thus to make sense of that data (Crossman, 2018). It is used to arrive at summary figures that describe the distribution of the sample data (Denscombe, 2007). It's important to realize that descriptive statistics can only be used to describe the population or data set under study (Crossman, 2018). Descriptive statistics also can be used to compare samples from one study with another (Thompson, 2009).

Naoum (2007) stated that there are three formal terms used to describe aspects of a group of data which are frequency distribution, measurement of central tendency, measurement of dispersion. A frequency distribution summarized how many times each score occurs (Field, 2009). Measures of central tendency are statistics that provide information on where the majority of data lie (Thompson, 2009). To do this, we use three measures of central tendency (mean, median, and mode) (Crossman, 2018, Neuman, 2013, Field, 2009). Within the dataset the actual values usually differ from one another and from the average value itself. The extent to which the median and mean are good representatives of the values in the original dataset depends upon the variability or dispersion in the original data (Student Learning Development, 2009). Dispersion or variability within a dataset can be measured or described in several ways including the range and standard deviation (Field, 2009). Datasets are said to have high dispersion when they contain values considerably higher and lower than the mean value (Student Learning Development, 2009). Salkind (2010) mentioned other techniques of the descriptive statistics more than frequencies, measures of central tendency, measurement of dispersion which are Relative Important Index (RII), factor analysis, normal distribution and homogeneity of variances.

In this research, descriptive analysis are used to describe the main features of the collected data in quantitative terms as most of researches related to the research topic. The descriptive statistics encompassed frequency distribution, mean score, RII, standard deviation and effect index. Additionally, Factor analysis was deemed necessary to be used in this study, due to the relatively large number of dependent variables. The following sections provide explanation of the statistics methods used to analyze the quantitative data.

3.5.1.1 Frequency distribution

Frequency distribution is about how many times a particular value occurs within a data set (Crossman, 2018, Thompson, 2009). A frequency distribution may include the percentage of the sample that this number represents. A frequency distribution can be shown using numeric values or using graphical techniques (Thompson, 2009). It can be used with nominal, ordinal, interval, or ratio-level data (Neuman, 2013). It can be presented in the form of tabulation, a bar chart, a pie chart or a graph (Naoum, 2007).

In this research, frequency distribution was employed for analyzing data related to the profile of the respondents and their organizations which is in section (A).

3.5.1.2 Average index

Average (or Mean) index is the most widely used measure of central tendency (Neuman, 2013, Field, 2009, Thompson, 2009). A mean is the mathematical average of all of data (Crossman, 2018). The use of means to describe a dataset should be limited to interval and ratio level data (Neuman, 2013, Thompson, 2009). The mean is a measure of central tendency that indicates which response item has the highest tendency to represent the sample (Denscombe, 2010). Nominal level data do not have a true numeric value, so it is not possible to compute a mean. Although ordinal data might be represented using numeric values, the conceptual intervals between the values may not be the same; therefore, the mean would be difficult to interpret (Thompson, 2009). The mean is calculated by adding up the value for all subjects and dividing by the total number of subjects (n) (Field, 2009, Thompson, 2009).

Adegbembo et al. (2016), Memon et al. (2006) used and explained the Average Index Method to analyze data in the ordinal or ranking scale as follows:

$$\text{Average index for five scale rating} = \frac{\sum_{i=1}^{5} a_i x_i}{\sum_{i=1}^{5} x_i} \; \ldots\ldots\ldots\ldots\ldots\ldots \; \text{Equation 3.3}$$

Where,

- ai= Constant expressing the weight given to i,
- xi= Variable expressing the frequency of the response for, i = 1, 2, 3, 4, 5 (For instance: $X1$= Frequency of the response corresponding to $a1$= 1).

The mean score (MS) or average index could be interpreted based on each respondents rating of each item in the questionnaire. By referring to Holt (2014), the average mean score for the item should be greater than the hypothesized mean (equal to 2 for five-point scale where $A_{min}=0$ and $A_{max}=4$). Where A_{min} and A_{max} are the minimum and maximum response category integers respectively.

In this research**,** average index will be used to analyze the data collected from the questionnaire survey for the sections (B, C, D and F) which are sequentially about awareness level of Lean Construction (LC) tools, application of LC techniques to reduce the causes of accidents on the construction sites, benefits of LC techniques related to safety improvement in construction projects; and success factors to apply LC techniques in safety improvement successfully.

3.5.1.3 Standard deviation

A standard deviation is a mathematical calculation of the variance of all the measurements in a sample (Thompson, 2009). It is based on the mean and gives an “average distance” between all scores and the mean (Neuman, 2013, Student Learning Development, 2009). Effectively it indicates how tightly the values in the dataset are bunched around the mean value. It is the most robust and widely used measure of dispersion. When the values in a dataset are pretty tightly bunched together the standard deviation is small. When the values are spread apart the standard deviation will be relatively large (Student Learning Development, 2009). The standard deviation of a sample is known as SD and is calculated using equation (3.4) (Student Learning Development, 2009, Naoum, 2007).

$$S=\frac{\sqrt{\Sigma(X-\bar{X})^2}}{n-1} \text{ ……………. Equation 3.4}$$

Where:

- X represents each value in the population
- $\bar{x}$ is the mean value of the sample
- Σ is the summation (or total)
- n-1 is the number of values in the sample minus 1

In this research, SD will be used to analyze the data collected from the questionnaire survey for the sections (B, C, D and F) which are sequentially about awareness level of Lean Construction (LC) tools, application of LC techniques to reduce the causes of accidents on the construction sites, benefits of LC techniques related to safety improvement in construction projects; and success factors to apply LC techniques in safety improvement successfully.

3.5.1.4 Relative Importance Index (RII)

The five-point Likert scale (from 0 to 4) was adopted in this research to determine the respondents opinions regarding their awareness level of LC tools, applicability of LC techniques in safety improvement, benefits of LC techniques related to safety and success factors encourage application of LC techniques in safety improvement sections which are B, C, D and F sequentially. The five point Likert scale transformed to relative importance indices (RII). Referring to Holt (2014), RII was calculated by the simple percentage model to rank items in the sections (B, C, D and F) as shown in equation (3.5). The simple percentage model was used in which the scale with A_{min} =0. A_{min} and A_{max} are the minimum and maximum response category integers respectively.

$$\text{RII} = \frac{\sum_{i=1}^{n} \text{i} * \text{Frequancy}_i}{AN} *100 \text{ …………….} \quad \text{Equation 3.5}$$

Where,

- 1 and n represent A_{min} and A_{max}, respectively
- A: largest integer in response scale (A_{max}) (i.e. 4 in this case); and
- N: is the total number of respondents.

The RII value had a range from 0 to 100, the higher RII indicates that a particular item is more significant than those with relatively lower RIIs. However, RII doesn't reflect the relationship between the various items.

3.5.1.5 Effect index

The effect index was calculated to obtain the effect level of the barriers prevented the application of LC techniques in safety improvement and the rank of each item which is summarized in section E. Hassanain et al. (2017) calculated the effect indexes as follows

$$\text{Effect index} = \frac{\sum_{i=0}^{4} a_i x_i}{4\Sigma x_i} *100\% \text{ …………….} \quad \text{Equation 3.6}$$

Where,

- ai= Constant expressing the weight assigned to i,
- xi= Variable expressing the frequency assigned to i = 0, 1, 2, 3, 4 and is illustrated
- x0=frequency of “extreme effect” response corresponding to a0=4;
- x1=frequency of “strong effect” response corresponding to a1=3;
- x2=frequency of “moderate effect” response corresponding to a2=2;
- x3=frequency of “slight effect” response corresponding to a3=1; and
- x4=frequency of “no effect” response corresponding to a4=0.

Hassanain et al. (2017) formulated a scale to establish the effect level of each factor which is explained in Table (3.10).

Table (3.10): Classification of the effect level

Effect level	Effect index value
No effect	$EI < 12.5$
Slight effect	$12.5 \leq EI < 37.5$
Moderate effect	$37.5 \leq EI < 62.5$
Strong effect	$62.5 \leq EI < 87.5$
Extreme effect	$87.5 \leq EI$

3.5.1.6 Factor analysis

Factor Analysis (FA) is an exploratory technique applied to a set of observed variables that seeks to find underlying factors (subsets of variables) from which the observed variables were generated (Lingard and Rowlinson, 2006). Factor analysis is a correlation matrix, in which the inter-correlations between a large number of items (questionnaire responses) are presented. The items can be reduced into smaller groups known as factors. These factors contain correlated variables and are typically quite similar in terms of content or meaning (Hooper, 2012).

Factor analysis provides a diagnostic tool to evaluate whether the collected data are in line with the theoretically expected pattern, or structure, of the target construct and thereby to determine if the measures used have indeed measured what they are purported to measure (Matsunaga, 2010). FA reduces a large number of variables (factors) into a smaller set. Furthermore, it establishes underlying dimensions between measured factors and latent constructs, thereby allowing the formation and refinement of theory. Moreover, it provides construct validity evidence of self-reporting scales (Taherdoost et al., 2014, Williams et al., 2010, Field, 2009).

Factor analysis is divided to two main categories namely Exploratory Factor analysis (EFA) and Confirmatory Factor analysis (CFA) (Reio Jr and Shuck, 2015, Van der Eijk and Rose, 2015, Taherdoost et al., 2014, Matsunaga, 2010). Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) are two statistical approaches used to examine the internal reliability of a measure. Both of them are used to investigate the theoretical constructs, or factors, that might be represented by a set of items; and to assess the quality of individual items (Newsom, 2005).

However, EFA and CFA play quite different roles in terms of the purpose of given research: One is used for theory-building, whereas the other is used primarily for theory-testing (Reio Jr and Shuck, 2015, Taherdoost et al., 2014, Matsunaga, 2010). With EFA, researchers usually decide on the number of factors by examining output from a principal components analysis. With CFA, the researchers must specify the number of factors a priori (Newsom, 2005). In this research, exploratory factor analysis (EFA) will be used. Since the researcher has no expectations of the number of the factors.

Exploratory factor analysis (EFA) is a method for identifying the factor structure of a set of multiple indicators or variables without imposing an a priori structure on the factors (Reio Jr and Shuck, 2015). The most frequent applications of EFA among researchers consists of reducing relatively large sets of variables (factors) into more manageable, developing and refining a new instrument’s scales, and exploring relations among variables to build theory (Reio Jr and Shuck, 2015, Taherdoost et al., 2014, Hooper, 2012, Matsunaga, 2010).

Despite EFA being a seemingly complex statistical approach, the approach taken in the analysis is in fact sequential and linear, involving many options (Williams et al., 2010). EFA requires the researcher to make a number of decisions that are too often misinformed to the detriment of theory, research, and practice (Howard, 2016). There are five methodological issues that researchers should consider for utilizing EFA including: Evaluation of Data Suitability for EFA (sample size and sample-to-variable ratio), factor extraction procedure, criteria will assist in determining factor extraction, select the rotation method to yield a final interpretable solution and naming of factors (Reio Jr and Shuck, 2015, Taherdoost et al., 2014, Williams et al., 2010). Failure to make a proper decision about one or more of above mentioned methodological issues may lead to erroneous results and limit the utility of the EFA (Hogarty et al., 2004). Figure (3.3) shows the steps toward implementing exploratory factor analysis.

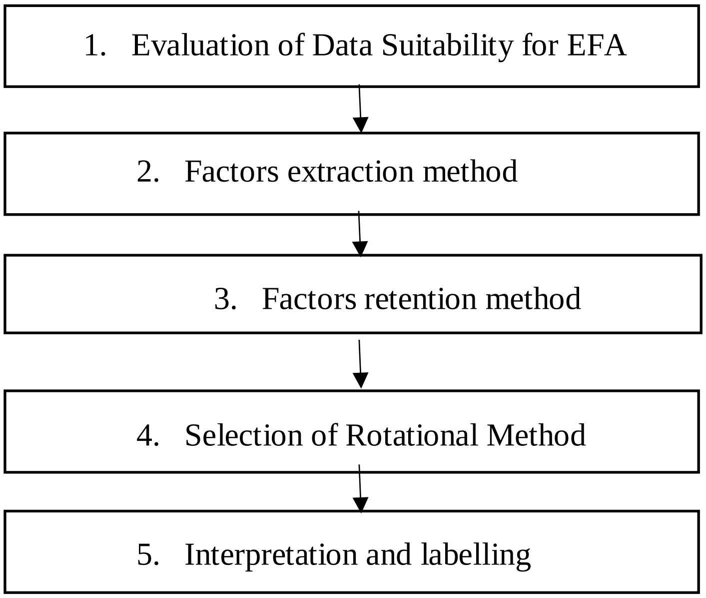


Figure (3.3): The five steps toward implementing exploratory factor

Step 1: Evaluation of Data Suitability for **EFA**

When designing a study, quality decision making requires attending to the select the sample size. Besides the notion that the sample should be representative of the population in question (Widaman, 2012). If all the participants attained roughly the same score on a factor, correlations will be lower and the factor may not emerge in the EFA (Tabachnick and Fidell, 2001). Thus, it is vital that the researcher selects participants who are expected to vary on the observed variables and underlying factors (and avoid possible restriction of range issues as noted above) (Reio Jr and Shuck, 2015).

1. Sample size

The issue of determining an optimal sample size is complicated by the fact that there is an interaction between sample size and the quality of the variables representing each factor (Goldberg and Velicer, 2006). Wide range of recommendations regarding sample size in factor analysis have been made. These are usually stated in terms of either the minimum sample size (N) for a particular analysis or the minimum ratio of N to the number of variables, p (N: p) (Reio Jr and Shuck, 2015, Lingard and Rowlinson, 2006).

- **Minimum sample size (N)**

Research remains unclear about what constitutes an ideal sample size for an analysis (considering that the sample is representative), but larger samples are better than smaller samples because the probability of error is less, population estimates are more accurate, and the findings are more generalizable (Reio Jr and Shuck, 2015). Williams et al. (2010) classified the sample size in his guide: 100 as poor, 200 as fair, 300 as good, 500 as very good, and 1000 or more as excellent.

Tabachnick and Fidell (2001) stated that a minimum of 300 cases is required for factor analysis, however in reality about 150 should be sufficient. On the other hand, Suhr (2006) suggested that sample sizes should be 100 or greater. Similarly, Hooper (2012) stated that as few as 100 cases can be adequate in situations where there are a small number of variables. Sapnas and Zeller (2002) pointed out that even 50 cases may be adequate for factor analysis. To sum, because small samples tend to yield less reliable correlation coefficients, and few, if any, interpretable factors, it is vital having a sample large enough to reliably estimate the correlations (Henson and Roberts, 2006).

The sample size of 107 respondents in this research is sufficient to conduct the factor analysis in line with Langford et al. (2000) in construction industry who used a sample size more than 100 respondents. It is considered adequate as it was larger than 50 as proposed by Sapnas and Zeller (2002)

- **N: p ratio**

Another set of recommendations also exist providing researchers with guidance regarding how many participants are required for each variable, often denoted as N:p ratio where (N: refers to the number of participants and p: refers to the number of variables). The same disparate recommendations also occur for sample to variable ratios as they do for determining adequate sample sizes (Williams et al., 2010). More recently, participant-to-variable ratios ranging from 5:1

to 10:1 rather than sample size have been touted as being more useful for analysis (Widaman, 2012).

Participant-to-variable ratios of 5:1 or greater are strongly recommended (with at least 100 participants), despite evidence though that 3:1 ratios can be useful for EFA work in the presence of strong, reliable correlations and few distinct factors (Tabachnick and Fidell, 2001). Williams et al. (2010) determined different ranges to be a rule from 3:1, 6:1, 10:1, 15:1, or 20:1.

In this research, sample to variable ratio for all sections to be factor analyzed have obtained from a sample size of 107 respondents, and with different number of variables in each section of the questionnaire. Table (3.11) described these N:p ratios values, and it can be seen that the sample to variable ratio for all sections are more than 3:1 unless barriers section. N:p ratio can be considered enough according to Williams et al. (2010) and Tabachnick and Fidell (2001).

Table (3.11): Study sample and variables characteristics

Sections	Participants NO. (N)	Variables NO. (p)	N:p ratio
Awareness level of Lean Construction tools	107	8	13.375
Application of LC techniques to reduce the causes of accidents on the construction sites	107	25	4.28
Benefits of LC techniques related to safety improvement in construction projects	107	22	4.864
Barriers to the application of LC techniques regarding safety improvement	107	39	2.744
Success factors to apply LC techniques in safety improvement successfully	107	26	4.115

2. Correlation matrix

In EFA, a correlation matrix as one of the most popular statistical technique is used to determine the relationships between variables which is known as R-matrix (Hooper, 2012, Field, 2009, Field, 2005). The diagonal elements of an R-matrix are all ones because each variable will correlate perfectly with itself. The off-diagonal elements are the correlation coefficients between pairs of variables, or questions (Field, 2009). The existence of clusters of large correlation coefficients between subsets of variables suggests that those variables could be measuring aspects of the same underlying dimension. These underlying dimensions are known as factors (or latent variables) (Field, 2009).

In factor analysis, R-matrix should be reduced down to its underlying dimensions by looking at which variables seem to cluster together in a meaningful way. This data reduction is achieved by looking for variables that correlate highly with a group of other variables, but do not correlate with variables outside of that group (Field, 2009).

The correlation coefficients in the Correlation Matrix should be greater than 0.3 "not all correlations" in magnitude (Taherdoost et al., 2014, Hooper, 2012, Williams et al., 2010). Hooper (2012) stated that if the Correlation Matrix do not have any correlations over 0.3, it might indicate factor analysis is not appropriate. On the other hand, Williams et al. (2010) categorized the correlation loadings as 0.30= minimal, 0.40= important, and 0.50= practically. If the correlations is less than 0.30, then it should be reconsidered if FA is proper approach to be used for the research.

The opposite problem is when variables correlate too highly. The correlation matrix between the variables should be scanned in order to see if there is any correlations coefficient above 0.9 (Field, 2009). We should look to eliminate any variables that don't correlate with any variable or that correlate very highly with other variable (R<0.9) (Field, 2005).

The determinant of R- matrix should be greater than 0.00001. If it less than this value them look through the correlation matrix for variables that correlate very highly (R>0.8) and consider eliminating one of the variables before proceeding (Field, 2005).

In this research, the correlation matrix with any variable without any correlation larger than 0.3 or with at least one correlation larger than 0.3 have been considered for elimination and removed for the next stages of factor analysis. Similarly, any variables that correlate very highly with other variable (R<0.9) should be eliminated.

3. Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett’s Test of Sphericity

Prior to the extraction of the constructs, there are some tests which must be conducted to examine the adequacy of the sample and the suitability of data for EFA (Howard, 2016, Burton and Mazerolle, 2011, Williams et al., 2010). These tests include Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity (Howard, 2016, Kim et al., 2016, Williams et al., 2010). Measures of sampling adequacy evaluate how strongly an item is correlated with other items in the EFA correlation matrix (Howard, 2016, Taherdoost et al., 2014, Burton and Mazerolle, 2011).

The sampling adequacy can be assessed by examining the Kaiser-Meyer-Olkin (KMO). KMO is an indicator of common variance within a dataset, which indicates that latent factors may be present and EFA may be performed (Howard, 2016). The KMO index, in particular, is recommended when the cases to variable ratio are less than 5:1 (Taherdoost et al., 2014, Williams et al., 2010). The KMO index ranges from 0 to 1, with 0.50 considered suitable for factor analysis (Taherdoost et al., 2014, Williams et al., 2010, Field, 2005).

On the other hand, Hooper (2012) stated that a KMO correlation should be either .6 or above. If a lower value is obtained, variables with small inter-correlations can be removed to improve suitability for EFA (Howard, 2016). Similarly, Netemeyer et al., (2003) demonstrated that KMO correlation above 0.60- 0.70 is considered adequate for analyzing the EFA output. Larose and Larose (2015) determined 0.50 as the minimum KMO value which is in line with Shang and Pheng (2014) and Zhou (2012).

Bartlett’s test of Sphericity provides a chi-square output that must be significant (Taherdoost et al., 2014). It checks whether the observed correlation matrix is an identity matrix which holds the property of having all off-diagonal values of zero (Howard, 2016). If the correlation matrix is an identity matrix (there is no relationship among the items), EFA should not be performed (Taherdoost et al., 2014, Williams et al., 2010). The Bartlett’s Test of Sphericity should be significant ($p<0.05$) for factor analysis to be suitable (Taherdoost et al., 2014, Ayarkwa et al., 2012b, Hooper, 2012, Williams et al., 2010). If Bartlett’s Test of Sphericity is significant, the results indicate that the data is not an identity matrix and appropriate for EFA (Howard, 2016).

Step 2: Factor extraction

The technique for extracting factors attempts to take out as much common variance as possible in the first factor. Subsequent factors are, in turn, intended to account for the maximum amount of the remaining common variance until, hopefully, no common variance remains. Direct extraction methods obtain the factor matrix directly from the correlation matrix by application of specified mathematical models (Suhr, 2006).

There are numerous ways to extract factors: Principal components analysis (PCA), principal axis factoring (PAF), image factoring, maximum likelihood, alpha factoring, and canonical (Howard, 2016, Taherdoost et al., 2014, Williams et al., 2010). However, PCA and PAF are used most commonly (Reio Jr and Shuck, 2015, Taherdoost et al., 2014). PCA is the default method in many statistical programs, and thus, is most commonly used in EFA, which likely contributes to its popularity (Hooper, 2012, Thompson, 2009, Costello and Osborne, 2005).

The aim of a PCA is to reduce large numbers of variables into something more manageable that retains as much as possible of a set of variables' observed variance, with little attention to interpreting latent constructs. Thus, all the observed variables' variance is analyzed in a PCA. (Conway and Huffcutt, 2003). A PCA uses ones that represent both common and unique variance in the observed variables) to eliminate measurement error due to common variance (Henson et al., 2004). Accordingly, the PCA is the appropriate method in this research to reduce the number of variables without interpreting the resulting variables as latent constructs in line with Howard (2016), Reio Jr and Shuck (2015) and Taherdoost et al. (2014).

Step3: Factor Retention Methods

After extraction the researcher must decide how many factors to retain when applying EFA and PCA phases (Taherdoost et al., 2014). Factor retention is more important than other phases (Taherdoost et al., 2014). Both over extraction and under extraction of factors retained for rotation can have deleterious effects on the results (Costello and Osborne, 2005). Determining the number of factors to extract in a factor analysis procedure means keeping the factors that account for the most variance in the data (Van der Eijk and Rose, 2015, Suhr, 2006, Conway and Huffcutt, 2003).

A number of criteria are available to assist these decisions, but they do not always lead to the same or even similar results (Taherdoost et al., 2014). The majority of factor analysts typically use multiple criteria. It is suggested that multiple approaches be used in factor extraction (Reio Jr and Shuck, 2015). Factor retention methods are Kaiser’s criteria (which is based on Eigenvalues (EV) that are > 1), the Scree test, the cumulative percent of variance extracted, and parallel analysis (Reio Jr and Shuck, 2015, Van der Eijk and Rose, 2015, Taherdoost et al., 2014, Williams et al., 2010).

- **Kaiser’s criteria**

The first and most popular method for deciding on the retention of factors is Kaiser’s eigenvalue greater than 1 criterion (Suhr, 2006, Fabrigar et al., 1999). Eigenvalues are calculated by summing the squared factor loadings. For this reason, factors with small eigenvalues represent little common variances and should not be included in analyses (Howard, 2016). Kaiser’s eigenvalue method specifies all factors greater than one are retained for interpretation (Taherdoost et al., 2014) which is supported by Ayarkwa et al. (2012b) and Langford et al. (2000). Kaiser himself reported that the number of components retained by K1 is commonly between 1/3, 1/5 or 1/6 the number of variables included in the correlation matrix (Zwick and Velicer, 1986).

This method offers the advantage of being easy to understand and is also the default method on most programs (Taherdoost et al., 2014, Hooper, 2012). A number of studies have mentioned that K1 is among the least accurate methods for selection of factor retention (Ledesma and Valero-Mora, 2007, Fabrigar et al., 1999). In fact, this method may lead to arbitrary decisions, for example it does not make sense to retain a factor with an eigenvalue of 1.01 and then to regard a factor with an eigenvalue of 0.99 as irrelevant (Howard, 2016, Ledesma and Valero-Mora, 2007).

- **Scree Test**

A technique which overcomes some of the deficiencies inherent in Kaiser’s approach is Cattell’s Scree Test (Hooper, 2012). The Scree Test graphically presents the number of eigenvalues in descending order against the number of factors (Reio Jr and Shuck, 2015, Van der Eijk and Rose, 2015, Hooper, 2012). This graph is then investigated to determine where there is a noticeable change in its shape which is known as ‘the elbow’ or point of inflection (Hooper, 2012, Suhr, 2006).

Once the researcher have identified the point at which the last significant break takes place, only factors above the elbow (to the left of the inflection) and excluding the inflection point should be retained (Van der Eijk and Rose, 2015, Hooper, 2012, Ledesma and Valero-Mora, 2007, Suhr, 2006). Unfortunately, the Scree test is frequently applied incorrectly by including the inflection point in the ‘meaningful’ set of eigenvalues (Van der Eijk and Rose, 2015). Williams et al. (2010) summarized the inspecting and interpretation of a Scree plot into two steps as the following:

1. Draw a straight line through the smaller eigenvalues where a departure from this line occurs. This point highlights where the debris or break occurs (If the Scree is messy, and difficult to interpret, additional manipulation of data and extraction should be undertaken).
2. The point above this debris or break (not including the break itself) indicates the number of factors to be retained.

Suhr (2006) stated that Kaiser’s eigenvalue is the first and most popular method for deciding on the retention of factors. Therefore, it is selected for factor extraction in this research. In Kaiser’s eigenvalue method, only the factors having eigenvalues greater than 1 are considered significant; all factors with eigenvalues less than 1 are considered insignificant and disregarded. In addition, Scree plot were provided here for verification of the analysis only.

- **Cumulative percentage of variance**

One measure of a good factor analysis is the amount of the total variance in the original set of variables that is explained by the factors. The greater the explained variance, the better the solution (Taherdoost et al., 2014, Suhr, 2006). There is no agreement in cumulative percentage of variance (CPV) in the FA method, particularly in different research area (Williams et al., 2010, Henson and Roberts, 2006). For instance, in the natural sciences, factors should be stopped when at least 95% of the variance is explained. However, in the humanities, the explained variance is generally as low as 50-60% (Hair et al., 1995). While for the social sciences a minimum of 60% cumulative variance is quite commonly accepted (Hooper, 2012). Reio Jr and Shuck (2015) stated that extracted factors should explain at least 40% of the total variance in the original variables, although some recommend at least 75%. ***In this research***, which is social science the cumulative variance will be adopted is 50% referring to Hair et al. (1995).

- **Communalities values**

Communality explains the total amount an original variable shares with all other variables included in the analysis and it is very useful in deciding which variables to finally extract in the rotation and in determining the adequacy of the sample size (Field, 2005). PCA works on the initial assumption that all variance is common; therefore before extraction the communalities are all 1 (Field, 2005). Once the underlying factors have been extracted, new communalities can be calculated that represent the squared multiple correlation between each variable and the factors extracted (Field, 2009, Suhr, 2006).

The communality is a measure of the proportion of variance explained by the extracted factors (Field, 2009). Large communality values indicate that the PCA have successfully extracted a large proportion of the variability in the original variables, while small communality values show that there is still much variation in the data set that has not been accounted for by the principal components (Larose and Larose, 2015).

Taherdoost et al. (2014) stated that item communalities are considered "high" if they are all .8 or greater but this is unlikely to occur in real data. In the social sciences, more common magnitudes of communalities are from 0.40 to 0.70 which are considered as low to moderate communalities (Taherdoost et al., 2014, Costello and Osborne, 2005). If an item has a communality of less than 0.40, it may either not be related to the other items, or suggest an additional factor that should be explored.

On the other hand, Larose and Larose (2015) stated that communalities less than 0.5 can be considered to be too low, as this would mean that the variable shares less than half of its variability in common with the other variables. Thus, it makes sense to remove them as inputs from the PCA, and try again. The low communality values reflect the fact that there is not much shared correlation among the variables. Note that the factor extraction increases the shared correlation.

Therefore, variables with communality less than 0.5 were removed from the analysis ***in this research*** and the factor analysis process repeated. In each run, the communality values of the remaining variables have been investigated and when there were more than one variable with communality value less than 0.5, the variable with the lowest communality values under 0.5 has been removed and the factor analysis processes retuned. Finally, all variables in the last solution should have a communality value equal or more than 0.5 to be accepted.

- **Factor loading values**

Factor loadings are analogous to the component weights in PCA, and represent the correlation between the ith variable and the jth factor (Larose and Larose, 2015). The factor loadings give an idea about how much the variable has contributed to the factor; the larger the factor loading the more the variable has contributed to that factor. Factor loadings represent the strength of the correlation between the variable and the factor (Yong and Pearce, 2013). Reio Jr and Shuck (2015) stated that it is best having three or more higher loading coefficients to constitute a meaningful, interpretable factor. While Henson and Roberts (2006) demonstrated that at least two or three variables must load on the factor so it can be given a meaningful interpretation.

A factor with fewer than three items is generally weak and unstable (Costello and Osborne, 2005). Both Dahling et al. (2012) and Nimon et al. (2011) focused on the pattern matrix and removed items that cross-loaded or weak loadings that were less than 0.33 (Dahling et al., 2012) or 0.40 (Nimon et al., 2011). A “cross-loading” item is an item that existed on two or more factors (components) (Hooper, 2012, Costello and Osborne, 2005).

Possibly the most popular cutoff for “good” factor loadings onto a primary factor is 0.40 (Hooper, 2012), but other authors have proposed values of 0.30 (Costello and Osborne, 2005), 0.32 and 0.45 (Tabachnick and Fidell, 2001). Burton and Mazerolle (2011) and Costello and Osborne (2005) stated that 0.5 or more strongly loading items are desirable and indicate a solid factor with no cross loadings.

In this research, items that were cross loaded on multiple factors are deleted and factor analysis process has been retuned. Factor loadings of 0.5 or more for was the cutoff value used in this study to delete items.

Step 4: Type of rotation

Most factor analysts agree that direct solutions attained from factor extraction are not sufficient. Adjustment to the frames of reference by rotation methods improves the interpretation of factor loadings by reducing some of the ambiguities which accompany the preliminary analysis. The process of manipulating the reference axes is known as rotation (Suhr, 2006). When conducting factor analysis, most researchers rotate the extracted factors (components) to assist interpretation (Reio Jr and Shuck, 2015). In order to produce a more interpretable and simplified solution, rotation will help by maximizing high item loadings and minimizing low item loadings (Taherdoost et al., 2014).

The aim of rotation is to simplify the factor structure of a group of items, or in other words, high item loadings on one factor and smaller item loadings on the remaining factor solutions (Williams et al., 2010, Suhr, 2006, Field, 2005). Oblique and orthogonal rotations are two types of rotation technique (Howard, 2016, Reio Jr and Shuck, 2015, Taherdoost et al., 2014, Williams et al., 2010, Field, 2005). Orthogonal rotation methods include quartimax and varimax. On the other hand, oblique rotation methods include promax and direct oblimin (Howard, 2016, Taherdoost et al., 2014, Williams et al., 2010, Field, 2005).

Orthogonal rotations do not allow the resultant rotated factors to be correlated, which is often not preferable. Alternatively, oblique rotations allow for the resultant factors to be correlated, causing authors to be preferable towards oblique rotations (Howard, 2016, Taherdoost et al., 2014, Williams et al., 2010). However, Costello and Osborne (2005) stated that orthogonal rotation produces more easily interpretable results and is slightly simpler than oblique rotation. Regardless of which rotation method is used, the main objectives are to provide easier interpretation of results, and produce a solution that is more parsimonious (Williams et al., 2010).

Orthogonal solutions are usually the default in most statistical packages, therefore it seem to be used most frequently by researchers (Henson et al., 2004). In addition, Varimax rotation is the most common form of rotational methods for exploratory factor analysis and will often provide a simple structure (Thompson, 2009). Varimax rotation seeks to increase the variances of the factor loadings, resulting in both large and small factor loadings. This is often preferable, as variables will (hopefully) clearly load or not load onto each factor. Since its inception, Varimax has continues to be a popular and useful rotation method (Howard, 2016). On the basis of the previous argument, this research has chosen the Varimax method for rotation.

Step5: Interpretation and naming of factors

Interpretation is the process of examination to select variables which are attributable to a construct and allocating a name for that construct. The labeling of constructs is a theoretical, subjective and inductive process (Pett et al., 2003). Interpretation involves the researcher examining which variables are attributable to a factor, and giving that factor a name or theme (Williams et al., 2010). It is significant that labels of constructs reflect the theoretical and conceptual intent. For instance, a construct may include four variables which all related to the user satisfaction thus the label "user satisfaction" will be assigned for that construct (Taherdoost et al., 2014).

Several questions arise before interpretation process. First, is a variable sufficiently loads onto a factor and is considered representative of that factor (component). Second, is a variable loads onto too many factors and is considered clearly representative of any (Howard, 2016, Hooper, 2012, Suhr, 2006). Having reached a suitable solution, the next stage is to interpret the factors themselves (Hooper, 2012).

There are a number of guidelines that can aid in the process of naming each dimension. Firstly, we can see there are two factors and variables load highly on only one factor. You will also note they are arranged in descending order to help us identify items with substantive loadings. These variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor (Hooper, 2012).

3.5.2 Inferential statistics analysis

Quantitative research in psychology and social science aims to test theories about the nature of the world in general (or some part of it) (or some part of it) based on samples of "subjects" taken from the world (or some part of it) (Gabrenya, 2003). Inferential statistics is the mathematics and logic of how this generalization from sample to population can be made (Crossman, 2018, Neuman, 2013, Gabrenya, 2003). Descriptive statistics remains local to the sample, describing its central tendency and variability, while inferential statistics focuses on making statements about the population. (Crossman, 2018, Gabrenya, 2003).

Inferential statistics are numbers that allow the researcher to determine whether there are differences between two or more samples and whether these differences are likely to be present in the population of interest (Thompson, 2009). Techniques used to examine the relationships between variables, and thereby to create inferential statistics, include but are not limited to regression analysis, ANOVA (Analysis of variance), correlation analysis, confidence intervals, T-distribution, hypothesis testing, structural equation modeling and survival analysis (Crossman, 2018).

Inferential statistics closely tied to the logic of hypothesis testing, and test whether descriptive results are likely to be due to random factors or to a real relationship (Neuman, 2013, Gabrenya, 2003). In hypothesis testing, the goal is usually to reject the null hypothesis. The null hypothesis is the null condition: no difference between means or no relationship between variables (Kaur and Kumar, 2015, Gabrenya, 2003). Basically we have two types of tests based parameters i.e. Parametric and Non-Parametric (Kaur and Kumar, 2015, Sedgwick, 2012, Naoum, 2007).

3.5.2.1 Parametric tests

Parametric tests are more robust and for the most part require less data to make a stronger conclusion than nonparametric tests (Kaur and Kumar, 2015, Neideen and Brasel, 2007). Parametric methods make assumptions about the distribution of the data, whereas non-parametric methods make none (Sedgwick, 2012, Naoum, 2007). However, to use a parametric test, 3 parameters of the data must be true or are assumed. First, the data need to be normally distributed, which means all data points must follow a bell-shaped curve without any data skewed above or below the mean (Kaur and Kumar, 2015, Sedgwick, 2012, Neideen and Brasel, 2007). The sampling distribution will tend to be normal regardless of the population distribution in samples of 30 or more (Field, 2009). Moreover, the data also need to have equal variance and have the same standard deviation to use the parametric methods. Finally, the data need to be continuous (Kaur and Kumar, 2015, Sedgwick, 2012, Neideen and Brasel, 2007).

As the sample in this research is 107 respondents which is more than 30, data are normally distributed. Therefore, the parametric tests will be used to test the research hypothesis. Commonly used parametric tests are described below:

- ***t*- test**

The *t*-test is a parametric test which is used to compare the difference between the mean scores of two samples (Sedgwick, 2012, Naoum, 2007). A single sample *t*-test is used to determine whether the mean of a sample is different from a known average. A two sample *t*-test is used to establish whether a difference occurs between the means of two similar data sets. The *t*-test uses the mean, standard deviation, and number of samples to calculate the test statistic. In a data set with a large number of samples, the critical value for the Student t-test is 1.96 for an alpha of 0.05, obtained from a t-test table (Neideen and Brasel, 2007).

- **Pearson Product Correlation Coefficient**

Pearson's correlation coefficient (r) is a parametric test which is used to calculate whether there is a strong relationship between two sets of scores (Naoum, 2007, Neideen and Brasel, 2007). The Pearson correlation varies from -1 through +1 (Naoum, 2007). An 'r' value of 1.0 means the data are completely positively correlated and one variable can be used to compute the other. An 'r' of zero means that the two variables are completely random. An 'r' of -1.0 is completely negatively correlated (Neideen and Brasel, 2007).

In this research, Pearson's correlation coefficient has been used in to infer information about relationship between the variables in two sections of the questionnaire as the research hypotheses. For instance, r will be used to measure the correlation between the level of using LC techniques to improve safety; and benefits of using LC techniques related to safety improvement, in order to determine the correlation type between them either positive, negative or random.

3.5.2.2 Non parametric tests

Non-parametric methods are also referred to as distribution-free methods (Sedgwick, 2012). If the data do not meet the criteria for a parametric test (normally distributed, equal variance, and continuous), it must be analyzed with a nonparametric test (Naoum, 2007, Neideen and Brasel, 2007). If a nonparametric test is required, more data will be needed to make the same conclusion (Neideen and Brasel, 2007). There are certain assumptions associated with most non-parametric tests, however, they are weaker than those associated with parametric tests (Naoum, 2007). Many nonparametric tests and multiple variations of each of those specific tests exist as Chi-Squared, Spearman Rank Coefficient, Mann-Whitney U Test and Kruskal-Wallis Test (Neideen and Brasel, 2007).

3.6 Summary

This chapter presents the research methodology adopted to achieve the aims and objectives of this research. A quantitative approach was used in this research to solve the research problems which related to improve safety by using Lean Construction techniques in construction projects. The research started with a thorough investigation of literature review followed by questionnaire design and development including face validity, pretesting and pilot study to increase the quality of the used questionnaire. The data collected were analyzed using IBM SPSS V.22, using a variety of statistical methods including descriptive and inferential statistics. Pearson correlation, Cronbach alpha, spilt half alpha, frequency distribution, relative index analysis, effect index, factor analysis are used to analyze the quantitative data collected using the questionnaire.

Chapter 4

Research results

Chapter 4
Research results

This chapter is specialized to present the research findings that have been collected using questionnaires. First section presents the respondents profile who are the supervising engineers work at construction projects which are externally funded and LC techniques are expected to be applied in safety improvement. Other findings fulfil the objectives of this research that are applicability level of Lean Construction (LC) techniques to reduce the causes of accidents in construction projects; and benefits, barriers and success factors that affect the application of LC techniques regarding safety improvement. Data analyzed using descriptive statistics and inferential statistics. The descriptive statistical analysis carried out include frequency distribution, mean scores, standard deviation, ranking and exploratory factor analysis for each objective except the barriers' objective which is analyzed using effect index and exploratory factor analysis. While the inferential statistics include correlation test.

4.1 Respondent profile

Answers of section A of the questionnaire (see Appendix C) were analyzed to determine the respondents' characteristics. The target respondents of the questionnaire were the supervising engineers who work at construction projects funded externally (like Qatar Committee) where LC techniques are expected to be applied in safety improvement. The targeted supervising engineers included (Project manager, site engineers, site supervisors and safety engineers). The profile of the 107 respondents is summarized in Table (4.1).

According to Table (4.1), 23.4% of the respondents were highly educated with postgraduate studies which reflects their experience in construction. Regarding the respondents' specialization, the majority of respondents were civil engineers with 76.6%; and the remaining were architect, mechanical and electrical engineers with percentages 18.7%, 1.9% and 2.8%, respectively. This result indicates that the most of supervising engineers on the sites are civil engineers. In terms of the type of respondents' organizations, most of respondents were working as contractors with 34.6%, 24.3% were working as consultants, 18.7% of the sample was working with the Non-Governmental Organizations (NGO's); and 22.4% were working with the governmental sector.

Regarding to the current job title, 16.8% of the respondents were project managers, 38.3% were site engineers, 40.2% site supervisors; and 4.7% safety engineers. This result indicates that although construction safety is growing up in Gaza Strip, there is no concern to employ a specialized engineer on the site to follow up the safety practice. This result is supported by Enshassi and Abu Zaiter (2014) who stated that in general most of construction organizations in Gaza Strip don’t have a safety program for its projects.

Table (4.1) shows that the level of working experience differs across the respondents. A large majority of respondents had ‘more than 10 years’ of working experience with 38.3%, 28.1% have an experience from ‘5 to 10 years’ of working experience, and 33.6% have experience ‘less than 5 years’. This indicates that most of respondents are very familiar with the site environment and causes of accident on site.

Table (4.1): Respondent’s profile

General information about respondents	Categories	Frequency	Percentage (%)
Educational Level	Bachelor	81	75.7
	Master	25	23.4
	PhD	1	0.9
Specialization	Architect	20	18.7
	Civil	82	76.6
	Mechanical	2	1.9
	Electrical	3	2.8
Organization type	Consultant	26	24.3
	Contractor	37	34.6
	NGO	20	18.7
	Governmental	24	22.4
Job title	Project manager	18	16.8
	Site engineer	41	38.3
	Supervisor engineer	43	40.2
	Safety engineer	5	4.7
Experience	Less than 5	36	33.6
	From 5 to 10	30	28.1
	More than 10	41	38.3

4.2 Awareness level of Lean Construction tools

Section B of the questionnaire measures the awareness level of respondents regard the LC tools as their expression. A LC tool comprise of one, two or more techniques. In other words, LC techniques are the features or practices adopted in LC tools (Bashir, 2013). Most of researchers revealed that the best LC tools to improve safety in construction projects are (Last Planner System (LPS), increased visualization (IV), 5S, Fail safe for quality and safety (Poka yoke), Daily Huddle Meetings (DHM), First Run Studies (FRS), Continuous improvement (Kaizen); and Accident investigation (5 Why's)) (Awada et al., 2016, Cudney et al., 2015, Enshassi and Abu Zaiter, 2014, Bashir, 2013, Forman, 2013, Gnoni et al., 2013, Bashir et al., 2011, Nahmens and Ikuma, 2009).

In this research, the respondents are requested to measure their awareness level regarding the eight LC tools using five Likert scale with (1= Never, 5=Very much). Table (4.2) summarizes the results of the awareness level of LC tools (AL1 to AL8) including mean score (MS), standard deviation (SD), relative importance index (RII), *t*-value, *p*-value and ranks. The mean values indicates which response item has the highest tendency to represent the sample (Denscombe, 2010). The average mean score for the item should be greater than the hypothesized mean (equal to 2 for five-point scale where A_{min}=0 and A_{max}=4) (Holt, 2014).

Result of the awareness level of LC tools shows that the mean scores for all tools are less than the hypothesized mean referring to Holt (2014). The findings shows that 5 whys has the highest tendency to represent the sample regardless its mean score is less than the average mean. The mean score reflect that most of respondents don't have an idea about LC tools as expressions. Furthermore, the values of standard deviation are small that is a good indication to conclude that respondents are pretty tightly bunched together (Neuman, 2013, Student Learning Development, 2009).

The average relative importance index (RII) for the awareness level of LC tools is 32.41%. To determine if this percentage is acceptable or not, it is essential to calculate the neutral value of RII and compare it with the average RII of each section. In this research, the five Likert scale was used which is (from 1=Low to 5=High). However, the scale ratings were entered in the SPSS in data analysis process (from 0=Low to 4=High). Therefore, the average of the rating scale used is (0+1+2+3+4)/5 = 2 (The neutral point) (Holt, 2014). As a result, the neutral RII is (2/4)*100 =

50%. Accordingly, the average RII of the awareness level of LC tools is under the neutral value of RII which ensure that respondents are not aware of LC tools as expressions. RII results for each item in this section are presented in the graphical Figure (4.1).

Additionally, *t*- value and *p*-value are summarized in Table (4.2) for the eight tools of LC. According to the *t*-test tables, critical *t*-value at degree of freedom (df) = [$N_{(Sample)}$-1] = [107-1] = 106 and significance level 0.05 equals “1.98” (Neideen and Brasel, 2007). While, *p*-value should be less than 0.05 to conclude that data is significant (Naoum, 2007). As shown in Table (4.2), all LC tool have *t*-values larger than the critical *t*-value 1.98 and *p*- values less than 0.05. Accordingly, the eight tools can be considered significant in assessing the awareness level of LC. In addition, al tools have negative *t*-values which indicated that their mean scores lower than the hypothesized mean value (2).

Table (4.2) presents that the highest level of awareness among the eight tools is *“accident investigation tool (5whys)”* with (MS= 1.53, SD=1.231; and RII=38.25%). It is followed by *“Daily Huddle Meetings (DHM)”* with (MS= 1.51, SD=1.16; and RII=37.75%). *“Continuous improvement (Kaizen)”* is ranked in the seventh position with (MS= 1.51, SD=1.16; and RII=37.75%). Finally, respondents ranked their awareness regard 5S tool as the lowest with (MS= 1.04, SD=0.961 and RII=26.00%).

Table (4.2): Ranks of awareness level of Lean Construction tools

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank
AL8	Accident investigation (5 Why’s)	1.53	1.231	38.25	-12.879	0.000	1
AL5	Daily Huddle Meetings (DHM)	1.51	1.160	37.75	-13.496	0.000	2
AL1	Last Planner System (LPS)	1.36	0.924	34.00	-15.170	0.000	3
AL6	First Run Studies (FRS)	1.27	0.927	31.75	-14.179	0.000	4
AL2	Increased visualization (IV)	1.26	0.935	31.50	-13958	0.000	5
AL4	Fail safe for quality and safety (Poka yoke)	1.21	0.887	30.25	-14.053	0.000	6

Table (4.2): Ranks of awareness level of Lean Construction tools

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank
AL7	Continuous improvement (Kaizen)	1.19	0.892	29.75	-13.770	0.000	7
AL3	5S process	1.04	0.961	26.00	-11.169	0.000	8
Overall awareness level of LC tools		1.30	0.99	32.41			

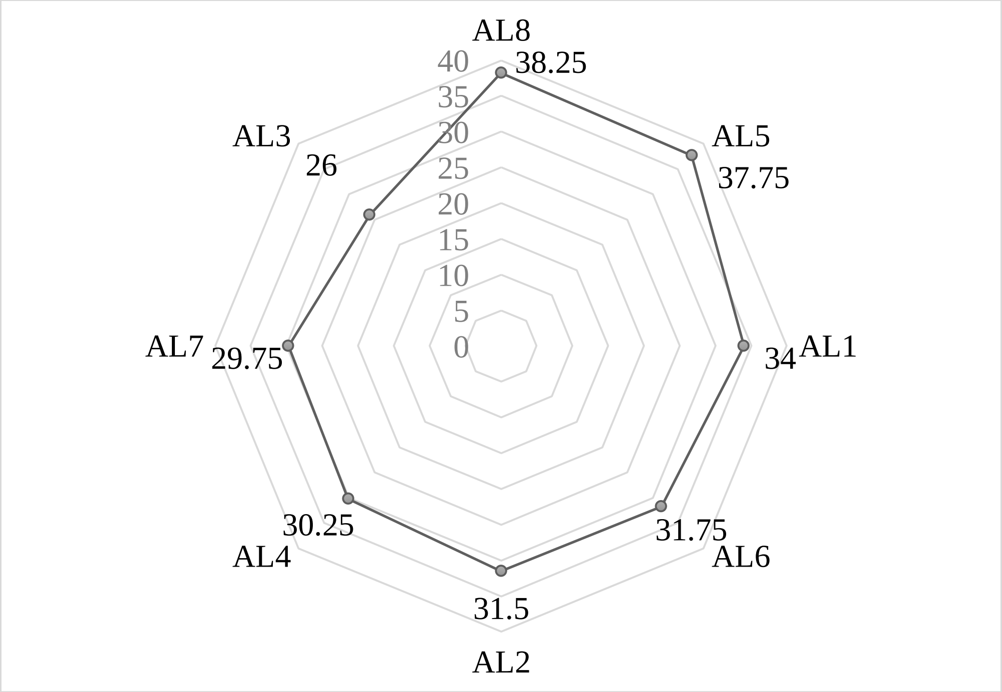


Figure (4.1): RII for the awareness level of Lean Construction tools (AL1 to AL8)

4.3 Applicability level of LC techniques to reduce the causes of accidents on the construction projects

From literature review, it is clear that Lean Construction techniques can be implemented to reduce the causes of accidents in the construction projects (Gambatese et al., 2016, Enshassi and Abu Zaiter, 2014, Bashir, 2013, Nahmens and Ikuma, 2009). However, the extent and adoption of LC techniques within construction industry is not widely known, despite the presence of implementation. To understand how far the LC techniques have been used to reduce the causes of accidents in the construction projects, section C of the questionnaire asked the supervising engineers whether they have incorporate these techniques within their projects or not. The respondents were provided with a list of LC techniques to determine the awareness level of using each of them in the construction projects to reduce the causes of accidents.

4.3.1 Ranks of LC techniques applied to reduce the causes of accidents in construction projects

Twenty five techniques were listed in section C of the questionnaire which were labeled as App1 to App25. Table (4.3) summarizes the analysis results of this section, including the mean score (MS), standard deviation (SD), RII, *t*-test results, *p*- values; and ranking order calculations on the level of using of each of LC techniques in reducing the causes of accidents in the construction projects. The mean scores for the 25 techniques were used to represent a project's level of application of LC techniques; the higher score, the higher application level of LC techniques in reducing accidents.

Table (4.3) shows that the overall average of the LC techniques applicability is (1.96) which is less than the average mean (equal to 2 for five-point scale where A_{min}=0 and A_{max}=4) (Holt, 2014). This result indicates that LC techniques as overall aren't adequately applied among Gaza Strip to reduce the causes of accidents in construction projects. However, some of these techniques are applied to reduce the causes of accidents. For instance, App12 has a mean score (2.57>2) which reflects that is highly applied, while App 9 with mean (0.53<2) is not adequately applied in Gaza Strip. Figure (4.2) concluded the average mean of LC tool which reflects that 5whys tool has the highest average mean while Poke Yoke has the lowest. Furthermore, the fact that the standard deviations for all techniques are small, indicated that there was little variability in the data and consistency in agreement among the respondents (Neuman, 2013, Student Learning Development, 2009).

The average relative importance index (RII) for the applying LC techniques to reduce the causes of accident in construction projects is (49.01% <50%). The average RII of the application level of LC techniques to reduce the causes of accidents in construction projects is under the neutral value of RII. This percent reflects that LC techniques are not implemented widely in reducing the causes of accidents among Gaza Strip construction industry, yet. RII results for each technique are presented in the graphical Figure (4.3). It is worth mentioning that ranking of the statements was based on the highest MS, RII, and the lowest SD. If some statements have similar means and RIIs, as in the case of App 21 and App 24; and App 20 and App 23, ranking will be depended on the lowest SD.

In this research, one-sample *t*-test has been performed to examine whether the respondents considered the proposed techniques to be important to measure application level of LC in reducing the causes of accidents. It is deduced from Table (4.3) that the respondents considered all the listed techniques significant in measuring the applicability level of LC in safety improvement because all of them have *p*-value less than the significance level 0.05 and all of them have *t*-values greater than the critical t-value (1.98). In addition, fourteen techniques has positive *t*-values which indicated that these techniques mean scores higher than the hypothesized mean value (2). All the other techniques have negative t-values which their mean scores lower than the hypothesized mean value (2).

Table (4.3): Ranks of application of LC techniques to reduce the causes of accidents on the construction sites

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank within group	Overall Rank
Last Planner System (LPS)								
App1	Providing employees with safety equipment	2.33	0.898	58.25	26.795	0.000	1	5
App8	Conducting weekly work planning	2.32	1.087	58	22.061	0.000	2	6
App2	Developing a plan for supervision	2.28	1.044	57	22.589	0.000	3	8
App3	Developing a schedule based on worker's abilities	2.17	0.986	54.25	22.756	0.000	4	9
App7	Conducting pre task hazard analysis to identify risks	2.15	0.979	53.75	22.710	0.000	5	11

Table (4.3): Ranks of application of LC techniques to reduce the causes of accidents on the construction sites

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank within group	Overall Rank
	predicted at activity and reducing it							
App5	Correlating work methods with worker's skills and abilities	2.11	0.828	52.75	26.390	0.000	6	12
App4	Worker's empowerment and involvement in task planning and scheduling	1.59	0.990	39.75	-16.599	0.000	7	21
App6	Involvement of all employees in safety planning	1.5	1.031	37.5	-15.092	0.000	8	23
Increased visualization (IV)								
App11	Using safety signs and labels on site	2.39	1.035	59.75	23.915	0.000	1	3
App10	Using visual demarcations and boards on site	2.16	1.109	54	20.142	0.000	2	10
App9	Using camera connected with computer algorithm to warn safety officer when workers violate safety conditions	0.53	0.705	13.25	-7.820	0.000	3	25

Table (4.3): Ranks of application of LC techniques to reduce the causes of accidents on the construction sites

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank within group	Overall Rank
5S								
App12	Cleaning the workplace and removing materials and machines that are not required	2.57	0.902	64.25	29.477	0.000	1	1
App13	Organizing material and plant	2.37	0.807	59.25	30.424	0.000	2	4
App14	Separating needed tools from unneeded materials and clearing the unwanted materials	2.30	0.934	57.5	25.468	0.000	3	7
App16	Creating continuous improvement in safety culture to increase safety culture among the workforce	1.94	0.989	48.5	-20.333	0.000	4	17
App15	Defining standard procedures to maintain the working environment clean and organized and improve safety culture	1.93	0.904	48.25	-22.147	0.000	5	18

Table (4.3): Ranks of application of LC techniques to reduce the causes of accidents on the construction sites

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank within group	Overall Rank
Poka yoke								
App19	Using safe guards and Personal Protective Equipment (PPE)	2.09	1.060	52.25	20.432	0.000	1	13
App17	Conducting visual inspection	2.01	1.032	50.25	20.132	0.000	2	14
App18	Using Alarms and warning gadgets to warn workers from crossing the unsafe boundaries	0.85	0.877	21.25	-10.026	0.000	3	24
Daily Huddle Meeting (DHM)								
App20	Conducting daily meeting to increase communication between teamwork, increase workers awareness of safety to make them identify risks and reduce it	1.74	1.022	43.5	-17.598	0.000	1	20
First Run Studies (FRS)								
App21	Make a plan for the critical tasks	1.99	1.137	49.75	-18.113	0.000	1	16
App22	Illustration of work methods	1.54	1.127	38.5	-14.157	0.000	2	22

Table (4.3): Ranks of application of LC techniques to reduce the causes of accidents on the construction sites

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank within group	Overall Rank
	using videos, photos, etc.							
Continuous improvement (Kaizen)								
App24	Conducting pre task hazard analysis to identify risks predicted at activity and reducing it	1.99	0.995	49.75	-20.690	0.000	1	15
App23	Involvement of all employees in improvement process	1.74	0.994	43.5	-18.095	0.000	2	19
Accident investigation (5Whys)								
App25	Conducting accident investigation and root-cause analysis program	2.42	1.037	60.5	24.136	0.000	1	2
Overall applicability level of LC techniques		1.96	0.98	49.01				

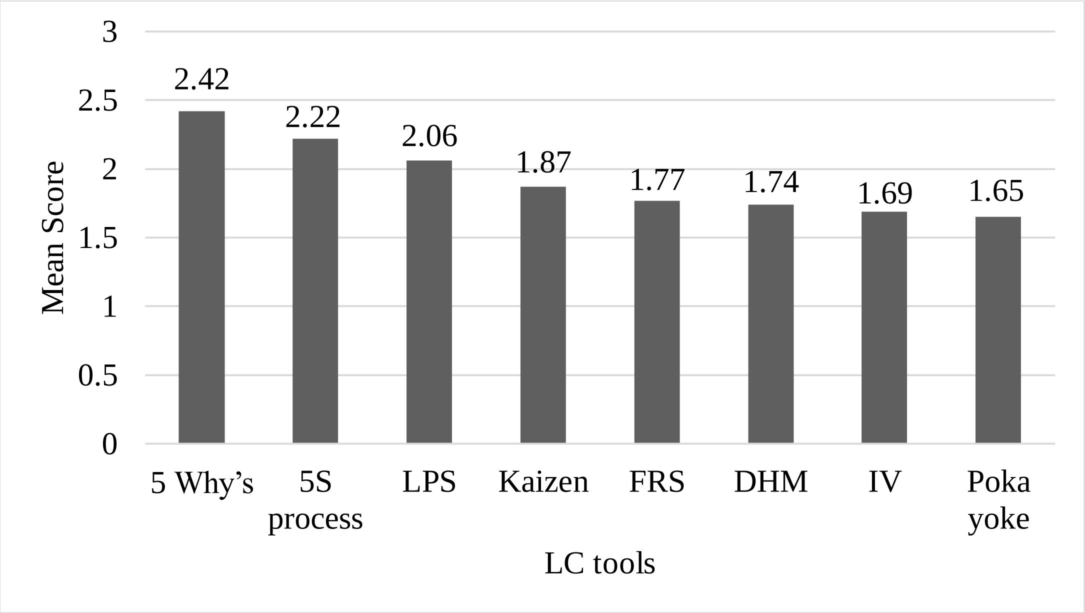


Figure (4.2): Average mean of applicability level of LC tools

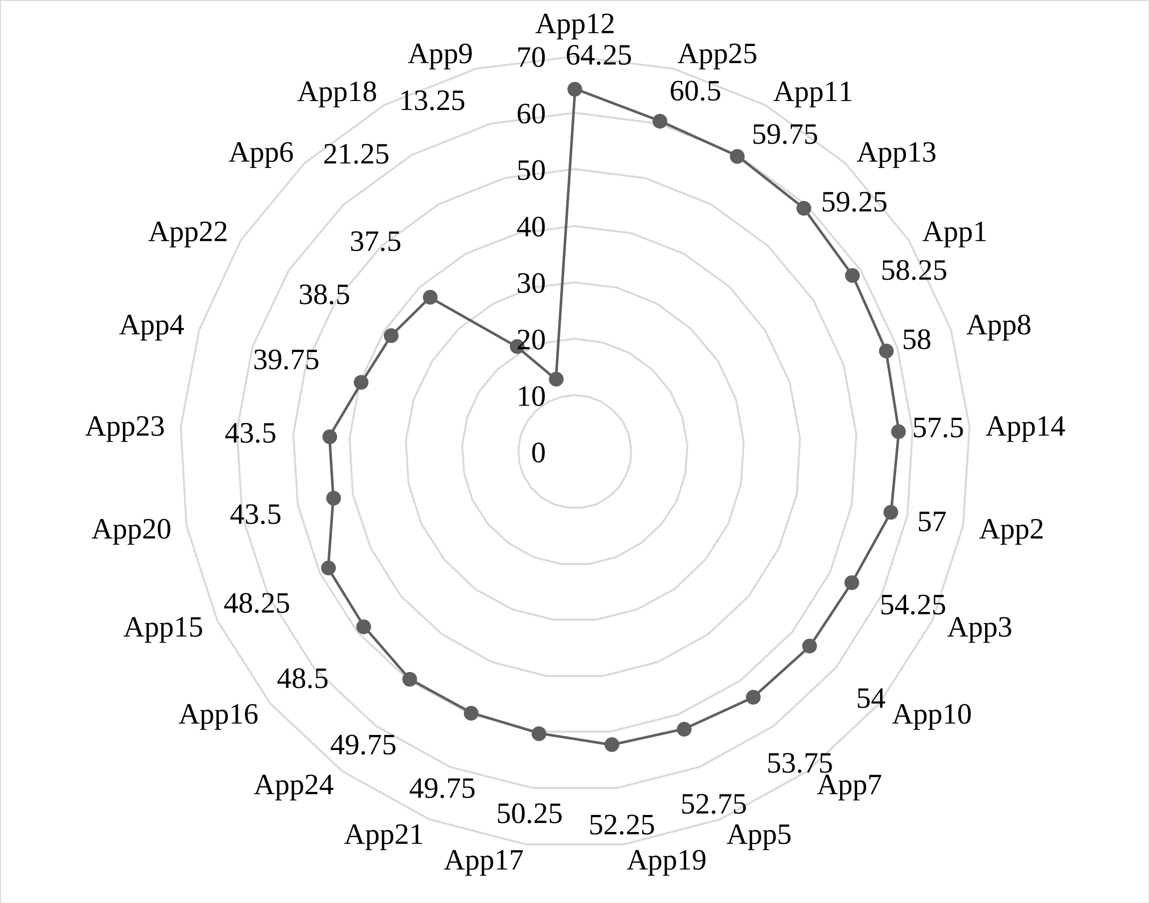


Figure (4.3): RII for the applicability level of Lean Construction techniques to reduce accidents (App1 to App25)

The top three LC techniques were used to reduce the causes of accidents are *"Cleaning the workplace and removing materials and machines that are not required"*, *"Conducting accident investigation and root-cause analysis program"* and *"Using safety signs and labels on site"*. From Table (4.3), it has been found that "*Cleaning the workplace and removing materials and machines that are not required",* is ranked as the first used technique by the respondents in all techniques and within 5S tool category with (MS=2.57, SD=0.902; and RII=64.25%). Respondents agreed that *"Conducting accident investigation and root-cause analysis program"* which is related to the tool of 5whys with (MS=2.42, SD= 1.037; and RII=60.5%) is the second rank in the overall techniques and the first technique in 5whys tool. It is followed by a techniques of increased visualization tool which is *"Using safety signs and labels on site*" with (MS=2.39, SD= 1.035; and RII=59.75%). This techniques is ranked as third techniques in the overall techniques and the first among IV tool.

On the other hand, the results indicate that the respondents agreed that "*Using Alarms and warning gadgets to warn workers from crossing the unsafe boundaries"* is ranked as 24th from 25 techniques and 3rd in the Poka Yoke tool with (MS=0.85, SD= 0.877; and RII=21.25%). Finally, *"Using camera connected with computer algorithm to warn safety officer when workers violate safety conditions"* which is lies into increased visualization tool is the last rank in both of IV tool (3rd) and in the overall techniques (25th) with (MS=0.705, SD= 0.705; and RII=13.25%).

4.3.2 Factor analysis results of LC techniques applied to reduce the causes of accidents in construction projects

Factor analysis reduces a large number of variables (factors) into a smaller set (Taherdoost et al., 2014, Williams et al., 2010, Field, 2009). In this research, exploratory factor analysis (EFA) is adopted. Since, EFA is a method for identifying the factor structure of a set of multiple indicators or variables without imposing a priori structure on the factors (Reio Jr and Shuck, 2015). The most frequent applications of EFA among researchers consists of reducing relatively large sets of variables (factors) into more manageable, developing and refining a new instrument's scales, and exploring relations among variables to build theory (Reio Jr and Shuck, 2015, Taherdoost et al., 2014, Hooper, 2012, Matsunaga, 2010).

There are five methodological issues that researchers should consider for utilizing EFA including: Evaluation of data suitability for EFA, factor extraction procedure, factor retention procedure, select the rotation method to yield a final interpretable solution and naming of factors (Reio Jr and Shuck, 2015, Taherdoost et al., 2014, Williams et al., 2010). Figure (4.4) shows the steps toward implementing exploratory factor analysis in this research.

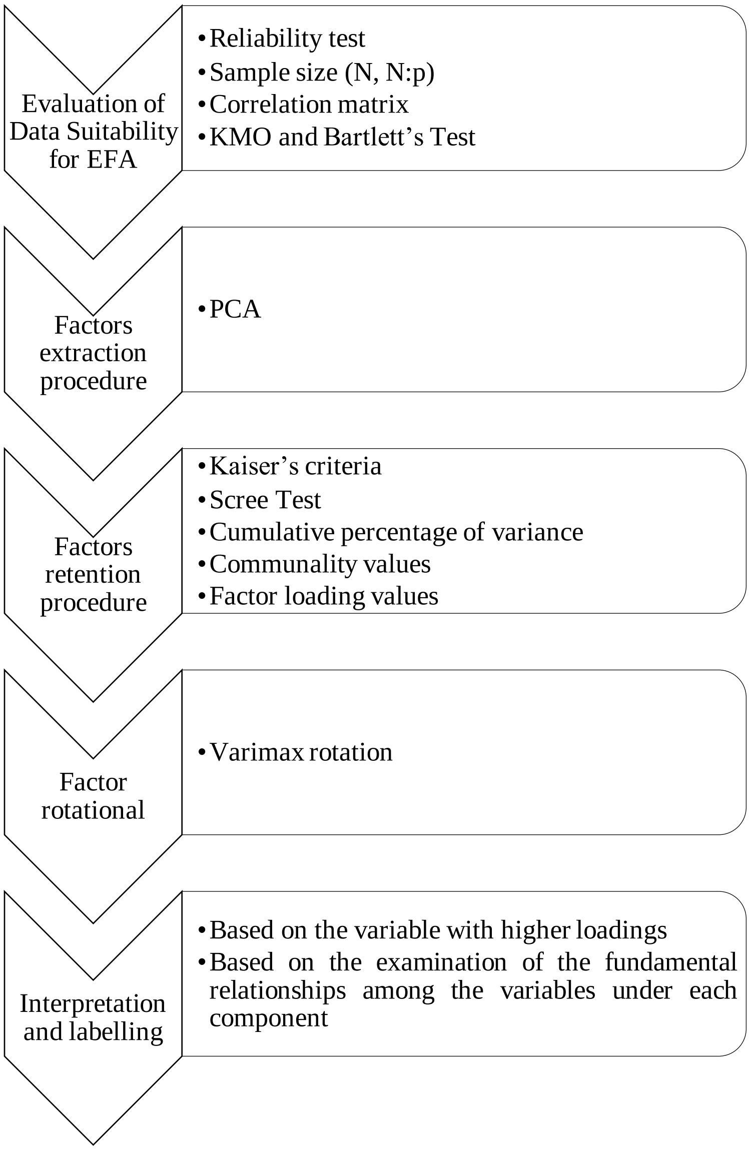


Figure (4.4): The five steps toward implementing exploratory factor

4.3.2.1 Evaluation of Data Suitability for EFA

When designing a study, quality decision making requires attending to test that it is suitable to conduct the factor analysis (Widaman, 2012). The following tests should be conducted prior to the factor analysis including reliability test, sample size, correlation matrix, Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity.

1. Reliability test

Reliability tests were carried out to ensure that the questionnaire was reliable. Reliability measurement is an indication of the stability and consistency of the instrument applied (Zhou, 2012). Reliability analysis provides a measure of how well a group of observed variables goes together (Field, 2009). Cronbach's Alpha was used to test the reliability (Zhou, 2012). The normal range of Cronbach's coefficient alpha (Cα) value is between 0.0 and +1 (Field, 2009). In factor analysis, the reliability should be tested in the first and last run to measure the reliability of the factors remained. Moreover, the reliability of each extracted components should be tested. The reliability in the first run of the applicability level of LC techniques to reduce the causes of accidents is 0.955 which is significantly high, and hence the data is reliable as shown in Table (4.5). In the last run of EFA, the reliability of data is 0.867 which is between 0.0 and +1 and reflects the reliability of data. Table (4.10) shows that the reliability coefficient for all of the extracted factors are between 0 and 1 which and reflect the reliability of data.

2. Sample size

Sample size in factor analysis usually stated in terms of either the minimum sample size (N) for a particular analysis or the minimum ratio of N to the number of variables, p (N: p) (Reio Jr and Shuck, 2015, Lingard and Rowlinson, 2006). ***In this research***, the sample size constituted of 107 respondents which is sufficient to conduct the factor analysis. It is considered adequate as it was larger than 50 as proposed by Sapnas and Zeller (2002). It is also more than the minimum sample sizes of 100 which is suggested by Suhr (2006) and Hair et al. (1995). By using the sample to variable ratio (N: p) for this section, it is 4.28:1 which is enough according to Williams et al. (2010) and Tabachnick and Fidell (2001) who stated that 3:1 ratios can be useful for EFA.

3. Correlation matrix

Correlation matrix is used to determine the relationships between variables which is known as R-matrix (Hooper, 2012, Field, 2009, Field, 2005). The diagonal elements of an R-matrix are all ones because each variable will correlate perfectly with itself. The off-diagonal elements are the correlation coefficients between pairs of variables, or questions (Field, 2009). The correlation coefficients in the Correlation Matrix should be greater than 0.3 “not all correlations” in magnitude (Taherdoost et al., 2014, Hooper, 2012, Williams et al., 2010). The opposite problem is when variables correlate too highly. The correlation matrix between the variables should be scanned in order to see if there is any correlations coefficient above 0.9 (Field, 2009). Any variables that don’t correlate sufficiently with any variable ($r < 0.3$) or that correlate very highly with other variable ($r > 0.9$) should be eliminated (Field, 2005).

A correlation matrix of 25 LC techniques used to reduce the causes of accidents in construction projects was calculated and presented in Table (4.4). The correlation matrix shows that all variables are correlated sufficiently with at least one variable is correlated by ($r > 0.3$) and none of the variables are correlated very highly with any other variable ($r < 0.9$). Therefore, there is no need to eliminate any variable at this stage. This result provided an adequate basis for proceeding to the next step to check the value of Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett’s Test of Sphericity.

Table (4.4): Correlation matrix of the applicability level of LC techniques to reduce the causes of accidents on the construction sites

App	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
App1	1.00																								
App2	0.56	1.00																							
App3	0.29	0.44	1.00																						
App4	0.32	0.49	0.45	1.00																					
App5	0.45	0.42	0.38	0.55	1.00																				
App6	0.33	0.50	0.30	0.55	0.49	1.00																			
App7	0.49	0.54	0.20	0.28	0.38	0.48	1.00																		
App8	0.51	0.42	0.33	0.26	0.25	0.27	0.33	1.00																	
App9	0.05	0.06	0.01	0.16	-.039	0.13	0.05	0.10	1.00																
App10	0.42	0.34	0.22	0.05	0.24	0.15	0.23	0.43	0.02	1.00															
App11	0.51	0.22	0.17	0.02	0.27	0.06	0.23	0.28	0.05	0.59	1.00														
App12	0.42	0.41	0.27	0.29	0.28	0.23	0.33	0.46	-.022	0.39	0.45	1.00													
App13	0.38	0.27	0.25	0.29	0.25	0.07	0.22	0.36	0.06	0.37	0.39	0.60	1.00												
App14	0.37	0.26	0.31	0.21	0.35	0.01	0.28	0.31	-.029	0.36	0.33	0.36	0.49	1.00											
App15	0.46	0.46	0.30	0.35	0.36	0.33	0.21	0.48	0.19	0.31	0.26	0.45	0.47	0.36	1.00										
App16	0.47	0.52	0.26	0.34	0.43	0.32	0.40	0.35	0.07	0.28	0.28	0.39	0.38	0.39	0.62	1.00									
App17	0.59	0.52	0.27	0.27	0.32	0.35	0.42	0.53	0.15	0.36	0.45	0.48	0.45	0.32	0.56	0.59	1.00								
App18	0.36	0.43	0.16	0.39	0.24	0.45	0.21	0.22	0.36	0.12	0.16	0.16	0.19	0.07	0.33	0.27	0.38	1.00							
App19	0.46	0.40	0.27	0.09	0.20	0.24	0.28	0.42	0.10	0.45	0.53	0.46	0.38	0.32	0.32	0.37	0.53	0.35	1.00						
App20	0.45	0.34	0.23	0.25	0.18	0.23	0.31	0.49	0.16	0.27	0.30	0.35	0.41	0.27	0.42	0.35	0.51	0.35	0.46	1.00					
App21	0.35	0.33	0.32	0.17	0.28	0.16	0.31	0.26	0.11	0.31	0.24	0.40	0.40	0.42	0.45	0.34	0.40	0.28	0.28	0.61	1.00				
App22	0.45	0.49	0.21	0.36	0.28	0.30	0.39	0.31	0.14	0.17	0.22	0.26	0.42	0.31	0.42	0.54	0.60	0.34	0.30	0.53	0.36	1.00			
App23	0.33	0.29	0.27	0.44	0.36	0.25	0.21	0.22	0.12	0.10	0.12	0.33	0.34	0.21	0.32	0.44	0.31	0.06	0.19	0.42	0.27	0.47	1.00		
App24	0.51	0.36	0.27	0.40	0.33	0.25	0.50	0.26	0.22	0.21	0.32	0.46	0.49	0.26	0.37	0.35	0.41	0.20	0.37	0.46	0.48	0.40	0.53	1.00	
App25	0.38	0.29	0.14	0.22	0.36	0.29	0.28	0.42	0.13	0.39	0.31	0.43	0.27	0.24	0.40	0.39	0.59	0.22	0.33	0.30	0.24	0.34	0.35	0.39	1.00

4. Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity

Measures of sampling adequacy evaluate how strongly an item is correlated with other items in the EFA correlation matrix (Howard, 2016, Taherdoost et al., 2014, Burton and Mazerolle, 2011). The sampling adequacy can be assessed by examining the Kaiser-Meyer-Olkin (KMO). The KMO correlation adopted in this research is either 0.5 or above referring to Larose and Larose (2015). Bartlett's test of Sphericity checks whether the observed correlation matrix is an identity matrix which holds the property of having all the diagonals of one and all off-diagonal values of zero (Howard, 2016). If the correlation matrix is an identity matrix, EFA should not be performed (Taherdoost et al., 2014, Williams et al., 2010). The Bartlett's Test of Sphericity should be significant ($p<0.05$) for factor analysis to be suitable (Taherdoost et al., 2014, Ayarkwa et al., 2012b, Hooper, 2012, Williams et al., 2010).

As shown in Table (4.5), the KMO of "applicability level of LC techniques to reduce the causes of accidents in construction projects" in the first run is 0.834. This value is exceeding the minimum score of 0.50, demonstrating that the sample is adequate and data is suitable of for EFA. Similarly in the first run of EFA, the Bartlett's Test of Sphericity (with Chi-Square =1339.070) and significance of data ($p= 0.000< 0.05$) is valid. This reflects that the correlation matrix is not an identity matrix and the relationship among the items is strong, so EFA can be performed. In the last run of EFA regarding this section, KMO value and Bartlett's Test of Sphericity are also valid which are 0.830 and 0.000, respectively.

Table (4.5): Results of KMO and Bartlett's Test of Sphericity

		First run	Last run (Third run)
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.834	0.830
Bartlett's Test of Sphericity	Approx. Chi-Square	1339.070	565.998
	Df	300	78
	Sig.	0.000	0.000
Reliability	Cronbach's alpha (Cα)	0.955	0.867

The valid results of the test of reliability test, sample size, correlation matrix, the measure of sampling adequacy and the test of Sphericity helped to determine that factor analysis was appropriate for the dataset in this research.

4.3.2.2 Factor Extraction

Direct extraction methods obtain the factor matrix directly from the correlation matrix by application of specified mathematical models (Suhr, 2006). PCA is the default method in many statistical programs, and thus, is most commonly used in EFA, which likely contributes to its popularity (Hooper, 2012, Costello and Osborne, 2005, Thompson, 2004). It is used to extract maximum variance from the data set with each component thus reducing a large number of variables into smaller number of components (Tabachnick & Fidell, 2007). PCA is used to determine the underlying structure of LC techniques which reflect the applicability level of LC in reducing the causes of accidents in construction projects. PCA works on the initial assumption that all variance is common; therefore before extraction the communalities are all 1 (Field, 2005). Once the underlying factors have been extracted, new communalities can be calculated (Field, 2009, Suhr, 2006).

- **Communality values**

The communality is a measure of the proportion of variance explained by the extracted factors (Field, 2009). Large communality values indicate that the PCA have successfully extracted a large proportion of the variability in the original variables, while small communality values show that there is still much variation in the data set that has not been accounted for by the PCA (Larose and Larose, 2015). The communality value after extraction should be more than 0.5 to be adequate (Field, 2005). Thus, the techniques with low communality values will be eliminated which is achieved by eliminating the techniques with loading values less than 0.5 and the factor analysis process will be repeated. Finally, all techniques in the last solution should have a communality value equal or more than 0.5 to be accepted as shown in Table (4.6).

By performing the first run of EFA on the 25 LC techniques which are used to reduce the causes of accidents in construction projects, the values of extracted communalities for all techniques were larger than 0.5 as shown in Table (4.6). The Large communality values indicates that the PCA have successfully extracted a large proportion of the variability in the original variables. During every run of EFA after eliminating the factors with low loadings, the communalities should be checked. For instance, in the second run of EFA the commonality value for *"Conducting accident investigation and root-cause analysis program"* (App 25) which is the technique of 5whys tool was (0.416 < 0.5). As a result, the third run of EFA should be without this technique.

Table (4.6): Communalities of the applicability level of LC techniques to reduce the causes of accidents in the construction projects

Items	Extracted communalities	
	First run	Last run (Third run)
App1	0.640	0.636
App2	0.654	0.600
App3	0.638	Removed in 2nd run
App4	0.731	0.744
App5	0.635	0.614
App6	0.723	0.646
App7	0.707	Removed in 2nd run
App8	0.507	Removed in 2nd run
App9	0.554	Removed in 2nd run
App10	0.630	0.670
App11	0.647	0.718
App12	0.544	Removed in 2nd run
App13	0.633	Removed in 3rd run
App14	0.570	Removed in 3rd run
App15	0.708	Removed in 3rd run
App16	0.640	Removed in 3rd run
App17	0.744	Removed in 3rd run
App18	0.728	Removed in 2nd run
App19	0.610	0.594
App20	0.652	0.717
App21	0.632	0.555
App22	0.592	0.545
App23	0.680	0.576
App24	0.752	0.590
App25	0.606	Removed in 3rd run

4.3.2.3 Factor Retention

After extraction the researcher must decide how many components to be retained when applying EFA and PCA phases (Taherdoost et al., 2014, Fabrigar et al., 1999). ***In this research***, multiple criteria were used to decide the number of factors to retain including Kaiser's criteria (which is based on Eigenvalues (EV) that are > 1), the Scree test; and the cumulative percent of variance (Reio Jr and Shuck, 2015, Van der Eijk and Rose, 2015, Taherdoost et al., 2014, Williams et al., 2010).

1. Kaiser's criteria

Eigenvalues are calculated by summing the squared factor loadings (Kline, 2014). For this reason, factors with small eigenvalues represent little common variances and should not be included in analyses (Howard, 2016). Kaiser's eigenvalue method specifies all components greater than one are retained for interpretation (Taherdoost et al., 2014). Kaiser's eigenvalue greater than 1 criterion is the most popular method for deciding on the retention of factors (Suhr, 2006, Fabrigar et al., 1999). ***In this research,*** the eigenvalue greater than one has been used to determine the number of components to be retained.

EFA is a method for identifying the factor structure of a set of multiple indicators or variables without imposing an a priori structure on the factors (Reio Jr and Shuck, 2015). Therefore, factor analysis can be repeated several times to obtain the optimum solution. Accordingly, any factor has an eigenvalue less than one represents little variance and will not be existed in the last run. After three runs of EFA to the 25 LC techniques, 12 techniques were removed and only 13 were remained in the final run which satisfied all requirements of EFA.

Table (4.7) summarizes the initial eigenvalues of the last run of EFA to the applicability level of LC techniques to reduce the causes of accidents in construction projects. The first column of the table of the Total Variance Explained consists of 13 eigenvalues, every component has only one eigenvalue. Summation of eigenvalues is 13 which is as same as the number of components. The 13 eigenvalues are arranged in descending order, the largest value (component 1) on the top while the least on the bottom (component 13). The eigenvalue of (component 1) is 5.128 which means that out of a total variance of 13, 5.128 can be related to component 1. Component 1 has a variance of 5.128 which accounts 39.443% of the total variance of 13 techniques. It is worth mentioning that this value should not be taken in consideration, as the direct solutions attained from factor extraction are not sufficient and need to be adjusted by rotation. In addition, from the table it is shown that three components have an eigenvalues greater than 1.0. Therefore, the 13 techniques will be underlined under 3 components.

Table (4.7): Total variance explained of applicability level of LC techniques to reduce the causes of accidents in construction projects

Components	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	5.128	39.443	39.443	5.128	39.443	39.443	2.916	22.431	22.431
2	1.800	13.847	53.290	1.800	13.847	53.290	2.718	20.911	43.342
3	1.278	9.831	63.121	1.278	9.831	63.121	2.571	19.779	63.121
4	0.818	6.290	69.410						
5	0.732	5.634	75.044						
6	0.597	4.589	79.633						
7	0.541	4.165	83.798						
8	0.489	3.763	87.561						
9	0.404	3.110	90.671						
10	0.384	2.951	93.622						
11	0.361	2.779	96.401						
12	0.269	2.066	98.467						
13	0.199	1.533	100.00						

2. Scree plot

The Scree plot graphically presents the number of eigenvalues in descending order against the number of factors (Reio Jr and Shuck, 2015, Van der Eijk and Rose, 2015, Hooper, 2012). This graph is then investigated to determine where there is a noticeable change in its shape which is known as ‘the elbow’ or point of inflection (Hooper, 2012, Ruscio and Roche, 2012, Suhr, 2006). Williams et al. (2010) summarized the inspecting and interpretation of a Scree plot into two steps as the following:

1. Draw a straight line through the smaller eigenvalues where a departure from this line occurs. This point highlights where the debris or break occurs.
2. The point above this debris or break (not including the break itself) indicates the number of factors to be retained.

As shown in Figure (4.5) which resulted from the last run of EFA regarding the applicability level of the LC techniques to reduce the causes of accidents in construction projects, there are 13 components at the horizontal axis. However, only 3 components have an eigenvalues greater than 1, which indicated that the LC techniques will be underlined under three groups.

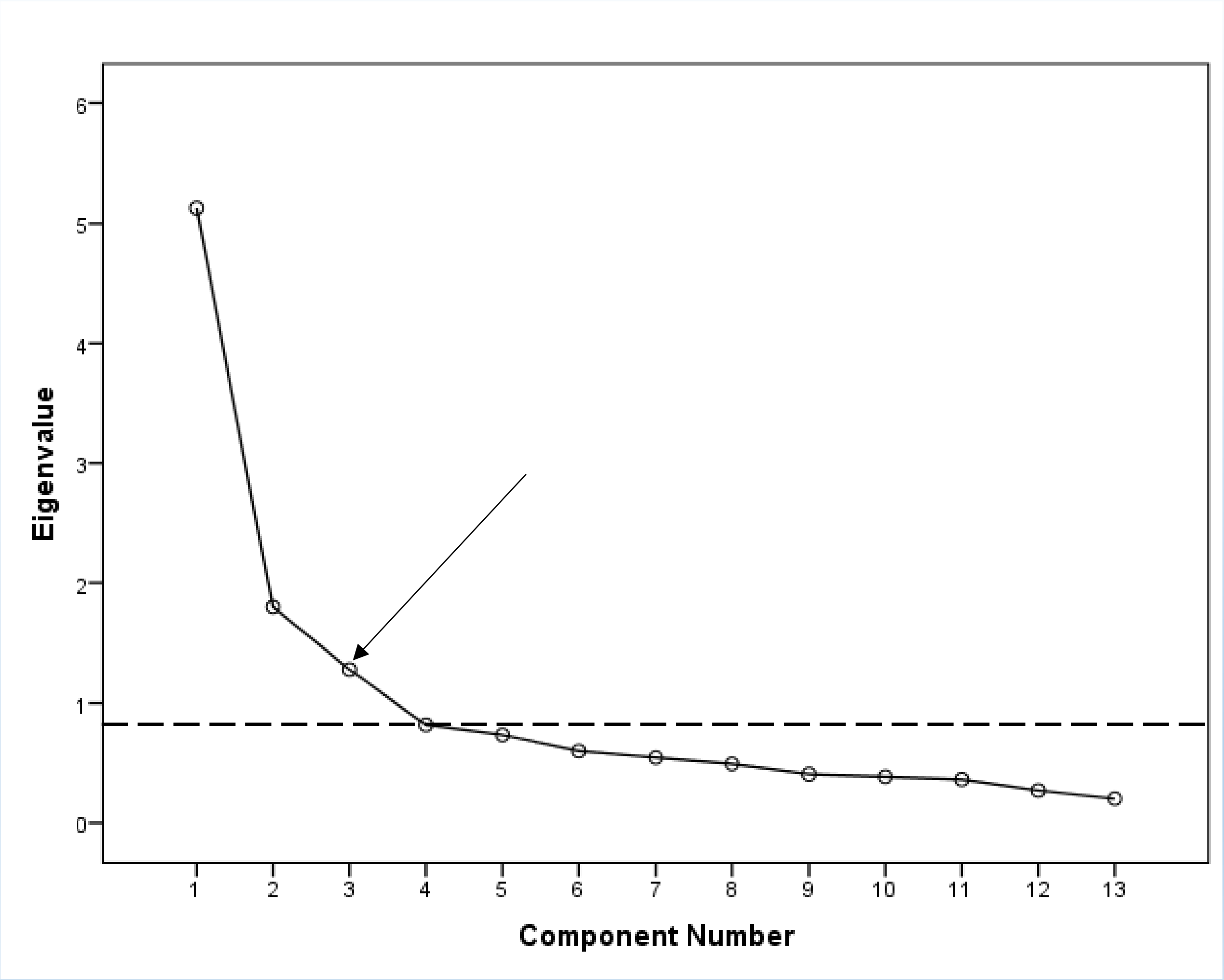


Figure (4.5): Scree plot of applicability level of using LC techniques to reduce the causes of accidents in construction projects

3. Cumulative percent of variance

One measure of a good factor analysis is the amount of the total variance in the original set of variables that is explained by the factors. The greater the explained variance, the better the solution (Taherdoost et al., 2014, Suhr, 2006, De Vaus, 2002). Table (4.7) shows the total variance explained for the 13 techniques remained in the last run. This table shows that 3 components with eigenvalue larger than one which mean that three components can be extracted from the 13 techniques. The retained three components explained 63.121% of the total variance. This means that a considerable amount of the 63.121% shared by the 13 variables (techniques) could be accounted for by these three factors. Accordingly, the cumulative variance could be acceptable since it is greater than the threshold value of 50% (Hair, 1995).

4.3.2.4 Factor rotation

Most factor analysts agree that direct solutions attained from factor extraction are not sufficient. Adjustment to the frames of reference by rotation methods improves the interpretation of factor loadings by reducing some of the ambiguities which accompany the preliminary analysis (Suhr, 2006). Rotation will help by maximizing high item loadings and minimizing low item loadings (Taherdoost et al., 2014). The Orthogonal-Varimax rotation was conducted to retain the factor and to interpret the components into simple structure solution. Costello and Osborne (2005) stated that orthogonal rotation produces more easily interpretable results and is slightly simpler than oblique rotation. Varimax rotation is the most common form of rotational methods for exploratory factor analysis and will often provide a simple structure (Thompson, 2004).

- **Rotated factor loading values**

The factor loadings give an idea about how much the variable has contributed to the factor; the larger the factor loading the more the variable has contributed to that factor. Factor loadings represent the strength of the correlation between the variable and the factor (Yong and Pearce, 2013). In order to obtain the optimum solution from EFA, many considerations should be taken including the minimum value of loading value, cross loading and minimum number of variables in each component.

1. Minimum loading value

There is no agreement about the minimum loading value, but in this research the minimum value will be 0.5 according to Burton and Mazerolle (2011) and Costello and Osborne (2005). If any variable has a loading value less than 0.5, it should be removed and EFA should be returned. EFA process should be retuned many times to ensure that all variables loadings are 0.5 or above. Result of the first run of EFA of the applicability level of LC techniques to reduce the causes of accidents in construction projects, both of App8 and App12 have loading values less than 5 and need to be removed and rerun the EFA. The obtained results from the second run of EFA shows that loading values of (App15, App16 and App25) were less than 0.5 and it were removed in the third run. By checking the loading values in third run results of EFA, all techniques have loading values higher than 0.5 as shown in Table (4.8).

2. Cross loading

A “cross-loading” item is an item that existed on two or more factors (components) (Hooper, 2012, Costello and Osborne, 2005). Both of Dahling et al. (2012) and Nimon et al. (2011) focused on the pattern matrix and removed items that cross-loaded. Regarding the applicability section, App 3 and App7 were cross loaded in the first run results which are removed and EFA is retuned. In the second run results of EFA, only App 17 was cross loaded and removed from the data subset. Table (4.8) shows that there is no cross loadings items in the result of last run.

3. Number of loaded items in each factor

According to Costello and Osborne (2005), a factor (component) with fewer than three items is generally weak and unstable. Any component doesn’t include at least three items should be deleted from analysis will all variables included in it and EFA should be returned. In the result of first run of applicability section, five components were extracted for the 25 techniques. Component 5 has only 2 techniques which are App9 and App18, therefore, component 5 with its variables was removed and EFA was returned. Component 4 in the second run results has only App13 and App14 that should be removed with its variables. Table (4.8) shows that each component has more than 3 techniques. Component 1 has 5 techniques, while component 2 has 4 techniques and similarly component 3 has 4 techniques.

Table (4.8): Rotated loading values of LC techniques

Items	Components		
	1	2	3
App1			0.567
App2		0.639	
App4		0.808	
App5		0.742	
App6		0.795	

Table (4.8): Rotated loading values of LC techniques

Items	Components		
	1	2	3
App10			0.809
App11			0.836
App19			0.706
App20	0.797		
App21	0.696		
App22	0.658		
App23	0.671		
App24	0.692		

In each time the analysis repeated, the proposed requirements of factor analysis for all LC techniques should be checked and verified. The EFA was stopped in the third run when all techniques have a loading value of 0.5 or more, no existence of cross loaded items and each components has at least three techniques with communality values of all more than 0.5. After three repetitions of the EFA, twelve (12) techniques of LC were eliminated and thirteen (13) are remained and organized under three components. The eliminated LC techniques are:

- App3: Developing a schedule based on worker's abilities. This technique was removed in the second run because it was cross loaded (existed in two components)
- App7: Conducting pre task hazard analysis to identify risks predicted at activity and reducing it. This technique was removed in the second run because it was cross loaded.
- App8: Conducting weekly work planning. It was removed in the second run of EFA due to its loading value which is less than 0.5.
- App9: Using camera connected with computer algorithm to warn safety officer when workers violate safety conditions. This techniques was removed in the second run of EFA because it was in a component which has only two items (less than 3)
- App12: Cleaning the workplace and removing materials and machines that are not required. . It was removed in the second run of EFA due to its loading value which is less than 0.5.
- App13: Organizing material and plant. This techniques was removed in the third run of EFA because it was in a component which has only two items (less than 3)
- App14: Separating needed tools from unneeded materials and clearing the unwanted materials. This techniques was removed in the third run of EFA because it was in a component which has only two items (less than 3)

- App15: Defining standard procedures to maintain the working environment clean and organized and improve safety culture. This technique was removed in the third run of EFA because its loading value less than 0.5.
- App16: Creating continuous improvement in safety culture to increase safety culture among the workforce. This technique was removed in the third run of EFA because its loading value less than 0.5.
- App17: Conducting visual inspection. This technique was removed in the third run because it was cross loaded.
- App18: Using Alarms and warning gadgets to warn workers from crossing the unsafe boundaries. This techniques was removed in the second run of EFA because it was in a component which has only two items (less than 3)
- App25: Conducting accident investigation and root-cause analysis program. This technique was removed in the third run of EFA because its loading value less than 0.5.

Table (4.9) summarizes the number of runs and reasons of removing the twelve LC techniques during the three runs of the EFA for the 25 LC techniques that are proposed in this study to reduce the causes of accidents in construction projects.

Table (4.9): Reasons to remove items from factor analysis for LC techniques

Run number	No. of removed item in the run	Removed items		Reasons for removal
		Item No.	Item description	
2	6	App8	Developing a schedule based on worker's abilities	Factor loading value is less than 0.5
		App12	Cleaning the workplace and removing materials and machines that are not required	
		App 3	Developing a schedule based on worker's abilities	Cross loaded factors

Table (4.9): Reasons to remove items from factor analysis for LC techniques

Run number	No. of removed item in the run	Removed items		Reasons for removal
		Item No.	Item description	
		App7	Conducting pre task hazard analysis to identify risks predicted at activity and reducing it	
		App9	Using camera connected with computer algorithm to warn safety officer when workers violate safety conditions	Component has less than 3 items
		App18	Using Alarms and warning gadgets to warn workers from crossing the unsafe boundaries	
3	6	App15	Defining standard procedures to maintain the working environment clean and organized and improve safety culture	Factor loading value is less than 0.5
		App16	Creating continuous improvement in safety culture to increase safety culture among the workforce	

Table (4.9): Reasons to remove items from factor analysis for LC techniques

Run number	No. of removed item in the run	Removed items		Reasons for removal
		Item No.	Item description	
		App25	Conducting accident investigation and root-cause analysis program	Communality less than 0.5
		App 17	Conducting visual inspection	Cross loaded factor
		App13	Organizing material and plant	Component has less than 3 items
		App14	Separating needed tools from unneeded materials and clearing the unwanted materials	

4.3.2.5 Interpretation and labelling

Interpretation is the process of examination to select variables which are attributable to a construct and allocating a name for that construct (Pett et al., 2003). Interpretation involves the researcher examining which variables are attributable to a factor, and giving that factor a name or theme (Williams et al., 2010). There are a number of guidelines that can aid in the process of naming each component. Factors and variables which load highly on only one factor. These variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor (Hooper, 2012). Based on the examination of the fundamental relationships among the variables under each component, interpretations can be proposed (Ayarkwa et al., 2012b). The components extracted in this research are labeled with names related to the variables included in it.

Table (4.10) summarizes the components resulted from the factor analysis of LC techniques used to reduce the causes of accidents in construction projects. Three components were extracted to summarize the 13 remained techniques. These three components constitute 63.121% of the total variance of the 13 factors. Names of these components reflects the applicability level of Lean Construction techniques to reduce the causes of accidents in construction projects. The three components are:

- **Component1 (Communication and planning):** consists of five techniques with eigenvalue of 5.128 and explained 22.431% of the total variance.
- **Component2 (Workers' involvement):** consists of four techniques with eigenvalue of 1.80 and explained 20.911% of the total variance
- **Component3 (Using safety equipment):** consists of four techniques with eigenvalue of 1.278 and explained 19.779% of the total variance.

Table (4.10): Factor analysis results of the applicability level of using LC techniques to reduce the causes of accidents in construction projects

	LC techniques	Factor loadings	Eigenvalue	Cronbach alpha
Component 1: Communication and planning				
App20	Conducting daily meeting to increase communication between teamwork, increase workers awareness of safety to make them identify risks and reduce it	0.797	5.128	0.803
App21	Make a plan for the critical tasks	0.696		
App24	Conducting pre task hazard analysis to identify risks predicted at activity and reducing it	0.692		
App23	Involvement of all employees in improvement process	0.671		
App22	Illustration of work methods using videos, photos, etc.	0.658		
Component 2: Workers' involvement				
App4	Worker's empowerment and involvement in task planning and scheduling	0.808	1.800	0.796
App6	Involvement of all employees in safety planning	0.795		

Table (4.10): Factor analysis results of the applicability level of using LC techniques to reduce the causes of accidents in construction projects

	LC techniques	Factor loadings	Eigenvalue	Cronbach alpha
App5	Correlating work methods with worker's skills and abilities	0.742		
App2	Developing a plan for supervision	0.639		
Component 3: Using safety equipment				
App11	Using safety signs and labels on site	0.836	1.278	0.795
App10	Using visual demarcations and boards on site	0.809		
App19	Using safe guards and Personal Protective Equipment (PPE)	0.706		
App1	Providing employees with safety equipment	0.567		

4.4 Benefits of implementing LC techniques related to safety improvement in construction projects

The introduction of the LC techniques and their application within the construction projects is reported to have a lot of benefits (Sarhan et al., 2017, Adegbembo et al., 2016, Fernandez-Solis et al., 2013, Al-Aomar, 2012). This research focused on the benefits which are related to safety improvement. Section D of the questionnaire asked the respondents to rate the importance degree of the expected benefits gained from implementing LC techniques and drive construction participants to use them in construction projects among Gaza Strip. The respondents were provided with a list of benefits consisted of twenty two which are all related to safety improvement.

4.4.1 Ranks of benefits of implementing LC techniques related to safety improvement in construction projects

Twenty two benefits were listed in section D of the questionnaire which were labeled as Ben1 to Ben25. Table (4.11) summarizes the analysis benefits results, including mean score (MS), standard deviation (SD), RII, *t*-test results, *p*- values; and ranking order. The mean scores for the 22 benefits reflect the importance degree of the benefits of implementing LC techniques related to safety improvement; the higher score, the higher importance degree in construction projects around Gaza Strip.

The results summarized in Table (4.11) shows that the overall mean for the 22 listed benefits is 2.8 which is greater than the hypothesized mean (equal to 2 for five-point scale where A_{min}=0 and A_{max}=4) (Holt, 2014). This indicated that the respondents agree that all the 22 benefits are very important which encourages them to implement LC techniques in construction projects to improve safety. Additionally, the standard deviations for all benefits are small which give an indication that there was a little variability in the data and there was a consistency in agreement among the respondents (Neuman, 2013, Student Learning Development, 2009).

The average relative importance index (RII) for the benefits of implementing LC techniques related to safety improvement in construction projects is 69.9%. As the average mean of the rating scale (From 0 to 4) is 2, the neutral RII is (2/4)*100 = 50%. Therefore, the average RII of the benefits is higher than the neutral value of RII (69.91%>50%). This indicated that most of respondents believe that these benefits are very important which drive them to adopt LC techniques to improve safety in construction projects. RII results for each benefit are presented in the graphical Figure (4.6). It is worth mentioning that ranking of the statements was based on the highest MS, RII, and the lowest SD. If some statements have similar means and RIIs, as in the case of Ben7 and Ben18; and Ben17 and Ben 22, ranking will be depended on the lowest SD.

It is shown from Table (4.11) that the 22 listed benefits have *t*-value larger than the critical *t*-value (1.98) (Neideen and Brasel, 2007). Moreover, these 22 benefits have *p*-value less than the significance level of (0.05) (Naoum, 2007). Accordingly, the 22 listed benefits can be considered significant in assessing the importance of these benefits which encourage the project practitioners to adopt LC techniques in safety improvement among Gazan Construction Projects. In addition, all of the listed benefits have positive *t*-values which indicated that these benefits have mean scores higher than the hypothesized mean value (2).

Table (4.11): Ranks of benefits of LC techniques related to safety improvement in construction projects

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank
Ben3	Improving the rate of workflow on-site	3.07	0.677	76.75	46.857	0.000	1
Ben1	Better work plan	3.05	0.650	76.25	48.496	0.000	2
Ben2	Better safety management plan	3.03	0.746	75.75	42.014	0.000	3

Table (4.11): Ranks of benefits of LC techniques related to safety improvement in construction projects

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank
Ben12	Distinguishing dangerous places from safe ones	2.97	0.985	74.25	31.199	0.000	4
Ben7	Reducing the additional costs resulting from accidents	2.93	0.861	73.25	35.265	0.000	5
Ben18	Employees can clearly know the critical work areas and durations of these	2.93	0.876	73.25	34.529	0.000	6
Ben6	Maximizing the workers productivity and work efficiency	2.92	0.715	73	42.162	0.000	7
Ben5	Submit work with high quality and less defects to minimize the rework	2.89	0.816	72.25	36.589	0.000	8
Ben10	Site organization to reduce clutter and congestion on workplace to create space and convenience for employees	2.81	0.837	70.25	34.765	0.000	9
Ben19	Improving employees' self-disciplined	2.80	0.818	70	35.467	0.000	10
Ben9	Reducing wastes on site	2.77	0.831	69.25	34.444	0.000	11
Ben20	Stakeholders satisfaction	2.76	0.899	69	31.720	0.000	12
Ben4	Delivering the projects on time or in some cases ahead of schedule	2.75	0.953	68.75	29.837	0.000	13
Ben11	Facilitating coordination in tools' handling	2.74	0.805	68.5	35.191	0.000	14
Ben16	Increasing communication and collaboration among project practitioners	2.72	0.810	68	34.720	0.000	15
Ben17	Enhancing employees' sense of belonging and their problem-solving ability	2.70	0.892	67.5	31.305	0.000	16

Table (4.11): Ranks of benefits of LC techniques related to safety improvement in construction projects

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank
Ben22	Promoting free flow of information on-site between project practitioners	2.70	0.871	67.5	32.074	0.000	17
Ben15	Creating a trust bond and enhancing transparency between the project parties	2.69	0.936	67.25	29.753	0.000	18
Ben21	Reducing stress level on management and conflicts in projects	2.68	0.820	67	33.854	0.000	19
Ben13	Reducing site hazards such as noise and dust	2.58	0.991	64.5	26.928	0.000	20
Ben8	Increasing profit	2.55	1.048	63.75	25.178	0.000	21
Ben14	Control the construction site environmentally (less weather effects)	2.48	0.935	62	27.396	0.000	22
Overall of benefits		2.80	0.85	69.91			

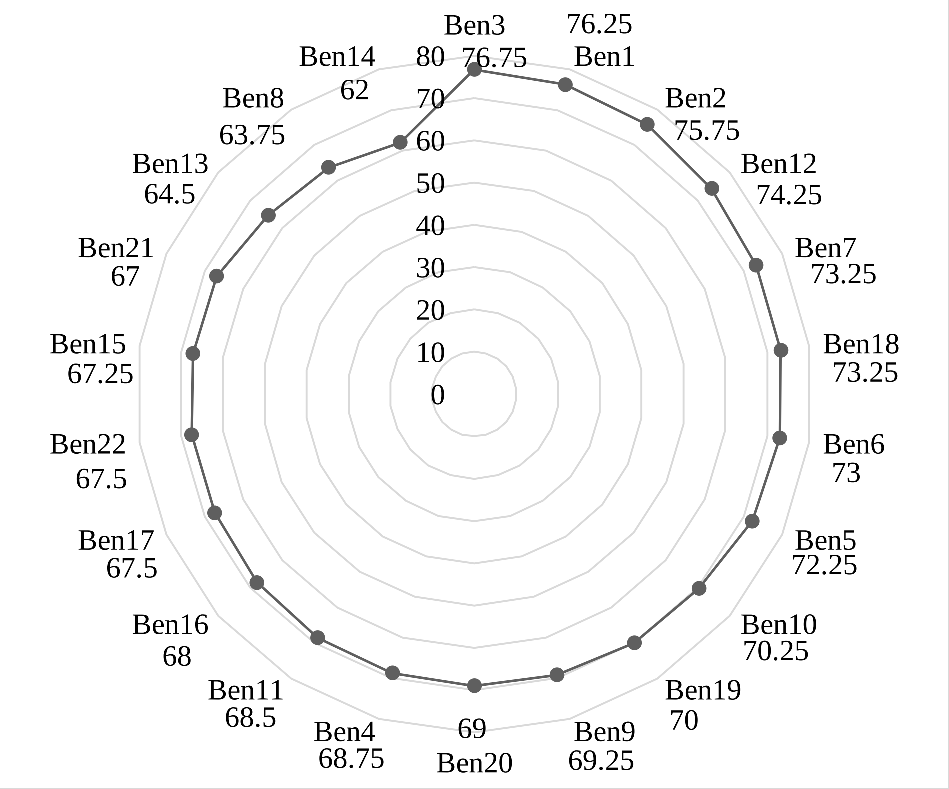


Figure (4.6): RII for benefits of LC techniques related to safety improvement in construction projects (Ben1 to Ben22)

Analysis of data enable to rank the expected benefits gained from the implementation of LC techniques which are related to safety improvement in construction projects (Table 4.12), whereby *"Improving the rate of workflow on-site"* was at the top of the list with (MS=3.07, SD= 0.677 and RII= 76.75%). Benefits of *"Better work plan"*; and *"Better safety management plan"* were ranked as second and third in the list with (MS=3.05, SD= 0.65 and RII= 76.25%) and (MS=3.03, SD= 0.746 and RII= 75.75%), respectively.

Conversely, respondents agreed that *"Increasing profit"* has a low importance comparing with the 22 benefits. It was ranked as 21th with (MS=2.55, SD= 1.048; and RII=63.75%). Meanwhile, *"Control the construction site environmentally (less weather effects)"* was ranked least with (MS=2.48, SD= 0.935; and RII=62%). The least ranks for these benefits doesn't mean that they are not important since both of their means are more than the average mean of 2.

4.4.2 Factor analysis results of the benefits of implementing LC techniques related to safety improvement in construction projects

Factor analysis reduces a large number of variables (factors) into a smaller set (Taherdoost et al., 2014, Williams et al., 2010, Field, 2009). In this research, exploratory factor analysis (EFA) is adopted. Since, EFA is a method for identifying the factor structure of a set of multiple indicators or variables without imposing a priori structure on the factors (Reio Jr and Shuck, 2015).

4.4.2.1 Evaluation of Data Suitability for EFA

The following tests should be conducted prior to the factor analysis including reliability test, sample size, correlation matrix, Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity.

Reliability tests were carried out to ensure that the questionnaire was reliable using Cronbach's Alpha. In factor analysis, the reliability should be tested in the first and last run to measure the reliability of the factors remained. Moreover, the reliability of each extracted components should be tested. Table (4.13) presents the reliability in the first and last run to the benefits of implementing LC techniques related to safety improvement in construction projects was 0.897 and 0.859, respectively. Both of them are significantly high (between 0.0 and +1); and hence the data is reliable. Table (4.18) shows that the reliability coefficient for all of the extracted factors are between 0 and 1 which and reflect the reliability of data.

Sample size in this research as mentioned before consisted of 107 respondents which is adequate as it was larger than 50 as proposed by Sapnas and Zeller (2002). Sample to variable ratio (N: p) for this section is 4.86:1 which is enough according to Williams et al. (2010) and Tabachnick and Fidell (2001) who stated that 3:1 ratios can be useful for EFA.

Correlation matrix is used to determine the relationships between variables which is known as R-matrix (Hooper, 2012, Field, 2009, Field, 2005). A correlation matrix of the 22 listed benefits of implementing LC techniques related to safety improvement in construction projects is summarized in Table (4.12). The correlation matrix shows that all variables are correlated sufficiently with at least one variable is correlated by ($r > 0.3$) and none of the variables are correlated very highly with any other variable ($r < 0.9$). Therefore, there is no need to eliminate any variable at this stage. This result provided an adequate basis for proceeding to the next step to check the value of Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett’s Test of Sphericity.

Table (4.12): Correlation matrix of the benefits of implementing LC techniques related to safety improvement in construction projects

Ben	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Ben1	1.00																					
Ben2	0.47	1.00																				
Ben3	0.38	0.39	1.00																			
Ben4	0.22	0.08	0.38	1.00																		
Ben5	0.37	0.19	0.30	0.41	1.00																	
Ben6	0.17	0.31	0.25	0.33	0.55	1.00																
Ben7	0.12	0.28	0.36	0.27	0.16	0.34	1.00															
Ben8	0.18	0.08	0.18	0.42	0.27	0.21	0.18	1.00														
Ben9	0.09	0.16	0.23	0.37	0.32	0.22	0.43	0.44	1.00													
Ben10	0.28	0.43	0.31	0.14	0.33	0.35	0.31	0.08	0.40	1.00												
Ben11	0.22	0.31	0.24	0.20	0.30	0.22	0.19	0.13	0.32	0.49	1.00											
Ben12	0.37	0.40	0.40	0.08	0.22	0.32	0.45	0.14	0.41	0.55	0.40	1.00										
Ben13	0.06	0.23	0.10	0.04	0.17	0.34	0.16	0.15	0.25	0.39	0.35	0.39	1.00									
Ben14	0.12	0.18	0.08	-.023	0.29	0.23	0.12	0.24	0.29	0.33	0.36	0.30	0.54	1.00								
Ben15	0.24	0.43	0.12	0.07	0.20	0.24	0.30	0.25	0.15	0.20	0.24	0.29	0.13	0.34	1.00							
Ben16	0.17	0.29	0.17	0.14	0.28	0.24	0.31	0.37	0.29	0.23	0.38	0.36	0.17	0.40	0.72	1.00						
Ben17	0.20	0.23	0.05	0.21	0.34	0.30	0.16	0.38	0.27	0.22	0.34	0.11	0.22	0.39	0.53	0.56	1.00					
Ben18	0.34	0.26	0.22	0.22	0.32	0.26	0.26	0.23	0.40	0.41	0.36	0.49	0.30	0.41	0.37	0.38	0.32	1.00				
Ben19	0.20	0.26	0.06	0.15	0.15	0.18	0.22	0.17	0.15	0.18	0.25	0.24	0.22	0.30	0.19	0.22	0.36	0.37	1.00			
Ben20	0.33	0.28	0.20	0.35	0.32	0.31	0.31	0.28	0.20	0.18	0.30	0.29	0.23	0.21	0.61	0.51	0.41	0.50	0.42	1.00		
Ben21	0.29	0.37	0.17	0.25	0.23	0.29	0.17	0.47	0.38	0.24	0.26	0.42	0.31	0.29	0.46	0.50	0.36	0.33	0.36	0.52	1.00	
Ben22	0.29	0.19	0.19	0.27	0.35	0.17	0.21	0.34	0.28	0.25	0.36	0.29	0.18	0.41	0.46	0.58	0.33	0.37	0.34	0.56	0.63	1.00

Kaiser-Meyer-Olkin (KMO) assess the sampling adequacy while Bartlett’s test of Sphericity checks whether the observed correlation matrix is an identity matrix (Howard, 2016). As shown in Table (4.13), the KMO of “benefits of implementing LC techniques related to safety improvement in construction projects” in the first run is (0.800>0.50), demonstrating that the sample is adequate and data is suitable of for EFA. Similarly in the first run of EFA, the Bartlett's Test of Sphericity (with Chi-Square =1049.785) and significance of data (p= 0.000< 0.05) is valid. This reflects that the correlation matrix is not an identity matrix and the relationship among the items is strong, so EFA can be performed. In the last run of EFA regarding this section, KMO value and Bartlett's Test of Sphericity are also valid which are 0.781 and 0.000, respectively.

Table (4.13): Results of KMO, Bartlett's Test of Sphericity and reliability

		First run	Last run (Third run)
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.800	0.781
Bartlett's Test of Sphericity	Approx. Chi-Square	1049.785	651.733
	df	231	105
	Sig.	0.000	0.000
Reliability	Cronbach's Alpha (Cα)	0.897	0.859

The valid results of the test of reliability test, sample size, correlation matrix, the measure of sampling adequacy and the test of Sphericity helped to determine that factor analysis was appropriate for the dataset in this research.

4.4.2.2 Factor Extraction

PCA method is used to determine the underlying structure of benefits of implementing LC techniques related to safety improvement in construction projects. After performing the first run of EFA to the benefits, the values of extracted communalities for the listed benefits were larger than 0.5 as shown in Table (4.14), except the variables of Ben11 and Ben19 which have communalities of (0.439 and 0.450), respectively. Both of them were removed in parallel with checking the loading values for all benefits and then the EFA has been retuned. The Large communality values indicates that the PCA have successfully extracted a large proportion of the variability in the original variables. During every run of EFA after eliminating the benefits with low loadings, the communalities should be checked to be more than 0.5.

Table (4.14): Communalities of the benefits of implementing LC techniques related to safety improvement in construction projects

Items	Extracted communalities	
	First run	Last run (Third run)
Ben1	0.711	0.596
Ben2	0.647	0.762
Ben3	0.603	0.583
Ben4	0.738	0.752
Ben5	0.747	0.605
Ben6	0.666	0.579
Ben7	0.680	Removed in the 2nd run
Ben8	0.612	0.545
Ben9	0.732	Removed in the 2nd run
Ben10	0.653	Removed in the 3rd run
Ben11	0.439	Removed in the 2nd run
Ben12	0.740	Removed in the 2nd run
Ben13	0.629	0.719
Ben14	0.672	0.698
Ben15	0.860	0.754
Ben16	0.785	0.728
Ben17	0.644	0.512
Ben18	0.512	Removed in the 2nd run
Ben19	0.450	Removed in the 2nd run
Ben20	0.645	0.594
Ben21	0.629	0.566
Ben22	0.630	0.594

4.4.2.3 Factor Retention

In order to decide the number of factors to be retained for the benefits of implementing LC techniques related to safety improvement in construction projects, multiple criteria were used to including Kaiser's criteria (which is based on Eigenvalues (EV) that are > 1), the Scree test; and the cumulative percent of variance.

Kaiser's eigenvalue method specifies all components greater than one are retained for interpretation (Taherdoost et al., 2014). EFA is a method for identifying the factor structure of a set of multiple indicators or variables without imposing an a priori structure on the factors (Reio Jr and Shuck, 2015). Therefore, factor analysis can be repeated several times to obtain the optimum solution. Accordingly, any factor has an eigenvalue less than one represents little variance and will not be existed in the last run. After three runs of EFA to the 22 benefits, seven benefits were removed and 15 were remained in the final run which satisfied all requirements of EFA.

Table (4.15) summarizes the initial eigenvalues of the last run of EFA to the benefits of implementing LC techniques related to safety improvement in construction projects. The first column of the table of the Total Variance Explained consists of 15 eigenvalues, every component has only one eigenvalue. Summation of eigenvalues is 15 which is as same as the number of components. The 15 eigenvalues are arranged in descending order, the largest value (component 1) on the top while the least on the bottom (component 15). The eigenvalue of (component 1) is 5.262 which means that out of a total variance of 15 variables, 5.262 can be related to component 1. Component 1 has a variance of 5.262 which accounts 35.077% of the total variance of 15 techniques. It is worth mentioning that this value should not be taken in consideration, as the direct solutions attained from factor extraction are not sufficient and need to be adjusted by rotation. In addition, from the table it is shown that four components have an eigenvalues greater than 1.0. Therefore, the 15 benefits will be underlined under 4 components.

Table (4.15): Total variance explained of the benefits of implementing LC techniques related to safety improvement in construction projects

Components	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	5.262	35.077	35.077	5.262	35.077	35.077	3.754	25.028	25.028
2	1.699	11.324	46.401	1.699	11.324	46.401	2.039	13.591	38.618
3	1.341	8.940	55.341	1.341	8.940	55.341	1.953	13.022	51.640
4	1.286	8.577	63.918	1.286	8.577	63.918	1.842	12.278	63.918
5	0.930	6.202	70.120						
6	0.764	5.095	75.214						
7	0.751	5.009	80.223						
8	0.669	4.459	84.682						
9	0.560	3.735	88.417						
10	0.396	2.639	91.056						
11	0.361	2.405	93.461						
12	0.300	1.997	95.458						
13	0.273	1.819	97.277						
14	0.220	1.464	98.741						

Table (4.15): Total variance explained of the benefits of implementing LC techniques related to safety improvement in construction projects

Components	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
15	0.189	1.259	100.000						

Scree plot which graphically presents the number of eigenvalues in descending order against the number of factors. This graph is then investigated to determine where there is a noticeable change in its shape which is known as ‘the elbow’ or point of inflection (Hooper, 2012, Ruscio and Roche, 2012, Suhr, 2006). As shown in Figure (4.7) which resulted from the last run of EFA regarding the benefits of implementing LC techniques related to safety improvement in construction projects, there are 15 components at the horizontal axis. However, only 4 components have an eigenvalues greater than 1, which indicated that the LC techniques will be underlined under four groups. Moreover, the point above this debris indicates the number of factors to be retained is 4.

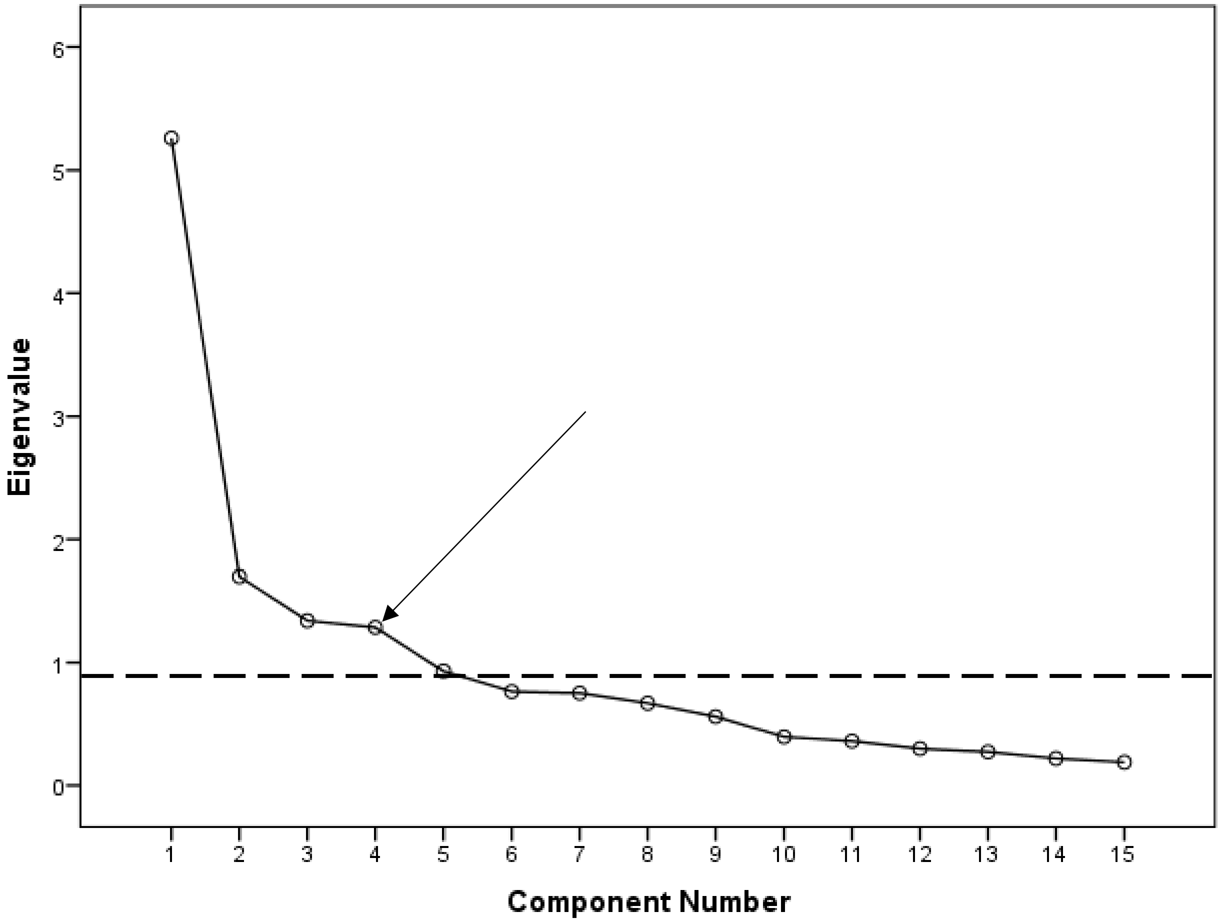


Figure (4.7): Scree plot of benefits of implementing LC techniques related to safety improvement in construction projects

Cumulative percent of variance is the amount of the total variance in the original set of variables that is explained by the factors. The greater the explained variance, the better the solution (Taherdoost et al., 2014, Suhr, 2006, De Vaus, 2002). Table (4.15) shows the total variance explained for the 15 benefits remained in the last run. This table shows that 4 components with eigenvalue larger than one which mean that four components can be extracted from the 15 benefits. The retained four components explained 63.918% of the total variance. This means that a considerable amount of the 63.918% shared by the 15 variables (benefits) could be accounted for by these four factors. Accordingly, the cumulative variance could be acceptable since it is greater than the threshold value of 50% (Hair, 1995).

4.4.2.4 Factor rotation

The Orthogonal-Varimax rotation was conducted to retain the factor and to interpret the components into simple structure solution.

- **Rotated factor loading values**

The factor loadings give an idea about how much the variable has contributed to the factor; the larger the factor loading the more the variable has contributed to that factor. Factor loadings represent the strength of the correlation between the variable and the factor (Yong and Pearce, 2013). In order to obtain the optimum solution from EFA, many considerations should be taken including the minimum value of loading value, cross loading and minimum number of variables in each component.

Minimum loading value of the benefits should be more than 0.5 (Burton and Mazerolle, 2011, Costello and Osborne, 2005). If any variable has a loading value less than 0.5, it should be removed and EFA should be returned. EFA process should be retuned many times to ensure that all variables loadings are 0.5 or above. Result of the first run of EFA of "Benefits of implementing LC techniques related to safety improvement in construction projects" shows that both of Ben12 and Ben18 have a loading values less than 5 and need to be removed and rerun the EFA. By checking the loading values in second and third run results of EFA, all benefits have loading values higher than 0.5 as shown in Table (4.16).

Cross loading item is an item that existed on two or more factors (components) (Hooper, 2012, Costello and Osborne, 2005). Both of Dahling et al. (2012) and Nimon et al. (2011) focused on the pattern matrix and removed items that cross-loaded. Regarding the benefits of implementing LC techniques related to safety improvement in construction projects, only Ben10 was cross loaded in the results of second run which was removed and EFA is retuned. Table (4.16) shows that there is no cross loadings items in the result of last run.

Number of loaded items in each factor should be three or more (Costello and Osborne, 2005). Any component doesn't include at least three variables should be deleted from analysis will all variables included in it and EFA should be returned. In the result of first run of benefits section, five components were extracted for the 22 benefits. Component 6 has only 2 benefits which are

Ben7 and Ben9. Therefore, component 5 with its variables was removed and EFA was returned. In the second run of the EFA to the benefits, only four components were extracted. All of them were have at least 3 variables. Table (4.16) shows that each component has more than 3 benefits. Component1 has 6 benefits, while component2, 3 and 4 have 3 benefits in each of them.

Table (4.16): Rotated loading values of the benefits of implementing LC techniques related to safety improvement in construction projects

Items	Components			
	1	2	3	4
Ben1			0.720	
Ben2			0.793	
Ben3			0.670	
Ben4		0.835		
Ben5		0.633		
Ben6				0.506
Ben8		0.560		
Ben13				0.839
Bent14				0.750
Ben15	0.818			
Ben16	0.835			
Ben17	0.628			
Ben20	0.693			
Ben21	0.682			
Ben22	0.723			

In each time the analysis repeated, the proposed requirements of factor analysis for all benefits should be checked and verified. The EFA was stopped in the third run when all benefits have a loading value of 0.5 or more, no existence of cross loaded items and each components has at least three benefits with communality values of all more than 0.5. After three repetitions of the EFA, seven (7) benefits of implementing LC techniques were eliminated and fifteen (15) are remained and organized under four components. The eliminated benefits are:

- Ben7: Reducing the additional costs resulting from accidents. This benefit was removed in the second run because it was in a component which has only two items (less than 3)
- Ben9: Reducing wastes on site. This benefit was removed in the second run because it was in a component which has only two items (less than 3).

- Ben10: Site organization to reduce clutter and congestion on workplace to create space and convenience for employees. This benefit was removed in the third run because it was cross loaded (existed in two components).
- Ben11: Facilitating coordination in tools' handling. This benefit was removed in the second run because its communality value was less than 0.5.
- Ben12: Distinguishing dangerous places from safe ones. This benefit was removed in the second run of EFA because it has a loading value less than 0.5.
- Ben18: Employees can clearly know the critical work areas and durations of these. This benefit was removed in the second run of EFA because it has a loading value less than 0.5.
- Ben19: Improving employees' self- disciplined. This benefit was removed in the second run because its communality value was less than 0.5.

Table (4.17) summarizes the number of runs and reasons of removing the seven benefits during the three runs of the EFA for the 22 benefits that are proposed in this study.

Table (4.17): Reasons to remove items from factor analysis for the benefits of implementing LC techniques related to safety improvement in construction projects

Run number	No. of removed item in the run	Removed items		Reasons for removal
		Item No.	Item description	
2	6	Ben11	Facilitating coordination in tools' handling	Communality value is less than 0.5
		Ben19	Improving employees' self- disciplined	
		Ben12	Distinguishing dangerous places from safe ones	Factor loading value is less than 0.5
		Ben18	Employees can clearly know the critical work areas and durations of these	
		Ben7	Reducing the additional costs resulting from accidents	Component has less than 3 items
		Ben9	Reducing wastes on site	

Table (4.17): Reasons to remove items from factor analysis for the benefits of implementing LC techniques related to safety improvement in construction projects

Run number	No. of removed item in the run	Removed items		Reasons for removal
		Item No.	Item description	
3	1	Ben10	Site organization to reduce clutter and congestion on workplace to create space and convenience for employees	Cross loaded factor

4.4.2.5 Interpretation and labelling

The components extracted in this research are labeled with names related to the variables included in it. Table (4.18) summarizes the components resulted from the factor analysis of the benefits of implementing LC techniques related to safety improvement in construction projects. Four components were extracted to summarize the 15 remained benefits. These four components constitute 63.918% of the total variance of the 15 benefits. There is a main guideline that can aid in the process of naming each component. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor (Hooper, 2012). Names of these components reflects the benefits of implementing LC techniques related to safety improvement in construction projects. The four components are:

- **Component1 (Communication and trust):** consists of six benefits with eigenvalue of 5.262 and explained 25.028% of the total variance.
- **Component2** (**Time and quality):** consists of three benefits with eigenvalue of 1.699 and explained 13.591% of the total variance
- **Component3 (Safety management plan):** consists of three benefits with eigenvalue of 1.341 and explained 13.022% of the total variance.
- **Component4 (Reducing site hazards):** consists of three benefits with eigenvalue of 1.286 and explained 12.278% of the total variance.

Table (4.18): Factor analysis results of the benefits of implementing LC techniques related to safety improvement in construction projects

	Benefits of implementing LC techniques	Factor loadings	Eigenvalue	Cronbach alpha
Component 1: Communication and trust				
Ben16	Increasing communication and collaboration among project practitioners	0.835	5.262	0.864
Ben15	Creating a trust bond and enhancing transparency between the project parties	0.818		
Ben22	Promoting free flow of information on-site between project practitioners	0.723		
Ben20	Stakeholders satisfaction	0.693		
Ben21	Reducing stress level on management and conflicts in projects	0.682		
Ben17	Enhancing employees' sense of belonging and their problem-solving ability	0.628		
Component 2: Time and quality				
Ben4	Delivering the projects on time or in some cases ahead of schedule	0.835	1.699	0.630
Ben5	Submit work with high quality and less defects to minimize the rework	0.633		
Ben8	Increasing profit	0.560		
Component 3: Safety management plan				
Ben2	Better safety management plan	0.793	1. 341	0.675
Ben1	Better work plan	0.720		
Ben3	Improving the rate of workflow on-site	0.670		
Component 4: Reducing site hazards				
Be13	Reducing site hazards such as noise and dust	0.839	1.286	0.646
Ben14	Control the construction site environmentally (less weather effects)	0.750		
Ben6	Maximizing the workers productivity and work efficiency	0.506		

4.5 Barriers to the application of LC techniques to improve safety in construction projects

To integrate Lean philosophy in a construction organization, it is recommended to understand and anticipate the barriers that might hinder the proper implementation of LC techniques in construction projects (Cano et al., 2015). Several studies have been carried out in different countries worldwide to identify the barriers to the successful implementation of LC techniques in construction projects (Attri et al., 2017, Bashir et al., 2015, Cano et al., 2015, Singh et al., 2014, Wandahl, 2014, Fernandez-Solis et al., 2013). This section focused on identifying the barriers that prevent the construction projects among Gaza Strip to apply LC techniques in safety improvement. Section E of the questionnaire asked the respondents according to their perspective to rate the effect degree of the barriers that face the application of LC techniques in safety improvement in the Gazan Construction Projects. The respondents were provided with a list of barriers consisted of thirty nine distributed under six groups (Management, Financial, Educational, Governmental, Technical and Human attitudinal). Data collected in the barriers section will be analyzed using the effect index and factor analysis. Effect index will be used to rank the barriers according to its value, while factor analysis to reduce the barriers and underline them in components.

4.5.1 Ranks of the barriers to the application of LC techniques to improve safety in construction projects

Thirty nine barriers were listed in section E of the questionnaire which were labeled as Bar1 to Bar39. They were grouped into six groups including: management barriers, financial barriers, educational barriers, governmental barriers, technical barriers; and human attitudinal barriers. Table (4.19) summarizes the results of barriers analysis, including the effect index (EI), effect level and ranking order. Hassanain et al. (2017) classified the effect level according to the effect index as (No effect $EI < 12.5$; Slight effect $12.5 \leq EI < 37.5$; Moderate effect $37.5 \leq EI < 62.5$; Strong effect $62.5 \leq EI < 87.5$; and Extreme effect $87.5 \leq EI$). The analysis results showed that all of the barriers have effect indices between 63.048 and 80.607 which are classified as strong effect level (SE) as presented in Table (4.19). As shown in Figure (4.8), the highest average of effect index is related to educational barriers group. On the other hand, the lowest average of effect index is related to technical barriers group. The results indicated that all the barriers are assessed to have strong effect on the application of LC techniques in safety improvement among Gazan Construction Projects. Effect index results (EI) for each item in this section are presented in the graphical Figure (4.9).

Table (4.19): Ranks of Barriers to the application of LC techniques regarding safety improvement

#	Item	Effect Index (%)	Effect Level	Rank within group	Overall Rank
Management Barriers group					
Bar1	Lack of management support and commitment to the application of LC techniques in safety improvement	77.103	SE	1	5
Bar7	Poor communication among project parties (managers, administrators, foremen, etc.)	72.664	SE	2	18
Bar8	Poor coordination among project parties (managers, administrators, foremen, etc.)	72.196	SE	3	19
Bar11	Logistics' problems (Ex. poor management of materials, equipment and tools and short supply of material)	72.196	SE	3	19
Bar4	Lengthy approval procedure from top management to take any step	71.028	SE	5	24
Bar9	Absence of long term forecast of safety improvement	70.561	SE	6	25
Bar3	Centralization of decision making	69.159	SE	7	29
Bar5	Lack of time in construction firms for innovation and application of any innovative strategy	69.159	SE	7	29
Bar6	Lack of transparency	67.757	SE	9	33
Bar2	Poor project definition which explain the vision, mission and main objectives of the project and its stakeholders	67.056	SE	10	34
Bar10	Inadequate planning to apply of LC techniques in safety improvement	67.056	SE	10	34
Financial Barriers group					
Bar16	Lack of incentives and motivation	77.804	SE	1	4

Table (4.19): Ranks of Barriers to the application of LC techniques regarding safety improvement

#	Item	Effect Index (%)	Effect Level	Rank within group	Overall Rank
Bar15	Poor salaries do not encourage employees to apply any innovative strategies	76.869	SE	2	6
Bar12	Inadequate funding of the project to provide the required resources and training	76.168	SE	3	8
Bar13	Low tender prices	74.299	SE	4	15
Bar14	High cost of LC implementation including cost of training, consultancy fees and cost to conduct workshops	71.262	SE	5	23
Educational Barriers group					
Bar17	Lack of LC concept understanding	80.607	SE	1	1
Bar18	Lack of knowledge to apply LC techniques in safety improvement	78.972	SE	2	3
Bar19	Lack of technical skills to apply LC techniques in safety improvement	76.869	SE	3	6
Bar20	Lack of education and training needed to apply LC techniques in safety improvement	75.935	SE	4	9
Bar21	Lack of awareness program to increase knowledge about LC	75.935	SE	4	9
Bar22	Lack of information and experiences sharing among construction firms	70.561	SE	6	25
Governmental Barriers group					
Bar23	Lack of government support towards the construction projects to apply any innovative strategy	79.439	SE	1	2
Bar26	Unsteady price of commodities (Ex. PPE, safety signs, etc.)	74.766	SE	2	14
Bar25	Government bureaucracy and instability	73.832	SE	3	16
Bar24	Inconsistency in the government policies	73.364	SE	4	17

Table (4.19): Ranks of Barriers to the application of LC techniques regarding safety improvement

#	Item	Effect Index (%)	Effect Level	Rank within group	Overall Rank
Technical Barriers group					
Bar27	Lack of agreed implementation methodology to implement LC techniques	75.234	SE	1	13
Bar30	Incomplete designs which leads to increases the probability of re-work	70.561	SE	2	25
Bar31	Poor performance measurement strategies	70.561	SE	3	25
Bar28	Complexity of LC implementation since LC does not just involve applying LC techniques on site, but also involves developing a culture among the staff for a continuous improvement	68.458	SE	4	32
Bar29	Long implementation period needed for LC techniques application in safety improvement	66.589	SE	5	36
Bar32	Fragmented nature of the construction industry	63.084	SE	6	39
Human Attitudinal Barriers group					
Bar35	Poor leadership	75.701	SE	1	11
Bar33	Selfishness among professionals to provide their experience in using LC techniques to improve safety	75.467	SE	2	12
Bar38	Lack of self-criticism which limited the capacity to learn from errors	71.963	SE	3	21
Bar37	Resistance to change by employees	71.495	SE	4	22
Bar34	Lack of teamwork	68.692	SE	5	31
Bar39	Fear of unfamiliar practices due to the misconceptions and misunderstandings of LC	66.589	SE	6	36
Bar36	Cultural issues	65.187	SE	7	38

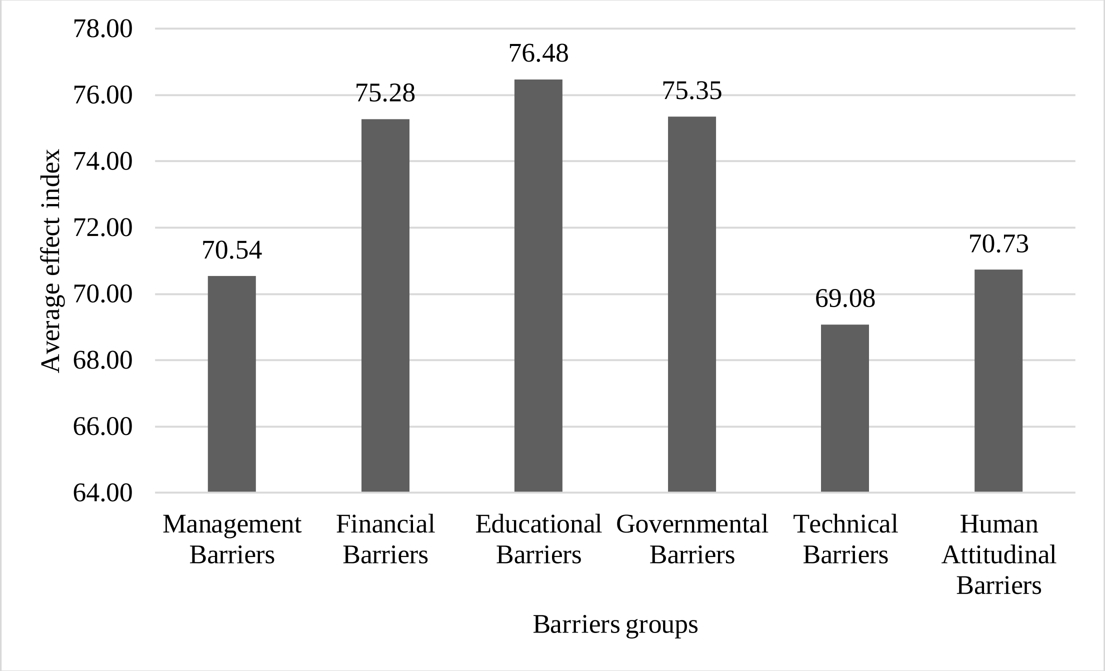


Figure (4.8): Average effect index of barriers to the application of LC techniques in safety improvement

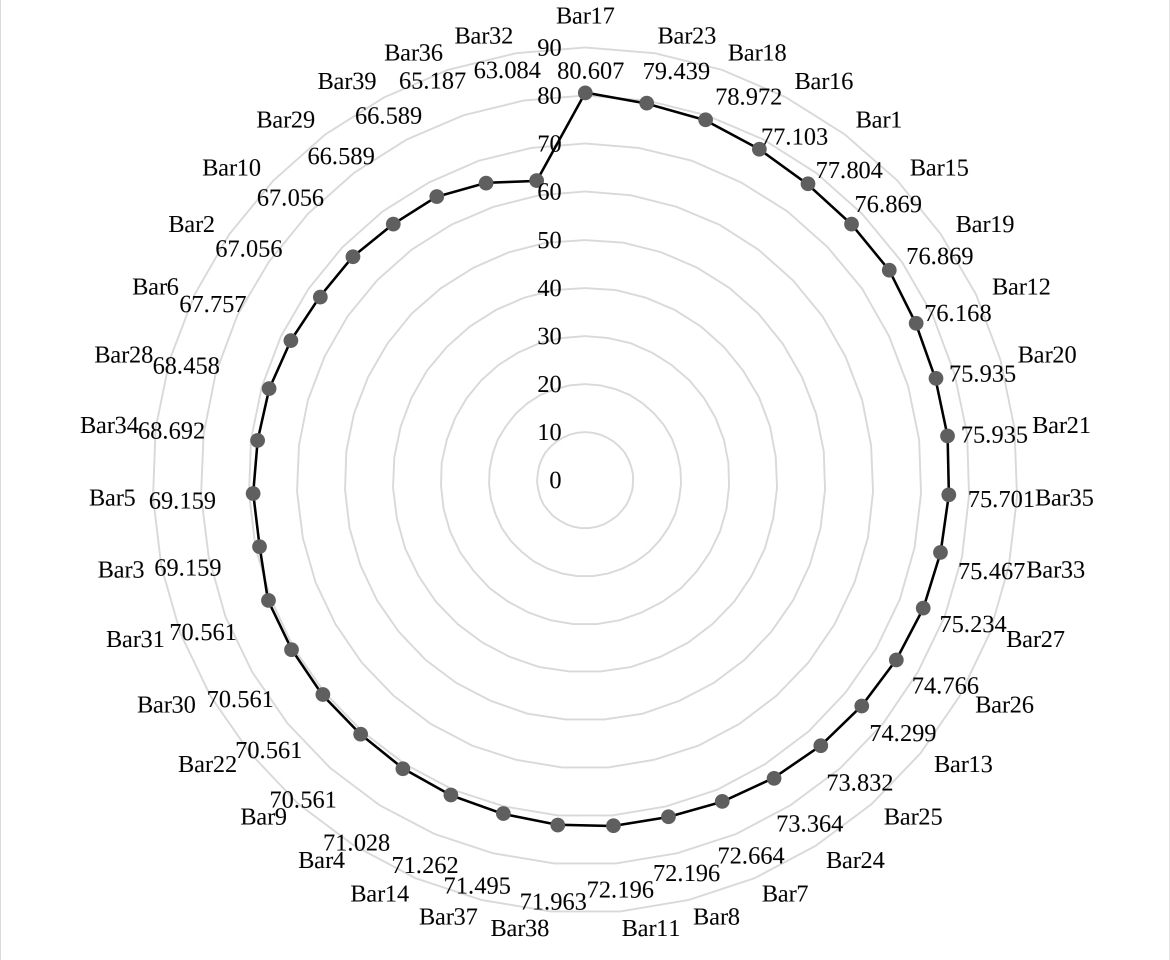


Figure (4.9): EI for the barriers to the application of LC techniques to improve safety in construction projects (Bar1 to Bar39)

The top three barriers, namely *"Lack of LC concept understanding"*, *"Lack of government support towards the construction projects to apply any innovative strategy"*; and *"Lack of knowledge to apply LC techniques in safety improvement"* are organized by the respondents to have a strong effect on the application of LC techniques to improve safety in construction projects. Table (4.19) shows that *"Lack of LC concept understanding"* which is related to the educational barriers is ranked as the highest barrier within education barriers group and among the overall barriers with (EI=80.607). It is followed by the barrier of *"Lack of government support towards the construction projects to apply any innovative strategy"* with an effect index of 79.439 and it is ranked as the first rank among the governmental barriers group. The third rank was positioned by the barrier of *"Lack of knowledge to apply LC techniques in safety improvement"* with (EI=78.972) and it is ranked as the second rank among the educational barriers.

At the same time, the barrier of *"Cultural issues"* is ranked in the 38th position among the overall barriers and it had the 7th position within the human attitudinal barriers with (EI=65.187). Finally, *"Fragmented nature of the construction industry"* is the least rank among the overall barriers and within the technical barriers group with (EI=63.084). Although these barriers have the least ranks, they have strong effects on the application of LC techniques to improve safety in construction projects.

4.5.2 Factor analysis results of the barriers to the application of LC techniques to improve safety in construction projects

Factor analysis reduces a large number of variables (factors) into a smaller set (Taherdoost et al., 2014, Williams et al., 2010, Field, 2009). In this research, exploratory factor analysis (EFA) is adopted. Since, EFA is a method for identifying the factor structure of a set of multiple indicators or variables without imposing an a priori structure on the factors (Reio Jr and Shuck, 2015).

4.5.2.1 Evaluation of Data Suitability for EFA

The following tests should be conducted prior to the factor analysis including reliability test, sample size, correlation matrix, Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity.

Reliability tests were carried out to ensure that the questionnaire was reliable using Cronbach's Alpha. The normal range of Cronbach's coefficient alpha (Cα) value is between 0.0 and +1 (Field, 2009). In factor analysis, the reliability should be tested in the first and last run to measure the reliability of the factors remained. Moreover, the reliability of each extracted components should be tested. Table (4.21) presents the reliability in the first and last run to the barriers to the application of LC techniques to improve safety in construction projects was 0.921 and 0.884, respectively. Both of them are significantly high (between 0.0 and +1); and hence the data is reliable. In addition, reliability of the extracted factors of the barriers are between 0 and 1 as shown in Table (4.26)

Sample size in this research as mentioned before constituted of 107 respondents which is adequate as it was larger than 50 as proposed by Sapnas and Zeller (2002). Sample to variable ratio (N: p) for this section is 2.74:1 which is not enough according to Williams et al. (2010) and Tabachnick and Fidell (2001) who stated that 3:1 ratios can be useful for EFA.

Correlation matrix is used to determine the relationships between variables which is known as R-matrix (Hooper, 2012, Field, 2009, Field, 2005). A correlation matrix of the 39 listed barriers to the application of LC techniques to improve safety in construction projects is summarized in Table (4.20). The correlation matrix shows that all variables are correlated sufficiently with at least one variable is correlated by ($r > 0.3$) and none of the variables are correlated very highly with any other variable ($r < 0.9$). Therefore, there is no need to eliminate any variable at this stage. This result provided an adequate basis for proceeding to the next step to check the value of Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett’s Test of Sphericity.

Table (4.20): Correlation matrix of the barriers to the application of LC techniques to improve safety in construction projects

	Bar1	Bar2	Bar3	Bar4	Bar5	Bar6	Bar7	Bar8	Bar9	Bar10	Bar11	Bar12	Bar13	Bar14	Bar15	Bar16	Bar17	Bar18	Bar19	Bar20	Bar21	Bar22	Bar23	Bar24	Bar25	Bar26	Bar27	Bar28	Bar29	Bar30	Bar31	Bar32	Bar33	Bar34	Bar35	Bar36	Bar37	Bar38	Bar39
Bar1	1.00																																						
Bar2	0.45	1.00																																					
Bar3	0.25	0.38	1.00																																				
Bar4	0.29	0.38	0.46	1.00																																			
Bar5	0.24	0.32	0.42	0.51	1.00																																		
Bar6	0.21	0.25	0.42	0.29	0.32	1.00																																	
Bar7	0.23	0.07	0.28	0.26	0.20	0.45	1.00																																
Bar8	0.26	0.13	0.32	0.27	0.22	0.48	0.82	1.00																															
Bar9	0.12	0.21	0.18	0.31	0.26	0.32	0.43	0.43	1.00																														
Bar10	0.27	0.33	0.35	0.35	0.30	0.29	0.24	0.28	0.51	1.00																													
Bar11	0.33	0.10	0.32	0.25	0.14	0.24	0.29	0.36	0.27	0.30	1.00																												
Bar12	0.33	0.16	0.24	0.23	0.30	0.19	0.18	0.26	0.21	0.20	0.43	1.00																											
Bar13	0.08	0.18	0.30	0.23	0.19	0.19	0.18	0.22	0.21	0.23	0.44	0.64	1.00																										
Bar14	0.16	0.25	0.21	0.21	0.36	0.13	0.07	0.19	0.25	0.29	0.16	0.58	0.49	1.00																									
Bar15	0.11	0.24	0.22	0.14	0.22	0.17	0.05	0.06	0.09	0.08	0.09	0.16	0.22	0.25	1.00																								
Bar16	0.14	0.30	0.27	0.19	0.25	0.22	0.24	0.23	0.21	0.20	0.17	0.19	0.27	0.21	0.67	1.00																							
Bar17	0.08	0.16	0.29	0.15	0.24	0.11	0.19	0.22	0.12	0.30	0.22	0.19	0.15	0.11	0.18	0.26	1.00																						
Bar18	0.07	0.14	0.22	0.17	0.35	0.09	0.10	0.16	0.22	0.26	0.21	0.17	0.14	0.16	0.13	0.14	0.79	1.00																					
Bar19	0.12	0.23	0.32	0.16	0.25	0.23	0.07	0.15	0.06	0.26	0.17	0.17	0.15	0.12	0.18	0.17	0.65	0.70	1.00																				
Bar20	0.11	0.09	0.20	0.08	0.18	0.10	0.20	0.24	0.11	0.23	0.14	0.19	0.14	0.25	0.25	0.32	0.69	0.63	0.64	1.00																			
Bar21	0.09	0.14	0.17	0.25	0.25	0.10	0.19	0.28	0.15	0.31	0.20	0.25	0.28	0.27	0.17	0.23	0.72	0.68	0.68	0.79	1.00																		
Bar22	0.27	0.34	0.28	0.18	0.30	0.22	0.26	0.34	0.17	0.42	0.18	0.25	0.17	0.21	0.16	0.20	0.64	0.57	0.61	0.57	0.59	1.00																	
Bar23	0.12	0.16	0.18	0.17	0.15	-0.12	-0.05	-0.04	0.05	0.20	0.12	0.19	0.20	0.34	0.37	0.39	0.28	0.16	0.14	0.23	0.29	0.31	1.00																
Bar24	0.19	0.16	0.21	0.19	0.27	0.08	0.08	0.16	0.01	0.14	0.23	0.33	0.33	0.34	0.34	0.46	0.13	0.05	0.12	0.11	0.20	0.20	0.60	1.00															
Bar25	0.09	0.23	0.26	0.29	0.14	0.23	0.18	0.27	0.11	0.14	0.20	0.35	0.50	0.39	0.33	0.38	0.07	-.014-	0.00	0.16	0.15	0.11	0.40	0.59	1.00														
Bar26	0.13	0.37	0.22	0.19	0.10	0.21	0.10	0.19	0.18	0.22	0.11	0.18	0.29	0.26	0.30	0.32	0.03	0.02	0.03	0.02	0.00	0.24	0.42	0.39	0.67	1.00													
Bar27	0.08	0.26	0.23	0.22	0.43	0.21	0.18	0.24	0.33	0.29	0.11	0.27	0.21	0.42	0.24	0.28	0.25	0.43	0.19	0.23	0.29	0.34	0.33	0.23	0.31	0.33	1.00												
Bar28	0.12	0.38	0.23	0.34	0.39	0.28	0.12	0.21	0.34	0.30	0.23	0.30	0.28	0.41	0.15	0.16	0.26	0.24	0.17	0.17	0.28	0.36	0.37	0.31	0.40	0.45	0.46	1.00											
Bar29	-0.09	0.11	0.27	0.26	0.39	0.14	-0.04	0.05	0.29	0.24	0.20	0.16	0.12	0.30	0.23	0.17	0.13	0.38	0.23	0.15	0.11	0.22	0.22	0.18	0.15	0.28	0.52	0.54	1.00										
Bar30	0.18	0.28	0.24	0.21	0.24	0.14	0.18	0.27	0.21	0.30	0.10	0.31	0.12	0.30	0.27	0.17	0.22	0.18	0.14	0.12	0.10	0.37	0.18	0.17	0.25	0.36	0.37	0.43	0.30	1.00									
Bar31	0.27	0.43	0.29	0.18	0.19	0.36	0.18	0.21	0.12	0.23	0.16	0.40	0.27	0.37	0.32	0.22	0.10	-0.01	-0.02	-0.06	-0.05	0.27	0.20	0.23	0.36	0.45	0.23	0.39	0.16	0.61	1.00								
Bar32	-0.02	0.17	0.17	0.26	0.39	0.17	0.18	0.25	0.26	0.19	0.06	0.15	0.07	0.26	0.26	0.30	0.04	0.10	0.02	0.00	-0.01	0.12	-0.01	0.13	0.26	0.18	0.32	0.31	0.37	0.48	0.34	1.00							
Bar33	0.27	0.18	-0.03	0.22	0.31	0.07	0.00	0.16	0.11	0.31	0.19	0.23	0.09	0.30	0.21	0.10	-0.08	-0.01	0.00	-0.08	-0.06	0.13	0.21	0.29	0.25	0.23	0.37	0.23	0.18	0.24	0.22	0.15	1.00						
Bar34	0.16	0.19	0.20	0.28	0.17	0.27	0.19	0.23	0.23	0.34	0.18	0.19	0.14	0.15	0.29	0.30	0.05	0.00	0.02	0.10	0.05	0.22	0.14	0.21	0.30	0.36	0.29	0.26	0.25	0.34	0.36	0.26	0.39	1.00					
Bar35	0.16	0.15	0.26	0.17	0.22	0.29	0.37	0.38	0.21	0.24	0.22	0.35	0.37	0.27	0.28	0.43	0.19	0.14	0.23	0.32	0.34	0.20	0.03	0.30	0.32	0.18	0.24	0.13	0.13	0.18	0.20	0.25	0.16	0.44	1.00				
Bar36	0.10	0.23	0.16	0.45	0.32	0.13	0.05	0.14	0.16	0.28	0.20	0.21	0.00	0.21	0.16	0.24	0.11	0.13	0.22	0.24	0.24	0.18	0.12	0.27	0.22	0.09	0.33	0.20	0.29	0.18	0.08	0.26	0.34	0.35	0.32	1.00			
Bar37	0.17	0.23	0.14	0.20	0.18	0.22	0.05	0.15	0.06	0.28	0.17	0.21	0.15	0.32	0.28	0.24	0.14	0.13	0.25	0.31	0.29	0.23	0.20	0.25	0.27	0.19	0.37	0.17	0.14	0.14	0.17	0.05	0.37	0.34	0.37	0.58	1.00		
Bar38	0.20	0.27	0.14	0.21	0.22	0.08	0.05	0.07	0.11	0.16	0.13	0.15	0.11	0.25	0.18	0.09	0.14	0.14	0.16	0.15	0.13	0.18	0.26	0.22	0.27	0.32	0.31	0.32	0.23	0.17	0.20	0.14	0.21	0.34	0.14	0.43	0.56	1.00	
Bar39	-0.09	0.17	0.08	0.24	0.36	0.14	0.11	0.19	0.21	0.33	0.00	0.07	-0.01	0.20	0.17	0.29	0.20	0.25	0.29	0.24	0.26	0.29	0.13	0.22	0.21	0.24	0.39	0.22	0.37	0.26	0.07	0.43	0.35	0.45	0.35	0.45	0.46	0.39	1.00

Kaiser-Meyer-Olkin (KMO) assess the sampling adequacy while Bartlett's test of Sphericity checks whether the observed correlation matrix is an identity matrix (Howard, 2016). As shown in Table (4.21), the KMO of "barriers to the application of LC techniques to improve safety in construction projects" in the first run is (0.737>0.50), demonstrating that the sample is adequate and data is suitable of for EFA. Similarly in the first run of EFA, the Bartlett's Test of Sphericity (with Chi-Square =2480.058) and significance of data (p= 0.000< 0.05) is valid. This reflects that the correlation matrix is not an identity matrix and the relationship among the items is strong, so EFA can be performed. In the last run of EFA regarding this section, KMO value and Bartlett's Test of Sphericity are also valid which are 0.756 and 0.000, respectively.

Table (4.21): Results of KMO, Bartlett's Test of Sphericity and reliability

		First run	Last run (Third run)
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.737	0.756
Bartlett's Test of Sphericity	Approx. Chi-Square	2480.058	1460.096
	Df	741	300
	Sig.	0.000	0.000
Reliability	Cronbach's Coefficient Alpha(Cα)	0.921	0.884

The valid results of the test of reliability test, sample size, correlation matrix, the measure of sampling adequacy and the test of Sphericity helped to determine that factor analysis was appropriate for the dataset in this research.

4.5.2.2 Factor Extraction

PCA method is used to determine the underlying structure of barriers to the application of LC techniques to improve safety in construction projects. After performing the first run of EFA to the barriers, the values of extracted communalities for the listed barriers were larger than 0.5 as shown in Table (4.22), except the Bar11 which has a communality value of 0.496, so it will be removed. Communality values should be checked in parallel with checking the loading values for all barriers and removing all the barriers that don't match the requirements of both communality and loading, then the EFA should be returned. The Large communality values indicates that the PCA have successfully extracted a large proportion of the variability in the original variables.

During every run of EFA after eliminating the barriers with low loadings, the communalities should be checked to be more than 0.5.

Table (4.22): Communalities of the barriers to the application of LC techniques to improve safety in construction projects

Items	Extracted communalities	
	First run	Last run (Sixth run)
Bar1	0.743	Removed in the 2nd run
Bar2	0.651	0.625
Bar3	0.665	0.637
Bar4	0.649	0.549
Bar5	0.682	Removed in the 4th run
Bar6	0.602	0.571
Bar7	0.795	0.851
Bar8	0.786	0.865
Bar9	0.609	Removed in the 5th run
Bar10	0.520	Removed in the 2nd run
Bar11	0.496	Removed in the 2nd run
Bar12	0.811	0.772
Bar13	0.769	0.771
Bar14	0.646	0.684
Bar15	0.686	Removed in the 2nd run
Bar16	0.809	Removed in the 2nd run
Bar17	0.798	0.800
Bar18	0.811	0.837
Bar19	0.752	0.748
Bar20	0.784	0.762
Bar21	0.820	0.817
Bar22	0.753	0.658
Bar23	0.799	0.720
Bar24	0.674	0.623
Bar25	0.757	0.734
Bar26	0.777	0.723
Bar27	0.579	0.646
Bar28	0.695	Removed in the 2nd run
Bar29	0.693	0.743
Bar30	0.721	Removed in the 2nd run
Bar31	0.806	Removed in the 2nd run
Bar32	0.688	0.585
Bar33	0.701	Removed in the 2nd run

Table (4.22): Communalities of the barriers to the application of LC techniques to improve safety in construction projects

Items	Extracted communalities	
	First run	Last run (Sixth run)
Bar34	0.552	Removed in the 3rd run
Bar35	0.667	Removed in the 2nd run
Bar36	0.681	0.731
Bar37	0.763	0.781
Bar38	0.622	0.592
Bar39	0.706	Removed in the 6th run

4.5.2.3 Factor Retention

In order to decide the number of factors to be retained for the benefits of implementing LC techniques related to safety improvement in construction projects, multiple criteria were used to including Kaiser's criteria (which is based on Eigenvalues (EV) that are > 1), the Scree test; and the cumulative percent of variance.

Kaiser's eigenvalue method specifies all components greater than one are retained for interpretation (Taherdoost et al., 2014). EFA is a method for identifying the factor structure of a set of multiple indicators or variables without imposing an a priori structure on the factors (Reio Jr and Shuck, 2015). Therefore, factor analysis can be repeated several times to obtain the optimum solution. Accordingly, any factor has an eigenvalue less than one represents little variance and will not be existed in the last run. After six runs of EFA to the 39 barriers, 14 barriers were removed and 25 were remained in the final run which satisfied all requirements of EFA.

Table (4.23) summarizes the initial eigenvalues of the last run of EFA to the barriers to the application of LC techniques to improve safety in construction projects. The first column of the table of the Total Variance Explained consists of 25 eigenvalues, every component has only one eigenvalue. Summation of eigenvalues is 25 which is as same as the number of components. The 25 eigenvalues are arranged in descending order, the largest value (component 1) on the top while the least on the bottom (component 25). The eigenvalue of (component 1) is 6.830 which means that out of a total variance of 25 variables, 6.830 can be related to component 1. Component 1 has a variance of 6.830 which accounts 27.320% of the total variance of 25 techniques. It is worth mentioning that this value should not be taken in consideration, as the direct solutions attained from factor extraction are not sufficient and need to be adjusted by rotation. In addition, from the

Table (4.23) it is shown that only seven components have an eigenvalues greater than 1.0. Therefore, the 25 barriers will be underlined under 7 components.

Table (4.23): Total variance explained of the barriers to the application of LC techniques to improve safety in construction projects

Components	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	6.830	27.320	27.320	6.830	27.320	27.320	4.474	17.895	17.895
2	3.163	12.650	39.971	3.163	12.650	39.971	2.620	10.481	28.376
3	2.204	8.817	48.788	2.204	8.817	48.788	2.305	9.221	37.597
4	1.783	7.132	55.920	1.783	7.132	55.920	2.238	8.951	46.548
5	1.376	5.505	61.426	1.376	5.505	61.426	2.224	8.896	55.443
6	1.299	5.196	66.622	1.299	5.196	66.622	2.022	8.088	63.531
7	1.170	4.681	71.303	1.170	4.681	71.303	1.943	7.772	71.303
8	0.936	3.746	75.049						
9	0.772	3.087	78.136						
10	0.703	2.812	80.948						
11	0.627	2.509	83.457						
12	0.584	2.336	85.793						
13	0.526	2.104	87.896						
14	0.456	1.826	89.722						
15	0.411	1.644	91.366						
16	0.377	1.509	92.875						
17	0.345	1.379	94.254						
18	0.261	1.045	95.299						
19	0.243	0.972	96.271						
20	0.226	0.903	97.174						
21	0.197	0.788	97.962						
22	0.169	0.677	98.639						
23	0.139	0.555	99.194						
24	0.110	0.441	99.635						
25	0.091	0.365	100.000						

Scree plot which graphically presents the number of eigenvalues in descending order against the number of factors (Reio Jr and Shuck, 2015, Van der Eijk and Rose, 2015, Hooper, 2012). This graph is then investigated to determine where there is a noticeable change in its shape which is known as 'the elbow' or point of inflection (Hooper, 2012, Ruscio and Roche, 2012, Suhr, 2006). As shown in Figure (4.10) which resulted from the last run of EFA regarding the barriers to the application of LC techniques to improve safety in construction projects, there are 25 components at the horizontal axis. However, only 7 components have an eigenvalues greater than 1, which indicated that the barriers will be underlined under seven groups. Moreover, the point above this debris indicates the number of factors to be retained is 7.

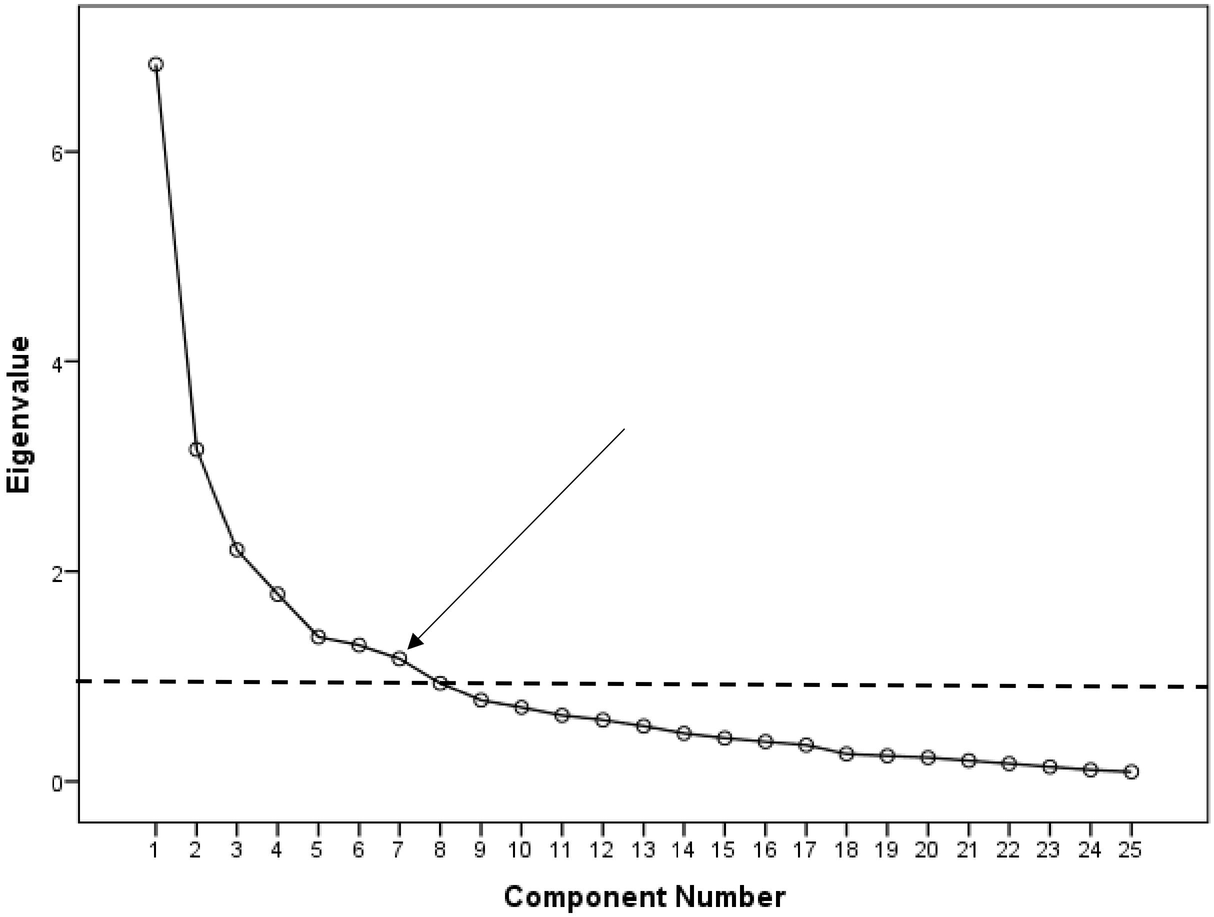


Figure (4.10): Scree plot of barriers to the application of LC techniques to improve safety in construction projects

Cumulative percent of variance is the amount of the total variance in the original set of variables that is explained by the factors. The greater the explained variance, the better the solution (Taherdoost et al., 2014, Suhr, 2006, De Vaus, 2002). Table (4.23) shows the total variance explained for the 25 barriers remained in the last run (Sixth run). This Table shows that 7 components with eigenvalue larger than one which mean that four components can be extracted from the 25 barriers. The retained seven components explained 71.303% of the total variance. This means that a considerable amount of the 71.303% shared by the 25 variables (barriers) could be accounted for by these seven factors. Accordingly, the cumulative variance could be acceptable since it is greater than the threshold value of 50% (Hair, 1995).

4.5.2.4 Factor rotation

Most factor analysts agree that direct solutions attained from factor extraction are not sufficient. Adjustment to the frames of reference by rotation methods improves the interpretation of factor loadings by reducing some of the ambiguities which accompany the preliminary analysis (Suhr, 2006). Rotation will help by maximizing high item loadings and minimizing low item loadings (Taherdoost et al., 2014). The Orthogonal-Varimax rotation was conducted to retain the factor and to interpret the components into simple structure solution.

- **Rotated factor loading values**

The factor loadings give an idea about how much the variable has contributed to the factor; the larger the factor loading the more the variable has contributed to that factor. Factor loadings represent the strength of the correlation between the variable and the factor (Yong and Pearce, 2013). In order to obtain the optimum solution from EFA, many considerations should be taken including the minimum value of loading value, cross loading and minimum number of variables in each component.

Minimum loading value of the barriers should be more than 0.5 (Burton and Mazerolle, 2011, Costello and Osborne, 2005). If any variable has a loading value less than 0.5, it should be removed and EFA should be returned. EFA process should be retuned many times to ensure that all variables loadings are 0.5 or above. Result of the first run of EFA of "Barriers to the application of LC techniques to improve safety in construction projects" shows that Bar10, Bar11, Bar28 and

Bar35 have a loading values less than 5 and need to be removed and rerun the EFA. By checking the loading values in second and third run results of EFA, all barriers have loading values higher than 0.5. In the fourth run, Bar9 is less than 0.5 and need to be removed. In both of fifth and sixth run, all barriers have a loading values more than 0.5. Table (4.24) presents that all of the remained barriers have loadings more than 0.5.

Cross loading item is an item that existed on two or more factors (components) (Hooper, 2012, Costello and Osborne, 2005). Both of Dahling et al. (2012) and Nimon et al. (2011) focused on the pattern matrix and removed items that cross-loaded. Regarding the barriers to the application of LC techniques to improve safety in construction projects, Bar5 and Bar39 were cross loaded in the results of third run and fifth run, respectively. Both of them were removed and EFA is retuned. Table (4.24) shows that there is no cross loadings items in the result of last run.

Number of loaded items in each factor should be three or more (Costello and Osborne, 2005). Any component doesn't include at least three variables should be deleted from analysis will all variables included in it and EFA should be returned. In the result of first run of barriers section, ten components were extracted for the 39 barriers. Component 8, 9 and 10 have only 2 barriers in each of them which are (Bar30, Bar31, Bar15, Bar16, Bar1 and Bar33), sequentially. Therefore, component 8, 9 and 10 with their variables were removed and EFA was returned. In the last run of the EFA to the barriers, seven components were extracted. All of them were have at least 3 variables. Table (4.24) shows that each component has more than 3 barriers. Component1 has 6 barriers, component2 has 4 barriers, while components 3, 4, 5, 6 and 7 have 3 barriers in each of them.

Table (4.24): Rotated loading values of the barriers to the application of LC techniques to improve safety in construction projects

Items	Components						
	1	2	3	4	5	6	7
Bar2						0.732	
Bar3						0.709	
Bar4						0.628	
Bar6			0.572				
Bar7			0.910				
Bar8			0.892				
Bar12				0.841			

Table (4.24): Rotated loading values of the barriers to the application of LC techniques to improve safety in construction projects

Items	Components						
	1	2	3	4	5	6	7
Bar13				0.804			
Bar14				0.702			
Bar17	0.881						
Bar18	0.855						
Bar19	0.816						
Bar20	0.827						
Bar21	0.850						
Bar22	0.727						
Bar23		0.767					
Bar24		0.716					
Bar25		0.713					
Bar26		0.767					
Bar27							0.640
Bar29							0.805
Bar32							0.707
Bar36					0.799		
Bar37					0.842		
Bar38					0.692		

In each time the analysis repeated, the proposed requirements of factor analysis for all barriers should be checked and verified. The EFA was stopped in the sixth run when all barriers have a loading value of 0.5 or more, no existence of cross loaded items and each components has at least three barriers with communality values of all more than 0.5. After six repetitions of the EFA, fourteen (14) barriers were eliminated and twenty five (25) are remained and organized under seven components. The eliminated barriers are:

- Bar1: Lack of management support and commitment to the application of LC techniques in safety improvement. This barrier was removed in the second run because it was in a component which has only two items (less than 3)
- Bar5: Lack of time in construction firms for innovation and application of any innovative strategy. This barrier was removed in the fourth run because it was cross loaded (existed in two components).

- Bar9: Absence of long term forecast of safety improvement. This barrier was removed in the fifth run because it has a loading value less than 0.5
- Bar10: Inadequate planning to apply of LC techniques in safety improvement. This barrier was removed in the second run of EFA because it has a loading value less than 0.5
- Bar11: Logistics' problems (Ex. poor management of materials, equipment and tools and short supply of material). This barrier was removed in the second run because its communality value was less than 0.5.
- Bar15: Poor salaries do not encourage employees to apply any innovative strategies. This barrier was removed in the second run because it was in a component which has only two items (less than 3)
- Bar16: Lack of incentives and motivation. This barrier was removed in the second run because it was in a component which has only two items (less than 3)
- Bar28: Complexity of LC implementation since LC does not just involve applying LC techniques on site, but also involves developing a culture among the staff for a continuous improvement. This barrier was removed in the second run of EFA because it has a loading value less than 0.5
- Bar30: Incomplete designs which leads to increases the probability of re-work. This barrier was removed in the second run because it was in a component which has only two items (less than 3)
- Bar31: Poor performance measurement strategies. This barrier was removed in the second run because it was in a component which has only two items (less than 3)
- Bar33: Selfishness among professionals to provide their experience in using LC techniques to improve safety. This barrier was removed in the second run because it was in a component which has only two items (less than 3)
- Bar34: Lack of teamwork. This barrier was removed in the third run because its communality value was less than 0.5.
- Bar35: Poor leadership. This barrier was removed in the second run of EFA because it has a loading value less than 0.5
- Bar39: Fear of unfamiliar practices due to the misconceptions and misunderstandings of LC. This barrier was removed in the sixth run because it was cross loaded.

Table (4.25) summarizes the number of runs and reasons of removing the fourteen barriers during the six runs of the EFA for the 39 barriers that are proposed in this study.

Table (4.25): Reasons to remove items from factor analysis for the barriers to the application of LC techniques to improve safety in construction projects

Run number	No. of removed item in the run	Removed items		Reasons for removal
		Item No.	Item description	
2	10	Bar1	Lack of management support and commitment to the application of LC techniques in safety improvement	Component has less than 3 items
		Bar15	Poor salaries do not encourage employees to apply any innovative strategies	
		Bar16	Lack of incentives and motivation	
		Bar30	Incomplete designs which leads to increases the probability of re-work	
		Bar31	Poor performance measurement strategies	
		Bar33	Selfishness among professionals to provide their experience in using LC techniques to improve safety	
		Bar11	Logistics' problems (Ex. poor management of materials, equipment and tools and short supply of material).	Communality value was less than 0.5.
		Bar10	Inadequate planning to apply of LC techniques in safety improvement.	Factor loading value is less than 0.5

Table (4.25): Reasons to remove items from factor analysis for the barriers to the application of LC techniques to improve safety in construction projects

Run number	No. of removed item in the run	Removed items		Reasons for removal
		Item No.	Item description	
		Bar28	Complexity of LC implementation since LC does not just involve applying LC techniques on site, but also involves developing a culture among the staff for a continuous improvement	
		Bar35	Poor leadership	
3	1	Bar34	Lack of teamwork	Communality value was less than 0.5.
4	1	Bar5	Lack of time in construction firms for innovation and application of any innovative strategy.	Cross loaded factor
5	1	Bar9	Absence of long term forecast of safety improvement	Factor loading value is less than 0.5
6	1	Bar39	Fear of unfamiliar practices due to the misconceptions and misunderstandings of LC	Cross loaded factor

4.5.2.5 Interpretation and labelling

The components extracted in this research are labeled with names related to the variables included in it. Table (4.26) summarizes the components resulted from the factor analysis of the barriers to the application of LC techniques to improve safety in construction projects. Seven components were extracted to summarize the 25 remained barriers. These seven components constitute 71.303% of the total variance of the 25 barriers. There is a main guideline that can aid in the process of naming each component. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor (Hooper, 2012). Names of these components reflects the barriers to the application of LC techniques to improve safety in construction projects. The seven components are:

- **Component1 (Educational related):** consists of six barriers with eigenvalue of 6.830 and explained 17.895% of the total variance.
- **Component2 (Governmental related):** consists of four barriers with eigenvalue of 3.163 and explained 10.481% of the total variance
- **Component3 (Communication):** consists of three barriers with eigenvalue of 2.204 and explained 9.221% of the total variance.
- **Component4 (Financial related):** consists of three barriers with eigenvalue of 1.783 and explained 8.951% of the total variance.
- **Component5 (Cultural related):** consists of three barriers with eigenvalue of 1.376 and explained 8.896% of the total variance.
- **Component6 (Decision making):** consists of three barriers with eigenvalue of 1.299 and explained 8.088% of the total variance.
- **Component7 (Technical related):** consists of three barriers with eigenvalue of 1.170 and explained 7.772% of the total variance.

Table (4.26): Factor analysis results of the barriers to the application of LC techniques to improve safety in construction projects

Barriers to the application of LC techniques to improve safety in construction projects		Factor loadings	Eigenvalue	Cronbach alpha
Component 1: Educational related				
Bar17	Lack of LC concept understanding	0.881	6.830	0.919
Bar18	Lack of knowledge to apply LC techniques in safety improvement	0.855		
Bar21	Lack of awareness program to increase knowledge about LC	0.850		
Bar20	Lack of education and training needed to apply LC techniques in safety improvement	0.827		
Bar19	Lack of technical skills to apply LC techniques in safety improvement	0.816		

Table (4.26): Factor analysis results of the barriers to the application of LC techniques to improve safety in construction projects

Barriers to the application of LC techniques to improve safety in construction projects		Factor loadings	Eigenvalue	Cronbach alpha
Bar22	Lack of information and experiences sharing among construction firms	0.727		
Component 2: Governmental related				
Bar23	Lack of government support towards the construction projects to apply any innovative strategy	0.767	3.163	0.805
Bar26	Unsteady price of commodities (Ex. PPE, safety signs, etc.)	0.767		
Bar24	Inconsistency in the government policies	0.716		
Bar25	Government bureaucracy and instability	0.713		
Component 3: Communication				
Bar7	Poor communication among project parties (managers, administrators, foremen, etc.)	0.910	2.204	0.795
Bar8	Poor coordination among project parties (managers, administrators, foremen, etc.)	0.892		
Bar6	Lack of transparency	0.572		
Component 4: Financial related				
Bar12	Inadequate funding of the project to provide the required resources and training	0.841	1.783	0.798
Bar13	Low tender prices	0.804		
Bar14	High cost of LC implementation including cost of training, consultancy fees and cost to conduct workshops	0.702		
Component 5: Cultural related				
Bar37	Resistance to change by employees	0.842	1.376	0.763
Bar36	Cultural issues	0.799		
Bar38	Lack of self-criticism which limited the capacity to learn from errors	0.692		

Table (4.26): Factor analysis results of the barriers to the application of LC techniques to improve safety in construction projects

Barriers to the application of LC techniques to improve safety in construction projects		Factor loadings	Eigenvalue	Cronbach alpha
Component 6: Decision making				
Bar2	Poor project definition which explain the vision, mission and main objectives of the project and its stakeholders	0.732	1.299	0.672
Bar3	Centralization of decision making	0.709		
Bar4	Lengthy approval procedure from top management to take any step	0.628		
Component 7: Technical related				
Bar29	Long implementation period needed for LC techniques application in safety improvement	0.805	1.170	0.660
Bar32	Fragmented nature of the construction industry	0.707		
Bar27	Lack of agreed implementation methodology to implement LC techniques	0.640		

4.6 Success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

A set of Critical Success Factors (CSFs) is used as elements which are opposed to the identified barriers as an efficient method to overcome or minimize their impact on the LC's implementation in construction projects (Bashir et al., 2015, Cano et al., 2015, Ogunbiyi et al., 2013). Section F of the questionnaire asked the respondents to indicate the influence degree of a sect of success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects among Gaza Strip. The respondents were provided with a list of success factors consisted of twenty six factors.

4.6.1 Ranks of success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

Twenty six success factors were listed in section F of the questionnaire which were labeled as SF1 to SF26. They were categorized into four groups including: management success factors, educational and skill development success factors, government success factors; and operation success factors. Table (4.27) summarizes the analysis results of the success factors, including mean score (MS), standard deviation (SD), RII, *t*-test results, *p*-values; and ranking order. The mean scores for the 26 success factors reflect the influence level of the variables on overcoming the barriers to the application of LC techniques to improve safety in construction projects; the higher score, the higher influence degree in construction projects around Gaza Strip.

The results summarized in Table (4.27) shows that the overall mean for the 26 listed success factor is 3.08 which is greater than the hypothesized mean (equal to 2 for five-point scale where A_{min}=0 and A_{max}=4) (Holt, 2014). This indicated that the respondents agree that all of the 26 success factor have high influence on overcoming the barriers to the application of LC techniques to improve safety in construction projects. Figure (4.11) showed that the highest average mean of success factors is related to the group of government success factors while the lowest average mean is related to operation success factors group. Additionally, the standard deviations for all success factors are small which give an indication that there was a little variability in the data and there was a consistency in agreement among the respondents. So, it can be said that results are confident (Neuman, 2013, Student Learning Development, 2009).

The average relative importance index (RII) for the success factors is 76.91%. As the average mean of the rating scale (From 0 to 4) is 2, the neutral RII is (2/4)*100 = 50%. Therefore, the average RII of the success factors is higher than the neutral value of RII (76.991%>50%). This indicates that most of respondents believed that these success factor have a higher influence on overcoming the barriers to the application of LC techniques to improve safety in construction projects. RII results for each success factor are presented in the graphical Figure (4.12). It is worth mentioning that ranking of the statements was based on the highest MS, RII, and the lowest SD. If some statements have similar means and RIIs, ranking will be depended on the lowest SD. As in the case of SF10 and SF11; SF3 and SF13; SF12 and SF16; SF4 and SF24; SF17, SF21 and SF26.

It is shown from Table (4.27) that the 26 listed success factors have *p*-value less than 0.05, and *t*-value for all of the success factors are more than the critical *t*-value (1.98). Hence, all the listed success factors are considered significant in measuring the influence level of the factors to overcome the barriers to the application of LC techniques in safety improvement. Moreover, all of the success factors have positive *t*-values which indicated that their mean scores are higher than the hypothesized mean value (2).

Table (4.27): Ranks of success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank within the group	Overall Rank
Management success factors								
SF7	Good leadership	3.31	0.782	82.75	43.762	0.000	1	1
SF1	Management support and commitment to the application of LC techniques in safety improvement	3.26	0.744	81.5	45.349	0.000	2	2
SF10	Establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety	3.22	0.756	80.5	44.105	0.000	3	3
SF11	Adequate funding of projects to cover the provisions of consultancy and training	3.22	0.839	80.5	39.752	0.000	4	4
SF2	Developing and implementing an effective plan to apply LC techniques in safety improvement	3.16	0.779	79	41.954	0.000	5	7
SF3	Ensuring the culture of continuous improvement in construction projects to obtain the reduction of costs, increase quality and productivity	3.16	0.779	79	41.954	0.000	5	7
SF9	Effective communication, cooperation, coordination	3.15	0.750	78.75	43.445	0.000	7	9

Table (4.27): Ranks of success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank within the group	Overall Rank
	and promoting integration between stakeholders							
SF12	Invest time as much as money to successfully apply LC techniques	3.06	0.822	76.5	38.447	0.000	8	15
SF4	A clear definition of roles, responsibilities, functions and levels of authority before the application of LC techniques	3.05	0.829	76.25	38.038	0.000	9	16
SF8	Constructing transparency between project participants	2.98	0.971	74.5	31.757	0.000	10	22
SF6	Construction managers should be proactive in decision-making	2.80	0.916	70	31.673	0.000	11	25
SF5	Decentralization of construction management	2.79	0.922	69.75	31.255	0.000	12	26
Education and skill development success factors								
SF13	Providing adequate education and training for employees at all levels on the LC concept and techniques	3.16	0.767	79	42.622	0.000	1	6
SF15	Establishing awareness programs to increase the understanding of the LC using workshops and research conferences to guide the application of LC techniques in safety improvement	3.10	0.835	77.5	38.447	0.000	2	11

Table (4.27): Ranks of success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank within the group	Overall Rank
SF14	Simplifying the language of Lean to enlighten the employees on the benefits of LC techniques application to achieve their compliance to the LC application	3.09	0.830	77.25	38.542	0.000	3	12
SF16	Promotion of the LC concept to the stakeholders of construction projects	3.06	0.775	76.5	40.791	0.000	4	14
SF17	Engagement of skillful site operatives and skillful professionals to guide the application of LC techniques in safety improvement	3.04	0.889	76	35.326	0.000	5	20
Government success factors								
SF19	Government agencies should introduce policies to encourage construction firms to engage in the application of LC techniques to improve construction safety	3.19	0.826	79.75	39.927	0.000	1	5
SF20	Legislation bodies should introduce laws to facilitate the full application of LC techniques among construction firms	3.12	0.855	78	37.782	0.000	2	10
SF18	Government should provide a clear direction for the construction firms to apply LC techniques in safety improvement	3.08	0.741	77	43.038	0.000	3	13

Table (4.27): Ranks of success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank within the group	Overall Rank
	through introducing policies to encourage construction firms to engage in the application of LC techniques to improve construction safety							
SF21	Government should provide the basic infrastructure and standards to apply LC techniques	3.04	0.835	76	37.642	0.000	4	19
Operation success factors								
SF24	Application of LC techniques gradually step-by-step in improving safety to decrease the complexity of LC implementation	3.05	0.851	76.25	37.033	0.000	1	17
SF26	Establishing appropriate performance measurement approaches to measure the effectiveness of implemented LC techniques in safety improvement and identifying the mistakes to improve their weak links	3.04	0.776	76	40.482	0.000	2	18
SF25	Constitution of an improvement committee to be responsible for the application of LC techniques in safety improvement	3.01	0.830	75.25	37.513	0.000	3	21
SF22	Standardize and ensure complete designs	2.95	0.817	73.75	37.388	0.000	4	23

Table (4.27): Ranks of success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

#	Item	MS	SD	RII (%)	*t*-value	*p*-value	Rank within the group	Overall Rank
SF23	Workers empowerment and involvement in the application of LC techniques in safety improvement	2.90	0.823	72.5	36.396	0.000	5	24
	Overall of success factors	3.08	0.82	76.91				

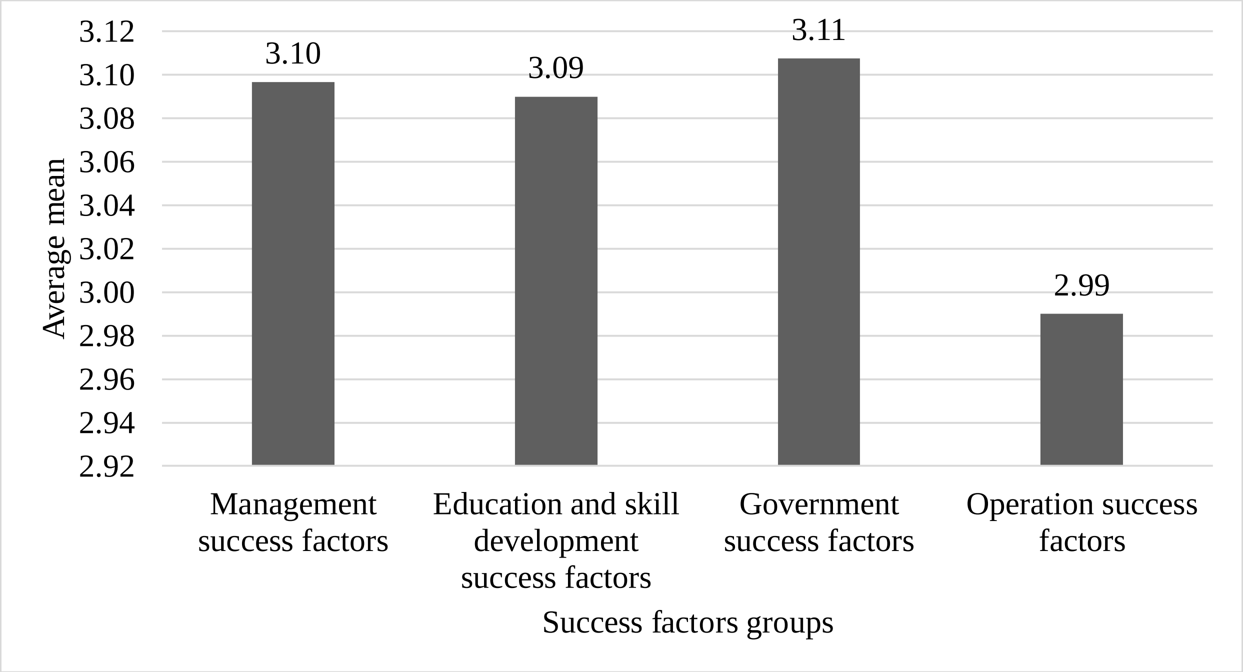


Figure (4.11): Average mean of success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

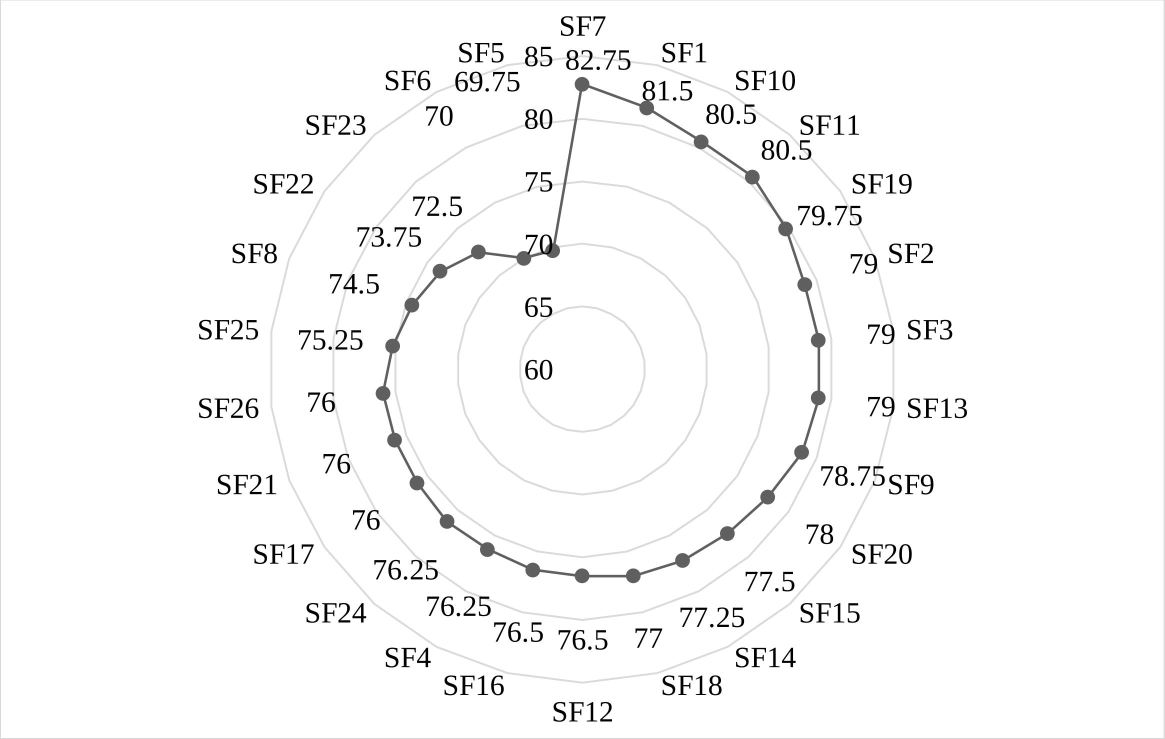


Figure (4.12): RII for success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects (SF1 to SF26)

The findings indicated that the success factor of *"Good leadership"* with (MS=3.31, SD= 0.782 and RII=82.75%) is the predominant success factor needed to overcome the barriers to the application of LC techniques to improve safety in construction projects in Gaza Strip. It is ranked in the first position in the management success factor and in the 1st position in the overall success factors. The success factor of "*Management support and commitment to the application of LC techniques in safety improvement"* with (MS=3.26, SD=0.744 and RII=81.5%) is ranked in the second position in both of management success factors and among the overall factors. The results also indicated that *"Establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety"* with (MS=3.22, SD=0.756 and RII=80.5%) is ranked in third position within the management success factors and in the overall success factors.

Conversely, respondents agreed that *"Construction managers should be proactive in decision-making"* with (MS=2.80, SD= 0.916; and RII=70%) has a low influence on overcoming the barriers to the application of LC techniques to improve safety in construction projects in Gaza Strip comparing with the remaining success factors. It is ranked as the 11th position in the management success factors and 25th in the overall success factors. Meanwhile, *"Decentralization of construction management"* with (MS=2.79, SD= 0.922; and RII=69.75%) has the lowest influence on overcoming the barriers to the application of LC techniques to improve safety in construction projects in Gaza Strip. It is ranked as the 12th position in the management success factors and 26th in the overall success factors. It should be noted that all of the success factors have a high influence degree on overcoming the barriers to the application of LC techniques to improve safety in construction projects in Gaza Strip, because the mean values for the success factors statements are more than the average mean of 2.

4.6.2 Factor analysis results of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

Factor analysis reduces a large number of variables (factors) into a smaller set (Taherdoost et al., 2014, Williams et al., 2010, Field, 2009). In this research, exploratory factor analysis (EFA) is adopted. Since, EFA is a method for identifying the factor structure of a set of multiple indicators or variables without imposing an a priori structure on the factors (Reio Jr and Shuck, 2015). The most frequent applications of EFA among researchers consists of reducing relatively large sets of variables into more manageable, developing and refining a new instrument's scales, and exploring relations among variables to build theory (Reio Jr and Shuck, 2015, Taherdoost et al., 2014, Hooper, 2012, Matsunaga, 2010).

4.6.2.1 Evaluation of Data Suitability for EFA

When designing a study, quality decision making requires attending to test that it is suitable to conduct the factor analysis (Widaman, 2012). The following tests should be conducted prior to the factor analysis including reliability test, sample size, correlation matrix, Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity.

Reliability tests were carried out to ensure that the questionnaire was reliable using Cronbach's Alpha. The normal range of Cronbach's alpha coefficient (Cα) value is between 0.0 and +1 (Field, 2009). In factor analysis, the reliability should be tested in the first and last run to measure the reliability of the factors remained. Moreover, the reliability of each extracted components should be tested. Table (4.29) presents the reliability in the first and last run to the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects was 0.913 and 0.780, respectively. Both of them are significantly high (between 0.0 and +1); and hence the data is reliable. Table (4.34) shows that the reliability coefficient for all of the extracted factors are between 0 and 1 which and reflect the reliability of data.

Sample size in this research as mentioned before constituted of 107 respondents which is adequate as it was larger than 50 as proposed by Sapnas and Zeller (2002). Sample to variable ratio (N: p) for this section is 4.12:1 which is enough according to Williams et al. (2010) and Tabachnick and Fidell (2001) who stated that 3:1 ratios can be useful for EFA.

Correlation matrix is used to determine the relationships between variables which is known as R-matrix (Hooper, 2012, Field, 2009, Field, 2005). A correlation matrix of the 26 success factors overcome the barriers to the application of LC techniques to improve safety in construction projects is summarized in Table (4.28). The correlation matrix shows that all variables are correlated sufficiently with at least one variable is correlated by ($r > 0.3$) and none of the variables are correlated very highly with any other variable ($r < 0.9$). Therefore, there is no need to eliminate any variable at this stage. This result provided an adequate basis for proceeding to the next step to check the value of Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity.

Table (4.28): Correlation matrix of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
SF1	1.00																									
SF2	0.55	1.00																								
SF3	0.38	0.52	1.00																							
SF4	0.38	0.53	0.47	1.00																						
SF5	0.15	0.09	0.23	0.25	1.00																					
SF6	0.12	0.27	0.16	0.14	0.37	1.00																				
SF7	0.35	0.43	0.40	0.21	0.13	0.23	1.00																			
SF8	0.39	0.39	0.34	0.27	0.23	0.29	0.32	1.00																		
SF9	0.23	0.30	0.28	0.26	0.16	0.14	0.23	0.38	1.00																	
SF10	0.18	0.34	0.37	0.27	0.14	0.04	0.41	0.25	0.39	1.00																
SF11	0.04	0.18	0.21	0.08	0.10	0.08	0.30	0.13	0.34	0.46	1.00															
SF12	0.02	0.24	0.09	0.16	0.07	0.03	0.08	0.23	0.45	0.48	0.61	1.00														
SF13	0.27	0.12	0.15	0.14	0.10	0.09	0.31	0.22	0.39	0.39	0.40	0.38	1.00													
SF14	0.16	0.27	0.21	0.25	0.15	0.15	0.29	0.24	0.28	0.52	0.43	0.43	0.67	1.00												
SF15	0.29	0.21	0.05	0.25	-0.07	0.15	0.15	0.40	0.28	0.31	0.37	0.46	0.49	0.46	1.00											
SF16	0.29	0.22	0.10	0.26	0.11	-0.01	0.08	0.30	0.29	0.32	0.39	0.42	0.48	0.58	0.53	1.00										
SF17	0.26	0.22	-0.01	0.16	0.07	0.17	0.19	0.30	0.32	0.25	0.32	0.42	0.53	0.44	0.57	0.57	1.00									
SF18	0.20	0.24	0.16	0.24	-0.06	0.07	0.15	0.00	0.18	0.25	0.39	0.24	0.39	0.40	0.31	0.42	0.32	1.00								
SF19	0.24	0.25	0.14	0.21	-0.06	-0.05	0.26	0.05	0.21	0.43	0.38	0.28	0.42	0.46	0.26	0.43	0.25	0.61	1.00							
SF20	0.19	0.33	0.16	0.21	0.05	0.13	0.33	0.06	0.07	0.26	0.34	0.11	0.22	0.45	0.25	0.26	0.28	0.64	0.60	1.00						
SF21	0.17	0.22	0.09	0.23	0.15	0.07	0.26	0.09	0.20	0.24	0.24	0.18	0.37	0.40	0.29	0.20	0.34	0.53	0.62	0.66	1.00					
SF22	0.13	0.07	0.31	0.12	0.15	0.14	0.23	0.28	0.40	0.32	0.39	0.26	0.37	0.29	0.17	0.30	0.25	0.26	0.25	0.20	0.24	1.00				
SF23	0.12	0.22	0.13	0.10	0.21	0.11	0.30	0.21	0.36	0.37	0.33	0.34	0.49	0.50	0.24	0.41	0.34	0.39	0.40	0.39	0.49	0.48	1.00			
SF24	0.19	0.37	0.26	0.26	0.04	0.10	0.35	0.17	0.36	0.56	0.38	0.35	0.50	0.61	0.33	0.41	0.46	0.47	0.48	0.51	0.46	0.33	0.56	1.00		
SF25	0.38	0.39	0.25	0.34	0.06	0.25	0.30	0.41	0.35	0.36	0.30	0.30	0.50	0.52	0.49	0.41	0.51	0.38	0.40	0.49	0.41	0.28	0.37	0.67	1.00	
SF26	0.28	0.38	0.30	0.34	0.12	0.10	0.51	0.34	0.44	0.50	0.42	0.32	0.55	0.42	0.40	0.37	0.42	0.32	0.37	0.32	0.38	0.21	0.48	0.54	0.57	1.00

Kaiser-Meyer-Olkin (KMO) assess the sampling adequacy while Bartlett's test of Sphericity checks whether the observed correlation matrix is an identity matrix (Howard, 2016). As shown in Table (4.29), the KMO of "success factors overcome the barriers to the application of LC techniques to improve safety in construction projects" in the first run was (0.805>0.50), demonstrating that the sample is adequate and data is suitable of for EFA. Similarly in the first run of EFA, the Bartlett's Test of Sphericity (with Chi-Square =1456.148) and significance of data (p= 0.000< 0.05) is valid. This reflects that the correlation matrix is not an identity matrix and the relationship among the items is strong, so EFA can be performed. In the last run of EFA regarding this section, KMO value and Bartlett's Test of Sphericity are also valid which are 0.832 and 0.000, respectively.

Table (4.29): Results of KMO, Bartlett's Test of Sphericity and reliability

		First run	Last run (Second run)
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.805	0.832
Bartlett's Test of Sphericity	Approx. Chi-Square	1456.148	884.052
	Df	325	136
	Sig.	0.000	0.000
Reliability	Cronbach's Alpha (Cα)	0.913	0.780

The valid results of the test of reliability test, sample size, correlation matrix, the measure of sampling adequacy and the test of Sphericity helped to determine that factor analysis was appropriate for the dataset in this research.

4.6.2.2 Factor Extraction

Direct extraction methods obtain the factor matrix directly from the correlation matrix by application of specified mathematical models (Suhr, 2006). PCA method is used to determine the underlying structure of success factors overcome the barriers to the application of LC techniques to improve safety in construction projects. After performing the first run of EFA to the success factors, the values of extracted communalities for the listed success factors were larger than 0.5 as shown in Table (4.30), except the SF9 and SF22 which have communalities of (0.499 and 0.483), respectively. Both of them are removed in parallel with checking the loading values for all success factors and then the EFA has been retuned. The Large communality values indicates that the PCA have successfully extracted a large proportion of the variability in the original variables. During every run of EFA after eliminating the success factors with low loadings, the communalities should be checked to be more than 0.5.

Table (4.30): Communalities of the success factors overcome the barriers to the application of LC techniques to improve safety in construction projects

Items	Extracted communalities	
	First run	Last run (Second run)
SF1	0.593	0.665
SF2	0.710	0.702
SF3	0.702	0.710
SF4	0.666	0.570
SF5	0.702	Removed in the 2nd run
SF6	0.601	Removed in the 2nd run
SF7	0.707	Removed in the 2nd run
SF8	0.601	Removed in the 2nd run
SF9	0.499	Removed in the 2nd run
SF10	0.655	Removed in the 2nd run
SF11	0.594	0.696
SF12	0.708	0.731
SF13	0.645	0.568
SF14	0.602	Removed in the 2nd run
SF15	0.702	0.659
SF16	0.676	0.595
SF17	0.688	0.702
SF18	0.697	0.642
SF19	0.701	0.684
SF20	0.774	0.777
SF21	0.682	0.699
SF22	0.483	Removed in the 2nd run
SF23	0.617	Removed in the 2nd run
SF24	0.653	0.601
SF25	0.670	0.614
SF26	0.657	Removed in the 2nd run

4.6.2.3 Factor Retention

In order to decide the number of factors to be retained for the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects, multiple criteria were used to including Kaiser's criteria (which is based on Eigenvalues (EV) that are > 1), the Scree test; and the cumulative percent of variance.

Kaiser's eigenvalue method specifies all components greater than one are retained for interpretation (Taherdoost et al., 2014). EFA is a method for identifying the factor structure of a set of multiple indicators or variables without imposing an a priori structure on the factors (Reio Jr and Shuck, 2015). Therefore, factor analysis can be repeated several times to obtain the optimum solution. Accordingly, any factor has an eigenvalue less than one represents little variance and will not be existed in the last run. After two runs of EFA to the 26 success factors, nine success factors were removed and 17 were remained in the final run which satisfied all requirements of EFA.

Table (4.31) summarizes the initial eigenvalues of the last run of EFA to the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects. The first column of the table of the Total Variance Explained consists of 17 eigenvalues, every component has only one eigenvalue. Summation of eigenvalues is 17 which is as same as the number of components. The 17 eigenvalues are arranged in descending order, the largest value (component 1) on the top while the least on the bottom (component 17). The eigenvalue of (component 1) is 6.421 which means that out of a total variance of 17 variables, 6.421 can be related to component 1. Component 1 has a variance of 6.421 which accounts 37.773% of the total variance of 17 factors. It is worth mentioning that this value should not be taken in consideration, as the direct solutions attained from factor extraction are not sufficient and need to be adjusted by rotation. In addition, from the table it is shown that four components have an eigenvalues greater than 1.0. Therefore, the 17 success factors will be underlined under 4 components.

Table (4.31): Total variance explained of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

Components	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	6.421	37.773	37.773	6.421	37.773	37.773	3.328	19.576	19.576
2	1.967	11.569	49.342	1.967	11.569	49.342	3.144	18.497	38.072
3	1.657	9.749	59.091	1.657	9.749	59.091	2.633	15.490	53.563
4	1.263	7.432	66.522	1.263	7.432	66.522	2.203	12.959	66.522

Table (4.31): Total variance explained of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

Components	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
5	0.816	4.798	71.320						
6	0.723	4.253	75.573						
7	0.612	3.598	79.171						
8	0.581	3.417	82.589						
9	0.558	3.284	85.873						
10	0.457	2.690	88.563						
11	0.395	2.323	90.886						
12	0.357	2.098	92.984						
13	0.307	1.806	94.790						
14	0.272	1.598	96.387						
15	0.236	1.391	97.778						
16	0.209	1.232	99.010						
17	0.168	0.990	100.000						

Scree plot which graphically presents the number of eigenvalues in descending order against the number of factors (Reio Jr and Shuck, 2015, Van der Eijk and Rose, 2015, Hooper, 2012). This graph is then investigated to determine where there is a noticeable change in its shape which is known as ‘the elbow’ or point of inflection (Hooper, 2012, Ruscio and Roche, 2012, Suhr, 2006). As shown in Figure (4.13) which resulted from the last run of EFA regarding the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects, there are 17 components at the horizontal axis. However, only 4 components have an eigenvalues greater than 1, which indicated that the success factors will be underlined under four groups. Moreover, the point above this debris indicates the number of factors to be retained is 4.

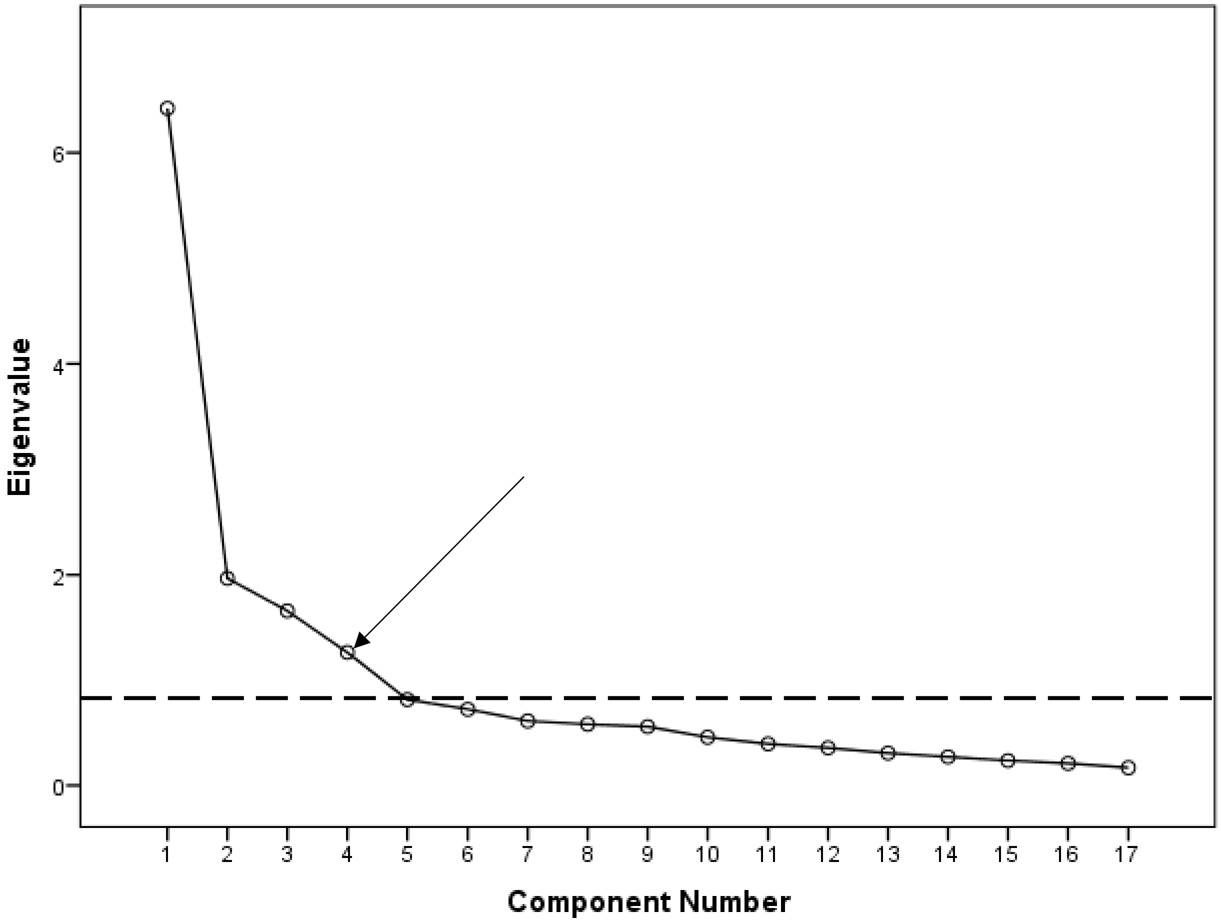


Figure (4.13): Scree plot of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

Cumulative percent of variance is the amount of the total variance in the original set of variables that is explained by the factors. The greater the explained variance, the better the solution (Taherdoost et al., 2014, Suhr, 2006, De Vaus, 2002). Table (4.31) shows the total variance explained for the 17 success factors remained in the last run. This table shows that 4 components with eigenvalue larger than one which mean that four components can be extracted from the 17 success factors. The retained four components explained 66.522% of the total variance. This means that a considerable amount of the 66.522% shared by the 17 variables (success factors) could be accounted for by these four factors. Accordingly, the cumulative variance could be acceptable since it is greater than the threshold value of 50% (Hair, 1995).

4.6.2.4 Factor rotation

Most factor analysts agree that direct solutions attained from factor extraction are not sufficient. Adjustment to the frames of reference by rotation methods improves the interpretation of factor loadings by reducing some of the ambiguities which accompany the preliminary analysis (Suhr, 2006). Rotation will help by maximizing high item loadings and minimizing low item loadings (Taherdoost et al., 2014). The Orthogonal-Varimax rotation was conducted to retain the factor and to interpret the components into simple structure solution.

- **Rotated factor loading values**

The factor loadings give an idea about how much the variable has contributed to the factor; the larger the factor loading the more the variable has contributed to that factor. Factor loadings represent the strength of the correlation between the variable and the factor (Yong and Pearce, 2013). In order to obtain the optimum solution from EFA, many considerations should be taken including the minimum value of loading value, cross loading and minimum number of variables in each component.

Minimum loading value of the success factors should be more than 0.5 (Burton and Mazerolle, 2011, Costello and Osborne, 2005). If any variable has a loading value less than 0.5, it should be removed and EFA should be returned. EFA process should be retuned many times to ensure that all variables loadings are 0.5 or above. Result of the first run of EFA of "the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects" shows that SF8, SF14 and SF23 have a loading values less than 0.5 and need to be removed and rerun the EFA. By checking the loading values in second run results of EFA, all success factors have loading values higher than 0.5 as shown in Table (4.32).

Cross loading item is an item that existed on two or more factors (components) (Hooper, 2012, Costello and Osborne, 2005). Both of Dahling et al. (2012) and Nimon et al. (2011) focused on the pattern matrix and removed items that cross-loaded. Regarding the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects, there is no cross loaded variables in both of first and second run if EFA. Table (4.32) shows that there is no cross loadings items in the result of last run.

Number of loaded items in each factor should be three or more (Costello and Osborne, 2005). Any component doesn't include at least three variables should be deleted from analysis will all variables included in it and EFA should be returned. In the result of first run of success factors section, four components were extracted for the 26 success factors. Component 5 and 6 has only 2 factors in each of them which are SF5, SF6, SF7 and SF26. Therefore, component 5 and 6 with their variables were removed and EFA was returned. In the second run of the EFA to the success factors, only four components were extracted. All of them were have at least 3 variables. Table (4.32) shows that each component has more than 3 success factors. Each of component 1 and 2 has 5 success factors, while component 4 has 4 success factors; and component 4 has 3 success factors.

Table (4.32): Rotated loading values of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

Items	Components			
	1	2	3	4
SF1			0.692	
SF2			0.803	
SF3			0.774	
SF4			0.730	
SF10				0.711
SF11				0.757
SF12				0.746
SF13		0.640		
SF15		0.775		
SF16		0.698		
SF17		0.820		
SF18	0.746			
SF19	0.762			
SF20	0.863			
SF21	0.812			
SF24	0.536			
SF25		0.548		

In each time the analysis repeated, the proposed requirements of factor analysis for all success factors should be checked and verified. The EFA was stopped in the second run when all success factors have a loading value of 0.5 or more, no existence of cross loaded items and each components has at least three benefits with communality values of all more than 0.5. After two repetitions of the EFA, nine (9) success factors were eliminated and seventeen (17) are remained and organized under four components. The eliminated success factors are:

- SF5: Decentralization of construction management. This success factor was removed in the second run because it was in a component which has only two items (less than 3).
- SF6: Construction managers should be proactive in decision-making. This success factor was removed in the second run because it was in a component which has only two items (less than 3).
- SF7: Good leadership. This success factor was removed in the second run because it was in a component which has only two items (less than 3).
- SF8: Constructing transparency between project participants. This success factor was removed in the second run because it has a loading value less than 0.5.
- SF9: Effective communication, cooperation, coordination and promoting integration between stakeholders. This success factor was removed in the second run because its communality value was less than 0.5.
- SF14: Simplifying the language of Lean to enlighten the employees on the benefits of LC techniques application to achieve their compliance to the LC application. This success factor was removed in the second run because it has a loading value less than 0.5.
- SF22: Standardize and ensure complete designs. This success factor was removed in the second run because communality value was less than 0.5.
- SF23: Workers empowerment and involvement in the application of LC techniques in safety improvement. This success factor was removed in the second run because it has a loading value less than 0.5.
- SF26: Establishing appropriate performance measurement approaches to measure the effectiveness of implemented LC techniques in safety improvement and identifying the mistakes to improve their weak links. This success factor was removed in the second run because it was in a component which has only two items (less than 3).

Table (4.33) summarizes the number of runs and reasons of removing the nine success factors during the two runs of the EFA for the 26 success factors that are proposed in this study.

Table (4.33): Reasons to remove items from factor analysis for the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

Run number	No. of removed item in the run	Removed items		Reasons for removal
		Item No.	Item description	
2	9	SF9	Effective communication, cooperation, coordination and promoting integration between stakeholders.	Communality value is less than 0.5
		SF22	Standardize and ensure complete designs	
		SF8	Constructing transparency between project participants	Factor loading value is less than 0.5
		SF14	Simplifying the language of Lean to enlighten the employees on the benefits of LC techniques application to achieve their compliance to the LC application	
		SF23	Workers empowerment and involvement in the application of LC techniques in safety improvement	
		SF5	Decentralization of construction management	Component has less than 3 items
		SF6	Construction managers should be proactive in decision-making.	
		SF7	Good leadership	
		SF26	Establishing appropriate performance measurement approaches to measure the effectiveness of implemented LC	

Table (4.33): Reasons to remove items from factor analysis for the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

Run number	No. of removed item in the run	Removed items		Reasons for removal
		Item No.	Item description	
			techniques in safety improvement and identifying the mistakes to improve their weak links.	

4.6.2.5 Interpretation and labelling

The components extracted in this research are labeled with names related to the variables included in it. Table (4.34) summarizes the components resulted from the factor analysis of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects. Four components were extracted to summarize the 17 remained success factors. These four components constitute 66.522% of the total variance of the 17 success factors. There is a main guideline that can aid in the process of naming each component. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor (Hooper, 2012). Names of these components reflects the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects. The four components are:

- **Component1 (Governmental factors):** consists of five success factors with eigenvalue of 6.421 and explained 19.576% of the total variance.
- **Component2** (**Educational factors):** consists of four success factors with eigenvalue of 1.967 and explained 18.497% of the total variance
- **Component3 (Effective planning):** consists of four success factors with eigenvalue of 1.657 and explained 15.490% of the total variance.
- **Component4 (Financial factors):** consists of three success factors with eigenvalue of 1.263 and explained 12.959% of the total variance.

Table (4.34): Factor analysis results of t the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

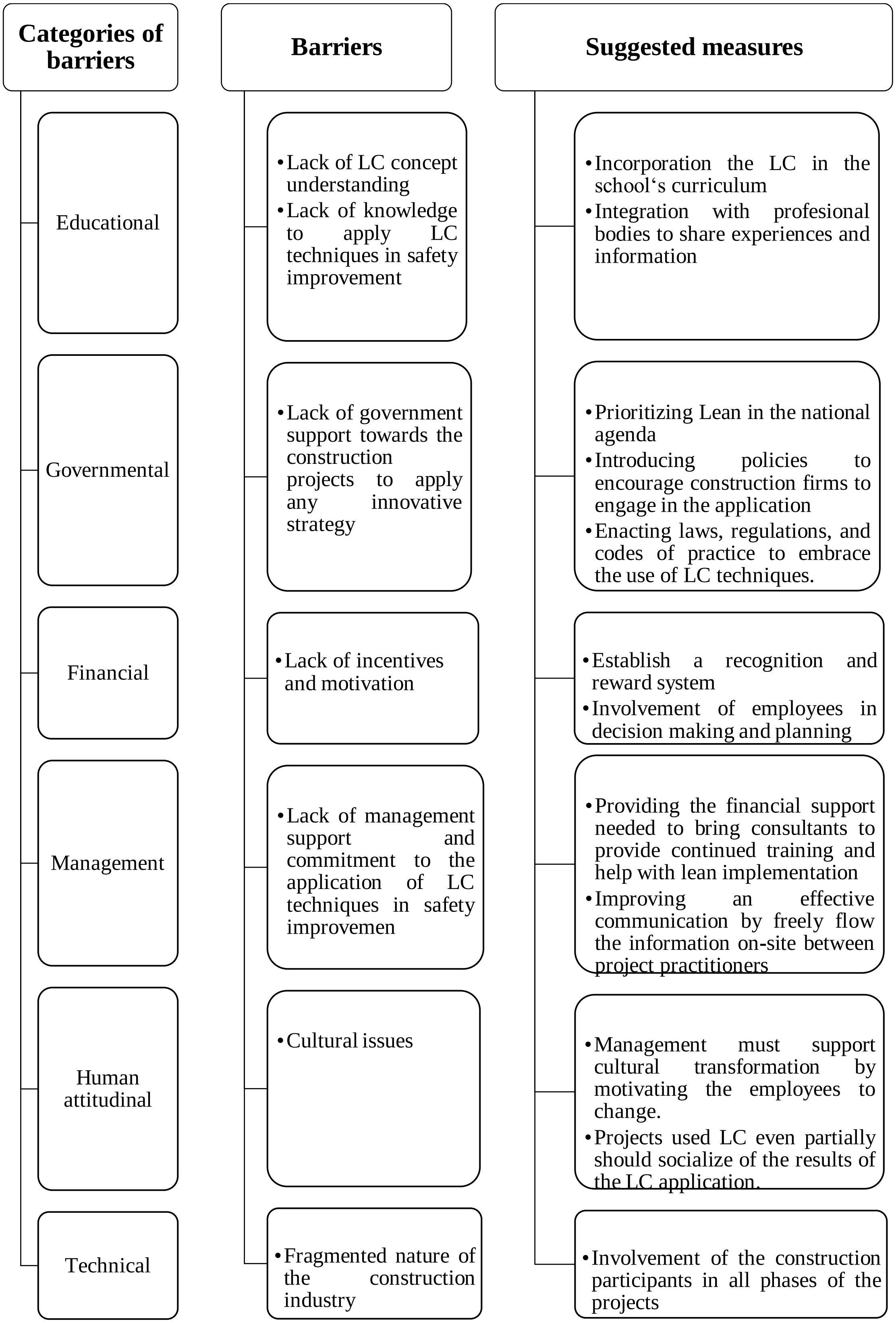
#	Success factors to overcome the barriers to the application of LC techniques	Factor loadings	Eigenvalue	Cronbach alpha
Component 1: Governmental factors				
SF20	Government should provide the basic infrastructure and standards to apply LC techniques	0.863	6.421	0.862
SF21	Government should work closely with professional bodies to introduce LC to improve construction safety	0.812		
SF19	Legislation bodies should introduce laws to facilitate the full application of LC techniques among construction firms	0.762		
SF18	Government should provide a clear direction for the construction firms to apply LC techniques in safety improvement through introducing policies to encourage construction firms to engage in the application of LC techniques to improve construction safety	0.746		
SF24	Application of LC techniques gradually step-by-step in improving safety to decrease the complexity of LC implementation	0.536		
Component 2: Educational factors				
SF17	Engagement of skillful site operatives and skillful professionals to guide the application of LC techniques in safety improvement	0.820	1.967	0.837
SF15	Establishing awareness programs to increase the understanding of the LC using workshops and research conferences to guide the application of LC techniques in safety improvement	0.775		
SF16	Promotion of the LC concept to the stakeholders of construction projects	0.698		
SF13	Providing adequate education and training for employees at all levels on the LC concept and techniques	0.640		

Table (4.34): Factor analysis results of t the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

#	Success factors to overcome the barriers to the application of LC techniques	Factor loadings	Eigenvalue	Cronbach alpha
SF25	Constitution of an improvement committee to be responsible for the application of LC techniques in safety improvement	0.548		
Component 3: Effective planning				
SF2	Developing and implementing an effective plan to apply LC techniques in safety improvement	0.803	1.657	0.780
SF3	Ensuring the culture of continuous improvement in construction projects to obtain the reduction of costs, increase quality and productivity	0.774		
SF4	A clear definition of roles, responsibilities, functions and levels of authority before the application of LC techniques	0.730		
SF1	Management support and commitment to the application of LC techniques in safety improvement	0.692		
Component 4: Financial factors				
SF11	Adequate funding of projects to cover the provisions of consultancy and training	0.757	1.263	0.762
SF12	Invest time as much as money to successfully apply LC techniques	0.746		
SF10	Establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety	0.711		

4.7 Roadmap to overcome the barriers to the application of LC techniques

This section is specialized to fulfill the fifth objective of this research. It is aimed to suggest measures that should be taken to overcome the critical barriers in each group including (Governmental, financial, educational, governmental, technical and human attitudinal) using a roadmap as shown in Figure (4.14).



Categories of barriers	Barriers	Suggested measures
Educational	• Lack of LC concept understanding • Lack of knowledge to apply LC techniques in safety improvement	• Incorporation the LC in the school‘s curriculum • Integration with profesional bodies to share experiences and information
Governmental	• Lack of government support towards the construction projects to apply any innovative strategy	• Prioritizing Lean in the national agenda • Introducing policies to encourage construction firms to engage in the application • Enacting laws, regulations, and codes of practice to embrace the use of LC techniques.
Financial	• Lack of incentives and motivation	• Establish a recognition and reward system • Involvement of employees in decision making and planning
Management	• Lack of management support and commitment to the application of LC techniques in safety improvemen	• Providing the financial support needed to bring consultants to provide continued training and help with lean implementation • Improving an effective communication by freely flow the information on-site between project practitioners
Human attitudinal	• Cultural issues	• Management must support cultural transformation by motivating the employees to change. • Projects used LC even partially should socialize of the results of the LC application.
Technical	• Fragmented nature of the construction industry	• Involvement of the construction participants in all phases of the projects

Figure 4.14): Roadmap to overcome the barriers to the application of LC techniques

4.8 Test of research hypotheses

Three hypotheses have been developed to study relations between the variables in order to support Lean Construction techniques in safety improvement in the Gazan Construction Projects. According to Figure (4.15), three hypotheses were tested through applying Pearson's correlation coefficient. The Pearson's correlation coefficient was used to measure the strength and direction of the relationship (linear association/correlation) between two quantitative variables, where the value r = 1 means a perfect positive correlation and the value r = -1 means a perfect negative correlation. Each hypothesis was tested separately. The three variables in Figure (4.15) represented parts of the questionnaire, where the questionnaire was built from the following four parts:

- Applicability level of LC techniques to improve safety in construction projects
- Benefits of applying LC techniques which is related to safety improvement in construction projects
- Barriers to the application of LC techniques to improve safety in construction projects.

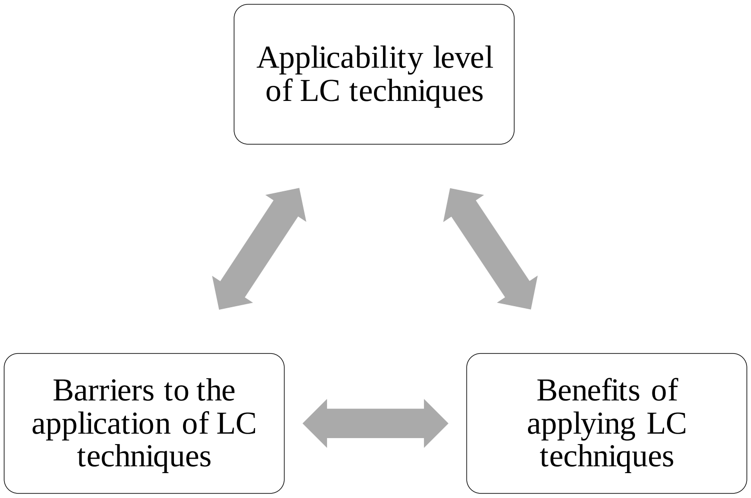


Figure 4.15): Hypotheses model

4.8.1 Correlation between applicability level of LC techniques and benefits of applying LC techniques

First H_0: There is a positive relationship between applicability level of LC techniques and benefits of applying LC techniques

In order to test the hypothesis, the Pearson's correlation coefficient was used to measure the strength and direction of the relationship (linear association/ correlation) between “Applicability level of LC techniques to improve safety in construction projects” and “Benefits of applying LC techniques which is related to safety improvement in construction projects”. According to results of the test shown in Table (4.35), “Applicability level of LC techniques to improve safety in construction” is positively related to “Benefits of applying LC techniques which is related to safety improvement in construction projects”, with a Pearson correlation coefficient of r = 0.068. However, the significance value is larger than 0.05 (*p*-value>0.05). The closer (r) is to +1, the stronger the positive correlation. According to that, it can be said that the relationship between “Applicability level of LC techniques to improve safety in construction” and “Benefits of applying LC techniques which is related to safety improvement in construction projects” is a positive relationship because (r = 0.068). This means, when one variable increases in value, the second variable also increase in value. In other words, increasing applicability level of LC techniques will increase obtaining of the benefits of implementing LC techniques. At the same time, the r correlation is too weak since the LC techniques are not adequately applied among Gaza Strip, however the respondents agreed on the importance of the benefits of implementing LC techniques.

Table (4.35): Correlation between Applicability level of LC techniques and Benefits of applying LC techniques

Field	Statistics	Benefits of applying LC techniques
Applicability level of LC techniques	Pearson correlation (*r*)	0.068
	p-value (Sig.) (2-tailed)	0.484
	Sample size (*N*)	107

4.8.2 Correlation between applicability level of LC techniques and barriers to the application of LC techniques

Second H_0: There is a inverse relationship between applicability level of LC techniques and barriers to the application of LC techniques

In order to test the hypothesis, the Pearson's correlation coefficient was used to measure the strength and direction of the relationship (linear association/ correlation) between “Applicability level of LC techniques” and “Barriers to the application of LC techniques”. According to results of the test that shown in Table (4.36), “Applicability level of LC techniques” is negatively related to “Barriers to the application of LC techniques”, with a Pearson correlation coefficient of r= -0.057 and the significance value is higher than 0.05 (*p*-value>0.05). The closer (r) is to -1, the stronger the negative correlation. According to that, it can be said that the relationship between “Applicability level of LC techniques” and “Barriers to the application of LC techniques” is a weak negative relationship because (r = -0.057). This is because LC techniques are not adequately applied among Gaza Strip, however the respondents agreed on the strong effect of the barriers on applying LC techniques. The negative correlation means that, when one variable increases in value, the second variable will decrease in value. In other words, increasing the barriers of implementing LC techniques will decrease the applicability level of LC techniques.

Table (4.36): Correlation between Applicability level of LC techniques and Barriers to the application of LC techniques

Field	Statistics	Barriers to the application of LC techniques
Applicability level of LC techniques	Pearson correlation (*r*)	-0.057
	p-value (Sig.) (2-tailed)	0.557
	Sample size (*N*)	107

4.8.3 Correlation between benefits of applying LC techniques and barriers to the application of LC techniques

Third H_0: There is an inverse relationship between benefits of applying LC techniques and barriers to the application of LC techniques

In order to test the hypothesis, the Pearson's correlation coefficient was used to measure the strength and direction of the relationship (linear association/ correlation) between "Benefits of applying LC techniques" and "Barriers to the application of LC techniques". According to results of the test that shown in Table (4.37), "Benefits of applying LC techniques" is negatively related to "Barriers to the application of LC techniques", with a Pearson correlation coefficient of r= -0.577 and the significance value is less than 0.05 (p-value < 0.05). The relationship is statistically significant at $\alpha \leq 0.05$. Consequently, the Third H_0 is accepted. The closer (r) is to -1, the stronger the negative correlation. According to that, it can be said that the relationship between "Benefits of applying LC techniques" and "Barriers to the application of LC techniques" is a strong negative relationship because (r= -0.577). This means, when one variable increases in value, the second variable will decrease in value. Increasing the barriers of implementing LC techniques will decrease the benefits gained by using LC techniques.

Table (4.37): Correlation between Benefits of applying LC techniques and Barriers to the application of LC techniques

Field	Statistics	Barriers to the application of LC techniques
Benefits of applying LC techniques	Pearson correlation (*r*)	-0.577**
	P-value (Sig.) (2-tailed)	0.000
	Sample size (*N*)	107

4.9 Summary

This chapter concluded the results gained using questionnaires which are related to the first four research objectives. It also included the suggested roadmap to overcome the barriers to the application of LC techniques in safety improvement. Data analyzed using descriptive and inferential analysis. Descriptive analysis including frequency distribution, mean score, relative importance index and exploratory factor analysis. On the other hand, inferential analysis used is Pearson correlation coefficient.

Ranking results revealed that the Lean Construction tools are not adequately known and applied to reduce the causes of accidents in Gazan Construction Projects. 5whys tool was the highest implemented tool to reduce the causes of accidents. The benefit gained from implementing Lean Construction techniques that got the top rank was improving the rate of workflow on-site, however, the strongest barrier to the application of Lean Construction techniques was lack of Lean Construction concept understanding. Furthermore, good leadership was the most influential success factor.

Meanwhile, factor analysis results demonstrated that the highest used component in the application of Lean Construction techniques to reduce the causes of accidents in construction projects was communication and planning. Additionally, Communication and trust was found as the most important component in the benefits of implementing Lean Construction techniques. Regarding the barriers to the application of Lean Construction techniques to improve safety, educational related was the strongest component. Finally, governmental factors was the most influential component in the success factors.

Chapter 5

Discussion of the results

Chapter 5
Discussion of the results

This chapter presents the discussion of the questionnaire results carried out in this research. The previous chapter summarizes the results of awareness level of Lean Construction tool, applicability level of Lean Construction techniques to reduce the causes of accidents in construction projects, benefits of implementing LC techniques which is related to safety improvement in construction projects, barriers to the application of LC techniques to improve safety in construction projects; and critical success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects. The questionnaire items were based on literature review and the discussion of findings presented in this chapter are linked with the findings from the previous literatures.

5.1 Awareness level of Lean Construction tools

The aim of this section is to discuss the findings related to the awareness section of Lean construction tools. A LC tool comprises of one, two or more techniques (Bashir, 2013). The listed LC tools are last planner system, increased visualization, 5S, Fail safe for quality and safety, daily huddle meetings, first run studies, continuous improvement; and accident investigation. The mean values of the eight LC tools are less than the average score (equal to 2 for five-point scale where A_{min}=0 and A_{max}=4) referring to (Holt, 2014).

The results reflect that the respondents are not aware of LC tools as expressions around Gaza Strip. In the same context, Enshassi and Abu Zaiter (2014) stated that the majority of the respondents didn’t know about LC as new managing technique in construction management. Similarly, Wandahl (2014) has a main conclusion in his study in Denmark that the awareness of LC is considerable low. Conversely, the results of Adegbembo et al. (2016) showed that most of the construction professionals in Nigeria are aware of LC and its approaches.

5.2 Applicability level of Lean Construction techniques to reduce the causes of accidents in construction projects

This section is specialized to discuss the results of the first objective of this research which is obtained using the questionnaire (Appendix C). The first objective is about investigating the applicability level of LC techniques to reduce the causes of accidents in construction projects. Discussion of the results will be in the two following sections in order to explain the ranks of LC techniques and to discuss the labelling and the extracted components that resulted from factor analysis of LC techniques.

5.2.1 Ranks of LC techniques applied to reduce the causes of accidents in construction projects

Ranking results of LC techniques applied to reduce the causes of accidents in construction projects will be discussed in this section. The results of this objective (See Chapter 4) shows that the overall average of LC techniques applied is (MS=1.96) which is less than the average mean (equal to 2 for five-point scale where A_{min}=0 and A_{max}=4) (Holt, 2014). Thus, LC techniques are not adequately used among Gazan Construction Projects to reduce the causes of accidents. Furthermore, the standard deviations for all techniques are small which reflects that there was a little variability in the data and consistency in agreement among the respondents was existed (Neuman, 2013). Regarding *t*-value, it is calculated using the one-sample *t*-test and the 25 techniques have t-value larger than the critical *t*-value (1.98) (Neideen and Brasel, 2007). Also, these 25 techniques have *p*-value less than the significance level of (0.05). Accordingly, the 25 techniques can be considered significant in assessing the applicability level of LC in reducing the causes of accidents in the construction projects. There is a statistically significant differences attributed to the respondents opinions at the level of $\alpha \leq 0.05$ between the statistical mean of the LC techniques and average mean (2).

The applicability level of using LC techniques to reduce the causes of accidents in construction projects was investigated using the third section of questionnaire. The results of this section indicated that LC techniques as overall are not highly applied among Gaza Strip to reduce the causes of accidents in construction projects. LC is considered as a new innovative strategy in construction projects which in not known in Gaza Strip as shown in the awareness section. This is related to the learning environment in the universities which are not included Lean in their courses. Moreover, lack of fund provided to the construction projects prevented them from conducting training programs to help the engineers to implement LC techniques in their projects.

This result is in line with the study of Bashir (2013) in the United Kingdom who concluded that the projects are involved in safety improvement issues but they don't go to comment deeply on applying LC techniques to improve safety. Further, Oladiran (2017) stated that there is inadequate implementation of LC techniques which poses a serious problem to the Nigerian construction process. In the same context, Awada et al. (2016) found that LC is not applied in the Lebanese Construction Industry yet, as its concepts remain poorly recognized among the several project participants. Similarly, In Gaza Strip, Enshassi and Abu Zaiter (2014) confirmed that LC is not implemented in Gaza Strip construction industry yet. In Abu Dhabi, Al-Aomar (2012) concluded that only 32% of surveyed companies are currently familiar with and/or already using LC techniques.

The following sections will discuss the critical results of techniques related to their tools:

5.2.1.1 Last Planner System (LPS)

Last Planner System (LPS) is a Lean Construction (LC) tool which is considered as the most beneficial tool to improve safety in construction projects (Pestana and Gambetese, 2016, Gambetese and Pestana, 2014). The overall average for the LPS techniques is 2.06 which is exceeded the threshold value of 2. Based on this value, it can be concluded that LPS tool as all is implemented in Gaza Strip to reduce the causes of accidents. In the same context, Awada et al. (2016) represent the extent of LPS application and its influence on safety in the Lebanese construction industry. Similarly, the result of Gambetese and Pestana (2014) ensured that LPS techniques have a high impact on worker safety and they are implemented to improve the safety performance in three projects from four chosen in their study. Despite the importance of LPS techniques, Bashir (2013) found that only four organizations from 10 organizations are applying LPS in their projects to reduce the causes of accidents.

Although LPS tool is applied in Gaza Strip by its techniques, the previous section regarding awareness level of LC tool presented that the supervisor engineers were not aware of LPS as an expression. In fact, Wandahl (2014) stated that respondents did not know the LPS as sub element of LC, even they applied the subparts of LPS without knowing that it is related to LC. This section investigated the awareness level of using the LPS tool to reduce the causes of accidents in construction projects around Gaza Strip through its techniques. A LPS tool comprise of eight LC techniques. The results of the critical techniques will be discussed, these are as followed:

- *"Providing employees with safety equipment*", MS= 2.33 , SD=0.898, RII= 58.25%, rank within LPS group=1 and overall rank=5
- *"Conducting weekly work planning",* MS= 2.32, SD=1.087, RII= 58 % and rank within LPS group=2 and overall rank=6.
- *"Involvement of all employees in safety planning",* MS= 1.5 , SD=1.031, RII= 37.5% and rank within LPS group=8 and overall rank =23

From the results above related to the applicability level of LPS techniques to reduce the causes of accidents, it can be seen that most of the construction projects are providing their employees with safety equipment. This techniques was ranked as the first in LPS tool and 5th among the overall techniques which both are considered as top ranks. This research was applied on the construction projects funded by external donors (like Qatar Committee) which always consider safety improvement as major concern throughout the construction projects. They always focus on providing the safety equipment required for the every task and enforce employees to use them. Moreover, external parties put a pressure on construction practitioners to ensure that all equipment used in the construction site are safe to be used. This result is agreed with the study of Bashir et al. (2010) and Sack et al. (2009) who concluded that making provision for safety equipment is very important to reduce the accidents caused by inadequate safety equipment. In the same line, Abu Hamra and Enshassi (2016) in Gaza Strip ensured that managers should identify in advance the special equipment, tools, or safety devices to implement works safely.

The previous result was followed by *"Conducting weekly work planning"* which was ranked in 2nd position in LPS techniques and as 6th position the overall LC techniques used to reduce the causes of accident in construction projects among Gaza Strip. The reason of why weekly work plan is considered very important is that project practitioners are obligated to detail the commitments and promised task completions weekly to reduce the accidents caused by poor planning. They also should define the tools that should be used in the weekly works to ensure safety. Along with this result, Wandahl (2014) concluded that weekly work plan is the most implemented technique among LPS techniques in the Danish construction industry. Awada et al.

(2016) concluded that employing a weekly work plan during the construction phase is of great importance in Lebanon.

Another technique related to the LPS is *“Involvement of all employees in safety planning*” with (MS= 1.5, SD=1.031, RII= 37.5%, rank within LPS group=8 and overall rank =23). It has a late position which in both of LPS techniques and among the 25 LC techniques. This is may be related to the long time needed to establish the employee suggestions and the rushed time of grants which lead to individual decisions by the employers in Gaza Strip. Sometimes projects did not have any separate safety plan but safety conditions were mentioned in the master plan. This result is disagreed with study of Nahmens and Ikuma (2009) whose finding stresses the importance of having all employees involved in safety planning and allows employees to discuss and reduce safety hazards. On the other hand, Adegbembo et al., (2016) confirmed that the adoption of direct involvement of employees in decision making in general is considered very low among Nigeria. Similarly, Enshassi and Abu Zaiter (2014) revealed that employees in Gaza Strip are rarely involved in safety planning. However, it is very important to enable them to identify risks and make suggestions to control them.

Construction participants should implement LPS techniques in their projects to reduce the causes of accidents. Foreman should put daily and weekly work plans and define tools that should be used to ensure safety. Workers should be involved in task scheduling to develop the schedule based on their abilities. Employees should be provided with appropriate safety equipment to each task. At the same time, a safety engineer at site is necessary to periodically inspect the commitment of employees to safety conditions.

5.2.1.2 Increased visualization (IV)

The increased visualization (IV) is a LC tool about communicating key information to the workers using visual devices like various signs and labels around the construction site (Sarhan et al., 2017, Enshassi and Abu Zaiter, 2014, Ogunbiyi, 2014, Bashir, 2013, Salem et al., 2005). Increased visualization can be identified as one of the key principles of promoting safety on the construction site (Enshassi and Abu Zaiter, 2014, Fewings, 2013). IV tool has an overall average mean of 1.69 which is considered low comparing with the average value of 2. This result reflects that IV tool is not applied adequately to reduce the causes of accidents in Gaza Strip. In the same line, Sarhan and Fox (2013) found that IV is considered low applied in British Construction Projects. While in USA, Zhou (2012) stated that IV tool is highly implemented in construction projects. This section measured the applicability level of IV tool to reduce the causes of accidents in construction projects around Gaza Strip through its techniques. An increased visualization tool comprise of three techniques. The critical results of these techniques will be discussed broadly, these IV techniques are as followed:

- *"Using safety signs and labels on site",* MS= 2.39, SD=1.035, RII= 59.75%, rank within IV group=1 and overall rank=3.
- *"Using camera connected with computer algorithm to warn safety officer when workers violate safety conditions",* MS= 0.53 , SD=0.705, RII= 13.25%, rank within IV group=3 and overall rank=25

The results revealed that most of construction projects around Gaza Strip used safety signs and labels on site with a mean value more than 2. It was ranked as the 1st technique in IV tool and as the 3rd technique among the 25 LC techniques which are both high ranks. This is returned back to the external donors whose interest is to improve safety. They obligate the construction practitioners to bring the required safety signs and labels and placed them on different spots of the projects to increase safety awareness of all employees and reduce the human error. In the same manner, most of the respondents in the study of Awada et al. (2016) stated that their companies use different types of safety signs on site to ensure a lower accident rate. Similarly, Enshassi and Abu Zaiter (2014) concluded that most of the construction projects used signs and labels around the construction site such as signs related to safety, schedule, quality, and work performance. They always use safety signs, schedule and visual tools to define the project, project name, owner, contractor, duration, donor and other information. In the United Kingdom, Bashir (2013) confirmed that using safety signs appear to be among the most commonly applied techniques. On the other hand, Salem et al. (2005) found that the signs required for increased visualization didn't get adequate attention from the project practitioners. A few safety signs were posted at the project site.

"Using camera connected with computer algorithm to warn safety officer when workers violate safety conditions" is ranked as the last technique in IV techniques and among all LC

techniques listed in this research. In this technique, cameras are installed in the construction sites to detect whether the construction workers are using their personal protective equipment and the real-time images are transferred to the computers by means of wireless technology. The images of the construction site are continuously displayed on an office computer. The low ranking of camera technique around Gaza Strip related to the cause that most of construction projects doesn't have a specialized safety engineer to review the images taken by camera. Further, contractors believe that additional tools in sites required additional cost and selecting contractors based mainly upon lowest price. This is in line with the Enshassi et al. (2014a) who concluded that safety criteria has a very low emphasis in contractors' selection.

The low rank doesn't mean that this technique is unimportant. Shrestha et al. (2011) proposed this technique in a study among USA to detect if any employee in the site not wearing their hard hats. They concluded that using camera in the site will significantly reduce the accidents caused by unsafe site conditions, which basically is due to inadequate supervision. They recommended to expand technique for detection of all personal protective equipment (PPEs) so that workers can be safer.

This section assured on the importance of using LC techniques in construction projects to improve safety. The workplace should be provided with adequate quantity of safety signs and labels to keep workers safe. Regarding the high cost of using cameras on sits in Gaza Strip, it can be replaced with a safety engineer on the site to obligate the employees to use all PPE along with their work.

5.2.1.3 5S

5S is a systematic method focuses on organizing and standardizing the workplace (Bashir, 2013, Bashir et al., 2011, Abdulmalek and Rajgopal, 2007, Kilpatrick, 2003). It is about a place for everything and everything in its place. (Anerao and Deshmukh, 2016, Ogunbiyi, 2014, Salem et al., 2005). Good housekeeping is a well-known practice that leads to safer jobsites (Pestana and Gambatese, 2016). 5S section investigated the applicability level of 5S tool to reduce the causes of accidents in construction projects around Gaza Strip through its techniques. The overall average for the 5S techniques is 2.22 exceeding the threshold value of 2. This result reflects that 5S tool is applied to reduce the causes of accidents in Gazan Construction Projects. Oladiran (2017) assured that 5S tool is considered among the most used tool in Nigeria. On the other hand, Sarhan et al. (2017) found that 5S has a low rank regarding its implementation in Saudi Arabia. A 5S tool comprise of five LC techniques, two of them were critical and will be discussed which are:

- *"Cleaning the workplace and removing materials and machines that are not required*", MS= 2.57 , SD=0.902, RII= 64.25%, rank within 5S group=1 and overall rank=1
- *"Organizing material and plant",* MS= 2.37 , SD=0.807, RII= 59.25, rank within 5S group=2 and overall= 4

"Cleaning the workplace and removing materials and machines that are not required" is found to be the most applicable technique among the 5S techniques and the 25 listed techniques with mean (2.57> 2). This indicated that the application of this technique is applied among Gaza Strip to reduce the causes of accidents. The reason behind positioning this technique as the first is related to the pursuit of project practitioners to decrease wastes and chaos in their site in order to give a good impression of their projects and as a result accidents and injuries could be decreased. Salem et al. (2005) confirmed this result as foremen in the construction projects demanded all their members to clean up the site continuously and employ a specialized housekeeping crew to pick up trash from the whole job site. Similarly, Awada et al (2016) ensured the importance of clean sites from wastes and chaos in the workplace. Conversely, Enshassi and Abu Zaiter (2014) found that the traditional working behavior became an obstacle for the enforcement of clean up the site. Workers are used to being messy and throwing garbage on the ground, and they think that they were hired to do physical construction work, but not to clean up.

The research findings revealed that "*Organizing material and plant"* has the fourth rank in the 5S techniques and among the overall LC techniques with (MS= 2.37, SD=0.807, RII= 59.25%). In Gaza Strip, workplace organization creates a safe and good workplace environment. Respondents also ensured that materials and plants were placed in a regular pattern where they were to be used, for ease of access during operations so that the job can be completed efficiently. Sarhan and Fox (2013) assured that workplace organization is a fundamental LC technique applied in UK to reduce accidents in construction projects. Similarly, Oladiran (2017) ensured that organizing materials and tools was highly implemented among Nigerian Construction Projects.

Housekeeping is important in the workplace to get effective results with zero accidents. Construction participants should encourage their employees to keep the site clean and organized. Safety culture among employees should be enhanced through training. They should be trained to carry out works properly and to deal with changes in working conditions, such as extreme heat, rain and slippery surfaces to prevent injuries.

5.2.1.4 Fail safe for quality and safety (Poka yoke)

Poka-yoke is a LC tools concentrates on all techniques that could contribute to reduction of accidents on construction sites (Bashir, 2013). These technique include visual inspection and error-proofing devices such as gadgets alerts (Bashir et al., 2011, Saurin et al., 2006). Poka yoke tool has an overall average mean of (1.65<2) which is lowest applied tool. Poka yoke section investigated the applicability level of Poka yoke tool to reduce the causes of accidents in construction projects around Gaza Strip through its techniques. A Poka yoke tool comprise of three LC techniques, one of them is critical and has a low rank which needed to be discuss:

- *"Using Alarms and warning gadgets to warn workers from crossing the unsafe boundaries",* MS= 0.85 , SD=0.877, RII= 21.25%, rank within Poka yoke group=3 and overall rank=24

As shown in the results, "*Using Alarms and warning gadgets to warn workers from crossing the unsafe boundaries"* has a very low rank in both of Poka yoke group and overall techniques which are 3rd and 24th, respectively. Similarly to the technique of using cameras on the site which is related to the increased visualization tool. In Gaza Strip, the contractor selection depends mainly on the cost and addressing alarms in the bids to increase safety will raise the bid cost. Oladiran (2017) confirmed that the usage of fail-safe quality and safety (Poka Yoke) is very poor in Nigeria. In the same context, Saurin et al. (2006) stated alarms and warning gadgets are not used adequately to reduce the causes of accidents and it should be considered as a part of the technology design on the site.

Managers, engineers and supervisors must be a good example for workers in using the PPE. Further, workers should be trained on safety techniques and wear the appropriate clothing for each task. A Periodically inspection should be conducted to assure that all employees are committed to the safety standards and regulations. Moreover, an adequate fund should be specialized to the safety equipment in the project to provide the sites with appropriate equipment.

5.2.1.5 Accident investigation (5whys)

Accident investigation or 5whys tool is identified as a key technique in safety management (Razuri et al., 2007). By conducting the accident investigation, the root causes of accidents could be identified as well as the ways to prevent them from reoccurrence (Bashir, 2013). This section is specialized to discuss the applicability level of 5 whys to reduce the causes of accidents in Gaza Strip. It consists of one technique which is *"Conducting accident investigation and root-cause analysis program"* with (MS=2.42, SD=1.037, RII=60.5 and rank within 5whys group=1, and overall rank=2). This technique appeared to be among the most commonly applied LC techniques in Gaza Strip to reduce the causes of accidents. The reason behind this result is that submitting a project with zero accidents occupies top priorities of construction industry in the external donors' background. If any accident occurred during the project implementation, a detailed accident investigation is required from project practitioners to recognize the root causes of accident and eliminate these causes in the future. Bashir (2013) concluded that the root cause analysis was the most used techniques in British Construction Projects to reduce the causes of accidents. In UK, Sarhan and Fox (2013) also stressed the importance of root cause analysis and it was among commonly used techniques.

Construction manager should concerned more with the accident investigation tool to prevent the future accidents from occurring. The occurred accidents should be analyzed carefully to reach the root causes of their occurring. Safety planner should prepare check lists with the expected causes of accidents in all of project tasks to specifically determine the causes of accidents. Further, they should prepare the actions can be taken to prevent these accidents from occurring, and if occurred how these accidents can be prevented from reoccurring.

5.2.2 Factor analysis of LC techniques applied to reduce the causes of accidents in construction projects

Factor analysis results of LC techniques applied to reduce the causes of accidents in construction projects will be discussed in this section. 25 LC techniques are listed in this research to investigate the applicability level of LC to reduce the causes of accidents in the Gazan Construction Projects. By using factor analysis, 25 techniques are reduced to 13 techniques and 12 are removed. The remained LC techniques which are 13 are underlined under three components which are labeled as communication and planning, workers' involvement and using safety equipment. The components are discussed below:

5.2.2.1 Component1: Communication and planning

The first component of the applied LC techniques to reduce the causes of accidents is labeled as communication and planning. Naming of this component based on the variables included in it which are all related to communication and planning. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. This component constitutes 22.431% of the total variance of 13 techniques which is the highest variance among three components extracted from the analysis. Communication and planning component consists of five variables (techniques) which all have a loading value more than 0.658. The variables underlined under this component are as followed:

- App20: "*Conducting daily meeting to increase communication between teamwork, increase workers awareness of safety to make them identify risks and reduce it"*, with loading value of 0.797.
- App21: "*Make a plan for the critical tasks"*, with loading value of 0.696.
- App24: "*Conducting pre task hazard analysis to identify risks predicted at activity and reducing it",* with loading value of 0.692
- App23: *"Involvement of all employees in improvement process"*, with loading value of 0.671.
- App22: *"Illustration of work methods using videos, photos, etc."*, with loading value of 0.658.

Communication and planning component appear to conclude the most important techniques used to reduce the causes of accidents in Gazan Construction. Communication and planning component comprised of five techniques which reflect the applicability level of LC techniques reduce the causes of accidents in Gaza Strip. All techniques under this component have loading value more than 0.6 which are considered significant in contributing to the interpretation of this component. It is the most important component since it constitutes the highest percentage of the total variance of the techniques.

Construction projects in Gaza Strip suffered from lack of communication and planning. Enshassi et al. (2015) and Enshassi (2010) found that one of the main causes of accidents in construction projects is poor planning and poor communication. This is related to the weakness in exchanging information between construction participants that are related to safety. This result confirmed with Enshassi et al. (2014a) and Sawalhi and Enshassi (2004). Moreover, lack of communication and planning returned back to the rushed time of grants which lead to individual decisions in projects and prevented employee involvement in Gaza Strip in consistent with Enshassi et al. (2016b).

The influence of proper communication and planning on the application of LC techniques has been well documented (Sarhan et al., 2017, Ogunbiyi, 2014, Aziz and Hafez, 2013, Bashir, 2013, Ogunbiyi et al., 2013, Nahmens and Ikuma, 2009, Salem et al., 2005). Proper communication and planning are significantly affect the using LC techniques in construction projects to reduce the causes of accidents (Adegbembo et al., 2016, Bashir, 2013). Communication and planning role is based on employee involvement to discuss the good and bad aspects of their tasks and to suggest ways to solve these problems together (Ogunbiyi, 2014, Bashir, 2013, Ogunbiyi et al., 2013, Bayfield and Roberts, 2005). It allows the team to improve method and performance as the standard, assemble people, analyze process steps, and brainstorm how to eliminate steps, check for safety, quality and productivity (Vieira and Cachadinha, 2011, Abdelhamid and Salem, 2005, Salem et al., 2005). Additionally, communication and planning conclude decisions regarding the elimination and control of safety hazards before accidents occur (Ikuma et al., 2011, Nahmens and Ikuma, 2009). Sarhan et al. (2017) and Belhadi and Touriki (2016) confirmed on the importance of proper planning and communication on the implementation of LC techniques in Saudi Arabia and Morocco, respectively.

These results highlighted the need for using LC techniques to reduce the causes of accidents in construction projects in Gaza Strip. They should seek to apply the communication and planning techniques including: Conducting daily meeting to increase communication between teamwork, increase workers awareness of safety to make them identify risks and reduce it; Make a plan for the critical tasks; Conducting pre task hazard analysis to identify risks predicted at activity and reducing it; Involvement of all employees in improvement process; and Illustration of work methods using videos, photos, etc.

5.2.2.2 Component2: Workers' involvement

The second component extracted from factor analysis of the LC techniques is labeled as workers' involvement. Since, the variables included in it are closely related to the involvement of workers. Additionally, variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. It constitutes 20.911% of the total variance of 13 techniques. Workers' involvement component contains four variables (techniques) with having a loading value for all techniques more than 0.639. The variables underlined under this component are as followed:

- App4: *"Worker's empowerment and involvement in task planning and scheduling",* with loading value of 0.808.
- App6: *"Involvement of all employees in safety planning",* with loading value of 0.795.
- App5: *"Correlating work methods with worker's skills and abilities",* with loading value of 0.742.
- App2: *"Developing a plan for supervision",* with loading value of 0.639.

Workers' involvement component comprised of four techniques which reflect the applicability level of LC techniques reduce the causes of accidents in Gaza Strip. All techniques under this component have loading value more than 0.6 which are considered significant in contributing to the interpretation of this component. Thus, component of "Workers' involvement" has high application degree in reducing the causes of accidents in the Gazan Construction Projects.

Workers involvement is not adequately existed in Gaza Strip due to the long time needed to establish the employee suggestions and the rushed time of grants which lead to individual decisions by the employers in line with Enshassi et al. (2016b). Enshassi and Abu Zaiter (2014) stated that workers should be involved and empowered to identify risks and make suggestions to control them which encourage them to participate in LC implementation.

The effect of workers' involvement on the applicability of LC techniques to reduce the causes of accidents has been documented in many literatures (Camuffo et al., 2017, Bashir, 2013, Bashir et al., 2011, Forman, 2010, Nahmens and Ikuma, 2009). Workers involvement in planning and scheduling can allow them to correlate the work methods with their abilities which highly reduce the accidents caused by pressure and physical and mental disability (Camuffo et al., 2017, Bashir, 2013, Bashir et al., 2011, Forman 2010). In Kuwait, Al-Najem et al. (2013) concluded that employees should be empowered and involved to successfully apply LC.

According to the high influence of workers involvement on reducing the causes of accidents in construction projects, all techniques underlined in it should be taken into consideration including: Worker's empowerment and involvement in task planning and scheduling; Involvement of all employees in safety planning; Correlating work methods with worker's skills and abilities; and Developing a plan for supervision.

5.2.2.3 Component3: Using safety equipment

The third component of LC techniques used to reduce the causes of accidents which reflects the awareness level of LC is labeled as using safety equipment. The underlined variables within it are all related to safety equipment. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. This component constitutes 19.779% of the total variance of 13 techniques which is the highest variance among three components extracted from the analysis. Using safety equipment component consists of four variables (techniques) which all have a loading value more than 0.567. The variables underlined under this component are as followed:

- App11: "*Using safety signs and labels on",* with loading value of 836.
- App10: *"Using visual demarcations and boards on site",* with loading value of 809.
- App19: *"Using safe guards and Personal Protective Equipment (PPE)",* with loading value of 706.
- *App1: "Providing employees with safety equipment",* with loading value of 0.567.

Using safety equipment component comprised of four techniques which reflect the applicability level of LC techniques reduce the causes of accidents in Gaza Strip. All techniques under this component have loading value more than 0.5 which are considered significant in contributing to the interpretation of this component. This component has the lowest application degree in reducing the causes of accidents in the Gazan Construction Projects. However, it is very important to be taken to reduce the causes of accidents.

In Gaza Strip, there is lack of knowledge by worker on wearing personal safety items. This related to workers' low level of safety awareness and their work culture. Most of the workers were either illiterate or had only basic reading and writing skills. They need to become more aware that wearing protective clothing and the use of safety tools are crucial in reducing the causes of accident. This result is in accordance with Enshassi et al. (2007).

Using safety equipment on the site is a significant component stated by many researchers to reduce the causes of accidents in construction projects (Sarhan et al., 2017, Enshassi and Abu Zaiter, 2014, Bashir, 2013, Arleroth and Kristensson, 2011, Bashir et al., 2011, Sacks et al. 2009, Saurin et al., 2006, Sack et al., 2005, Kilpatrick, 2003). Safety equipment include the personal protective equipment and the equipment should be on site like signs, labels and boards. Aziz and Hafez (2013) in Egypt demonstrated that safety equipment should be provided with appropriate quantitates for employees; and signs and labels like (Safety first) should be placed the on different spots of the projects to increase safety awareness of all employees and reduce the human error. Using safety equipment could protect workers from wide range of hazards and absorb several possible errors (Bashir et al., 2011, Saurin et al., 2006). It also allow workers to identify issues, the boundaries for safe performance and compare the expected safety performance (Enshassi and Abu Zaiter, 2014).

5.3 Benefits of implementing LC techniques related to safety improvement in construction projects

The second objective of this research is to investigate the benefits of implementing LC techniques which are related to safety improvement in construction projects. Data of the expected benefits of using LC techniques in safety improvement among Gazan Construction Projects are collected using section D in the questionnaire (Appendix C). Discussion of the results obtained will be presented in the two following sections in order to explain the ranks of benefits according to their importance and to discuss the labelling and the extracted components that resulted from factor analysis of benefits of LC techniques.

5.3.1 Ranks of the benefits of implementing LC techniques related to safety improvement in construction projects

Ranking results of the benefits of implementing LC techniques related to safety improvement in construction projects will be discussed in this section. Benefit results presents that the overall average mean of the benefits is (MS=2.8) which is higher than the average mean (equal to 2 for five-point scale where A_{min}=0 and A_{max}=4) (Holt, 2014). Thus, respondents assured on the importance of the safety benefits that can be attained by using LC techniques in construction projects. Further, the standard deviations for all benefits are small which reflects that there was a little variability in the data and consistency in agreement among the respondents was existed (Neuman, 2013).

Regarding *t*-value, it is calculated using the one-sample *t*-test and the 22 listed benefits have *t*-value larger than the critical *t*-value (1.98) (Neideen and Brasel, 2007). Additionally, all benefits have (p<0.05). This indicated the agreement of the respondents' on the significance of all benefits to measure the importance of the benefits of implementing LC techniques.

In the opinion of the respondents, the first three most important benefits expected from the application of LC techniques are:

- *"Improving the rate of workflow on-site",* MS=3.07, SD=0.677, RII=76.75 and rank=1
- *"Better work plan",* MS=3.05, SD=0.650, RII=76.25 and rank=2
- *"Better safety management plan",* MS=3.03, SD=0.746, RII=75.75 and rank=3

The results shows that *"Improving the rate of workflow on-site"* is the highest rank among the 22 listed benefits with (MS=3.07, SD=0.677 and RII=76.75). According to LC, improving workflow on site is about creating a smoother schedule with less workflow variation. In Gaza Strip, one of the most important factors to measure the success of contractors and subcontractors in their projects is their adherence to project schedule in line with (Abu Hamra and Enshassi, 2016). The delay behind the time schedule may lead to financial penalties and poor reputation for both the contractors and subcontractors which affect their selection to any project. However, delay in construction projects can be related to many problems associated with Gaza situation including the blockade, border closure and monthly payment difficulties from agencies which is agreed with Enshassi et al., (2014c).

Al-Aomar (2012) confirmed that creating a smooth workflow is one of main benefits of using LC techniques in Abu Dhabi. In the same line, Hamzeh et al. (2016) concludes that implementing LC and especially LPS can help in improving workflow and reducing waiting times across project areas according to a case study conducted in Lebanon. Fernandez-Solis et al. (2013) reported that the highest benefit realized by LC techniques implementation on 26 test case projects among USA is improving the workflow. This study gives credence to Oladiran (2017) study in Nigeria that usage of LC techniques resulted in improvement of workflow.

The second rank of the 22 listed benefits was "*Better work plan*" with *(*MS=3.05, SD=0.650 and RII=76.25). Construction projects in Gaza Strip suffered from lack of planning. Enshassi et al. (2015) and Enshassi (2010) found that one of the main causes of accidents in construction projects is poor planning. Construction planning in Gazan Projects affects the delivery of a project on schedule and within budget which overcome the political and economic situation. Better planning allow project practitioners to mitigate the impact of work changes in Gaza like delay in material delivery. Bashir (2013) ensured that better planning is one of the main positive outcomes attached to the application of the LC techniques which is stated by the various interviewees. In Saudi Arabia, AlSehaimi et al. (2009) applied LPS in two projects and concluded that planning is improved significantly by using the LPS techniques which is considered as a benefit.

"Better safety management plan" with (MS=3.03, SD=0.746 and RII=75.75) was ranked in third position. In Gaza Strip, most of construction projects do not have a separately safety plan. Respondents needs to have a safety plan in their projects to cope with donors' priority to improve safety. Hence, project employees and workers will be less exposed to expected hazards, and accidents will be decreased. By taking safety into account, project would cost less as compensation will reduce, productivity will increase and quality will increase too. Bashir (2013) in UK demonstrated that organizations generally believe that Lean Construction techniques has a positive outcome on improving safety management plan. Likewise, Hamzeh et al. (2016) found through a case study in Lebanon that applying LC techniques have a significant impact on safety planning.

On the contrary, *"Increasing profit"* was ranked as 21st from the 22 benefits with (MS=2.55, SD=1.048, and RII=63.75%). This may related to the respondents thinking that using any new management techniques is a waste of money which decrease their expected profit from the projects. Despite the late position of this benefits comparing with the remaining benefits, it is an important benefit as its mean score more than the threshold value (2.55>2). Chikhalikar and Sharma (2015) in India found that increasing profit is a benefit ranked among the last positions but by using Lean production system. In Abu Dhabi, Al-Aomar (2012) reported that increasing profit has a low rank compared with other benefits of using LC techniques. On the other hand, Zhou (2012) concluded that implementing LC techniques resulted in increasing profit and ranked as one of the top benefits in the USA.

Finally, *"Control the construction site environmentally (less weather effects)"* with (MS=2.48, SD=0.935, and RII=62%) is rank as the last benefit. In Gaza Strip, the weather is usually fair and construction sites didn't need to be protected from the weather effect. Work in the majority of construction sites especially in the opened is stopped when there is an air depression in order to decrease the impact of rainfall on site preparation and ground works. In this case, additional time will not influence the project schedule, because most of schedules are built by taking into consideration additional days for bad weather. Oladiran (2017) in Nigeria and Satao et al. (2012) in USA found that control the site environmentally has a low rank among the benefits of LC techniques. Likewise, Bashir (2013) concluded that better site control is a positive outcome of LC techniques but only one organization from the interviews in his study in UK believe that it is a positive outcome of implementing LC techniques. Although the benefit of *"Control the construction site environmentally (less weather effects)"* has the last rank, it is an important benefit gained by the implementation of LC techniques because it has a mean of 2.48 which is more than the average mean of 2.

Project practitioners should study the LC techniques which are appropriate to be applied in their projects. They should apply these techniques properly and comprehensively. Further, they should prepare a detailed plan to apply LC techniques. Accordingly, construction projects can gain the full benefits of LC techniques implementation.

5.3.2 Factor analysis of benefits of implementing LC techniques related to safety improvement in construction projects

Factor analysis results of benefits of implementing LC techniques related to safety improvement in construction projects will be discussed in this section. Twenty two benefits are listed in this research to investigate the importance of LC techniques implementation. The 22 benefits are analyzed using factor analysis and reduced to 15 benefits while 7 were removed. The remained benefits are underlined under four components which are labeled as communication and trust, time and quality, safety management plan and reducing site hazards. The components are discussed below:

5.3.2.1 Component1: Communication and trust

The first component of the benefits of implementing LC techniques related to safety improvement in construction projects is labeled as communication and trust. Naming of this component based on the variables included in it. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. Component 1 (Communication and trust) constitutes 25.028% of the total variance of 15 benefits which is the highest variance among the four components extracted from the analysis. Communication and trust component consists of six variables (benefits) which all have a loading value more than 0.628. The variables underlined under this component are as followed:

- Ben16: *"Increasing communication and collaboration among project practitioners"*, with loading value of 0.835
- Ben15: *"Creating a trust bond and enhancing transparency between the project parties"*, with loading value of 0.818
- Ben22: *"Promoting free flow of information on-site between project practitioners"*, with loading value of 0.723
- Ben20: *"Stakeholders satisfaction"*, with loading value of 0.693
- Ben21: *"Reducing stress level on management and conflicts in projects"*, with loading value of 0.682
- Ben17: *"Enhancing employees' sense of belonging and their problem-solving ability"*, with loading value of 0.628

This component was named as "Communication and trust" because all the variables (benefits) included in this components are closely related to communication and trust,. The six benefits included in this component reflect the importance of implementing LC techniques in construction projects among Gaza Strip. All benefits under this component have loading value more than 0.6 which are considered significant in contributing to the interpretation of this component. This component is the most important component since it constitutes the highest percentage of the total variance of the benefits of implementing LC techniques. Thus, component of "Communication and trust" has the most important benefits which reflect the importance of implementing LC techniques in the Gazan Construction Projects.

Construction projects in Gaza strip suffer from lack of communication between different professionals and stakeholders. This result has been confirmed by the findings of Enshassi and Abu Hamra (2017) and Enshassi et al. (2015). Poor of communication is related to the weakness of exchanging information which leads to the existence of limited trust among them in consistent with (Enshassi et al., 2016b). Ineffective communication is highly resulted in problems between the project practitioners especially contractors and subcontractors. Enshassi et al. (2007) confirmed that many companies in the Gaza strip look for a secure and fast profit; thus subcontracting projects seems as a safe option in achieving a certain percentage of the profits which gives rise to many problems like communication.

Using LC techniques in construction projects significantly improve communication and create a trust bond between the project practitioners (Sarhan et al., 2017, Oladrin, 2017, Adegbembo et al., 2016, Dave et al., 2015, Bashir, 2013, Fernandez-Solis et al., 2013). Communication usually involves the free transfer of information between project participants (Enshassi et al., 2016b). Effective communication creates a bridge between diverse stakeholders involved in a project, connecting various cultural and organizational backgrounds, different levels of expertise and various perspectives and interests in the project execution or outcome which create a trust bond among them (Senaratne and Ruwanpura, 2016). The quality of communication and trust is a key factor in the success of construction projects (Nielsen and Erdogan, 2007). Sarhan et al. (2017) demonstrated that injection of communication and trust in the project environment improve the employees' sense of belonging and their problem-solving ability. Communication difficulties during the projects can directly increase unnecessary expenditure, and affect the progress and quality of the project (Senaratne and Ruwanpura, 2016).

Construction participants should implement LC techniques successfully in order to affect the communication and trust problems. By using LC techniques, the communication and trust can be enhanced by: Increasing communication and collaboration among project practitioners; Creating a trust bond and enhancing transparency between the project parties; Promoting free flow of information on-site between project practitioners; Stakeholders satisfaction; Reducing stress level on management and conflicts in projects; and Enhancing employees' sense of belonging and their problem-solving ability.

5.3.2.2 Component2: Time and quality

The second component extracted from factor analysis of the benefits is labeled as time and quality according to the higher values of factor loadings. Moreover, the variables included in it are all related to time and quality. It constitutes 13.591% of the total variance of 15 benefits. Component of time and quality has three benefits under it with loading values for the three benefits more than 0.560. The variables underlined under this component are as followed:

- Ben4: *"Delivering the projects on time or in some cases ahead of schedule",* with loading value of 0.835.
- Ben5: *"Submit work with high quality and less defects to minimize the rework",* with loading value of 0.633.
- Ben8: *"Increasing profit",* with loading value of 0.560.

The three benefits included in the second components are closely related to time and quality. They reflect the importance of implementing LC techniques in construction projects among Gaza Strip. Therefore, the component was interpreted with "Time and quality". All benefits under this component have loading value more than 0.5 which are considered significant in contributing to the interpretation of this component.

Political condition in Gaza Strip including blockade and border closure hindered the adherence to time schedule. Moreover, material shortage in the local market enforce the construction participants to use the local material which is sometime with low quality. Enshassi et al. (2013) stated that construction projects in Gaza Strip can be regarded as successful when the project is completed on time and with appropriate quality. In addition, selection of suitable contractor or subcontractor depends on their adherence to time schedule, good reputation and commitment to quality.

Using LC techniques enable the project practitioners to shorten the construction periods and improve the quality of work with fewer defects (Chikhalikar and Sharma, 2015, Mehra et al., 2015, Modi and Thakkar, 2014, Al-Aomar, 2012, Ayarkwa et al., 2012a, Mossman, 2009). Time and quality are amongst the most important factors affecting the construction projects (Adegbembo et al., 2016, Joiya and Saifullah, 2016). Submitting work on time and with best quality is an indication on the high productivity and skills of the workers which give a good image of the project (AbuHamra and Enshassi, 2016). Enshassi et al. (2012) revealed that adherence to time schedule and commitment to quality are important factors used by main contractors for selection of suitable subcontractors.

The findings assured on construction participants to adopt LC techniques in their projects to deliver the projects on time or in some cases ahead of schedule; Submit work with high quality and less defects to minimize the rework; and increase profit.

5.3.2.3 Component3: Safety management plan

The third component of the benefits of implementing LC techniques related to safety improvement in construction projects is labeled as “Safety management plan”. The interpretation of this component based on the variables included in it. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. The highly loading value was for the benefit of “better safety management plan”, therefore the naming of the component was similarly to this benefit. It constitutes 13.022% of the total variance of 15 benefits. “Safety management plan” underlined three benefits which all have a loading value more than 0.670. The variables underlined under this component are as followed:

- Ben2: *“Better safety management plan”,* with loading value of 0.793.
- Ben1: *“Better work plan”,* with loading value of 0.720.
- Ben3: *“Improving the rate of workflow on-site”,* with loading value of 0.670.

The three benefits underlined in the third components the importance of implementing LC techniques in construction projects among Gaza Strip. The component was interpreted with "Safety management plan" because it has highest value of loading. All benefits under this component have loading value more than 0.6 which are considered significant in contributing to the interpretation of this component.

In Gaza Strip, most of construction projects don't have a separately safety plan, however, they included safety in the work plan. There was shortage in safety application and little concern is shown for safety issues. Enshassi et al. (2007) revealed that many companies in the Gaza strip look for a secure and fast profit; thus subcontracting projects seems as a safe option in achieving a certain percentage of the profits which affect safety planning and allocation of safety responsibilities. However, safety plan is very important to reduce the causes of accidents in construction projects.

Safety management plan can be improved using LC techniques in construction projects (Hamzeh et al., 2016, Bashir, 2013). Hammad et al. (2011) stated that safety planning is important to increase the productivity at construction sites. Moreover, effective safety planning is essential to deliver the projects on time, without cost overrun, and without accidents or damaging the health of site personnel (Saurin et al., 2005). Safety planning should define any special equipment, tools, and safety devices to perform work efficiently and safely (AbuHamra and Enshassi, 2016). With detailed work planning, all materials and equipment necessary to perform each task safely would be on hand when required (Enshassi et al., 2007).

Application of LC techniques in construction projects would benefit the safety improvement. Gazan Construction Participants should encourage the application of LC techniques to gain Better safety management plan; Better work plan; and Improving the rate of workflow on-site.

5.3.2.4 Component4: Reducing site hazards

The last component of extracted by the factor analysis regarding the benefits of implementing LC techniques related to safety improvement in construction projects is labeled as "Reducing site hazards". Variables with higher loadings in this component are used to identify the nature of the underlying latent variable represented by each factor. The highly loading value was for the benefit of "Reducing site hazards", therefore the naming of the component was similarly to this benefit. It constitutes 12.278% of the total variance of 15 benefits. "Component of "Reducing site hazards" consists of three benefits which all have a loading value more than 0.506. The variables underlined under this component are as followed:

- Ben13: *"Reducing site hazards such as noise and dust"*, with loading value of 0.839.
- Ben14: *"Control the construction site environmentally (less weather effects)",* with loading value of 0.750.
- Ben6: *"Maximizing the workers productivity and work efficiency",* with loading value of 0.506.

The three benefits included in this component reflect the importance of implementing LC techniques in construction projects among Gaza Strip. All benefits under this component have loading value more than 0.5 which are considered significant in contributing to the interpretation of this component. This component is the lowest important component since it constitutes the lowest percentage of the total variance of the benefits of implementing LC techniques.

Construction site safety on the Gaza strip are considered poor and most of employees face daily risks from existed hazards on sites that need to be managed and eliminated to prevent death and injury. In addition, Gazan Construction industry suffers from poor safety conditions as safety rules do not exists and work hazards at the workplace are not perceived in line with Ibrahim and Al Hallaq (2015).

Site hazards can be reduced by using LC techniques in construction projects (Oladrin, 2017, Ahuja, 2013). Reducing site hazards is important to save the life of employees and accordingly maximize their productivity; and submit the project on time and without over cost (Couto et al. 2017, Khosravi et al., 2014). Moreover, reducing site hazards prevent the accidents from occurring and reduce the social cost in form of emotional and psychological impact to families (Couto et al. 2017, Bashir, 2013).

Construction participant in Gaza Strip will be motivated to participate in the application of LC techniques when they are enlightened about their benefits which related to site hazards reduction. Application of LC techniques can benefit safety by Reducing site hazards such as noise and dust; Control the construction site environmentally (less weather effects); and Maximizing the workers productivity and work efficiency.

5.4 Barriers to the application of LC techniques to improve safety in construction projects

The third objective of this research is to investigate the barriers to the application of LC techniques to improve safety in construction projects. Section E in the questionnaire specialized to collect the respondents' perspectives regarding the barriers effects on the application of LC techniques to improve safety in the Gazan Construction Projects. Discussion of the results attained by questionnaires will be in the two following sections in order to illustrate the ranks of barriers according to their effect and to discuss the labelling and the extracted components that resulted from factor analysis of the barriers.

5.4.1 Ranks of the barriers to the application of LC techniques to improve safety in construction projects

Barriers to the application of LC techniques to improve safety in construction projects are ranked depending on the effect index according to their values. The analysis results of the barriers showed that all of the barriers have effect indices between 63.048 and 80.607 which are classified as strong effect level (SE) referring to Hassanain et al. (2017) classification (No effect $EI < 12.5$; Slight effect $12.5 \leq EI < 37.5$; Moderate effect $37.5 \leq EI < 62.5$; Strong effect $62.5 \leq EI < 87.5$; and Extreme effect $87.5 \leq EI$).

The results revealed that the highest average of effect index of the barriers groups is related to the educational group followed by governmental barriers, then financial, human attitudinal and management group. The first rank for the group of educational barriers is due to the weakness of the learning environment and lack of budget to provide training in Gaza Strip to recognize the benefits of LC. This result is consistent with Enshassi and Abu Hamra (2017) and Enshassi and Abu Zaiter (2014) who stated that lack of education or training whether in the university or any governmental or private training centers is a main barrier to implement any innovative strategies. On the other hand, the lowest average of effect index is related to technical barriers group. Bashir (2013) found that the highest barriers to the application of LC techniques are related to human issues, followed by management, technical, financial and educational, while none is related to the government. This shows that most of the challenges facing LC techniques are related to the human nature of the worker. This is then followed by challenges related to the management of the organizations.

The detailed results regarding the significant barriers to the application of LC techniques to improve safety in construction projects in Gaza Strip are presented according to their categories (management, educational, financial, governmental, operation and human attitudinal) in the following sections:

5.4.1.1 Management Barriers

Successful implementation of LC or any new innovative strategy needs to be supported by top management (Attri et al., 2017, Small et al., 2017, Sandeep and Panwar, 2016, Bashir et al., 2015, Mehra et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013). The role of management is a key factor potentially enhancing or hindering the effect of LC techniques on safety improvement (Camuffo et al., 2017). This section investigated the management barriers to the application of LC techniques to improve safety in construction projects in Gaza Strip. It contains twelve barriers related to management.

The results indicated that the highest effect index in the management barriers was for the barrier of *"Lack of management support and commitment to the application of LC techniques in safety improvement"*, with (EI=77.103). It is ranked in the 1st position in the management barriers and in the 5th position in the overall barriers. In Gaza Strip, lack of management support and commitment referring to their limited experience regarding LC, so they don't tend to change the strategies used in construction projects. Construction managers believed that using new techniques is a waste of time and cost because they need a long time to be trained and usually they need to bring skillful professionals to guide the application of LC techniques in order to improve safety. On the other hand, the main focus of construction managers in Gaza Strip is to submit the projects with lowest cost, highest profits, least time and with the required quality (Enshassi et al., 2014b).

In the same line, Attri et al. (2017) and Mehra et al. (2015) in India confirmed on the effect of the lack of commitment of top management on the application of LC techniques especially the techniques of 5S tool. Sarhan and Fox (2013) and Abdullah et al. (2009) found that "lack of commitment of top management" is the highest rank in the barriers to the application of LC techniques in the construction projects among UK and Malaysia, respectively. In China, Shang and Pheng (2014) stated that "lack of the support from top management" is the fifth rank among 22 barriers which indicate that this barriers highly affected the application of LC techniques in construction projects. Conversely, respondents in the study of Ayarkwa et al. (2012b) ranked the barrier of "Lack of management support and commitment" in 16th position among 33 barriers which indicated the moderately effect of this barrier on the application of LC techniques.

In order to overcome this barrier, it is required to use measures like training and education for employers to enlighten them about the benefits of adopting LC techniques in construction projects. Moreover, LC experts should provide the construction firms with roadmaps to guide them to apply LC techniques successfully. Additionally, construction managers should incorporate with professional bodies like Lean Construction Institute (LCI) to benefit from their experience in LC implementation.

5.4.1.2 Financial Barriers

Financial issues are among the most common barriers to LC practice across different organizations in various countries but it varies across countries (Bashir et al., 2015, Wandahl, 2014, Bashir, 2013, Sarhan and Fox, 2013). This section investigated the financial barriers to the application of LC techniques to improve safety in construction projects in Gaza Strip. It contains five barriers related to finance. The results indicated that the highest effect index in the financial barriers is for the barrier of *"Lack of incentives and motivation"* with (EI=77.804). It is positioned as the 1st in the financial barriers and as the 4th in the overall barriers. In Gaza Strip, employers are pearly afford the salaries for their employees due to the blockade and the poorly economic conditions. So, they can't appreciate their employees' efforts with additional incentives to motivate them to put greater efforts to adopt new techniques in their work.

In the same line, Mehra et al. (2015) demonstrated that lack of incentives and motivation hindered the application of LC techniques in the Indian Construction Projects. Similarly, Attri et al. (2017) in India found that lack of incentives and motivation is the third barrier prevented the implementation of LC techniques. According to Bashir et al. (2015) and Bashir (2013), one of the barriers affecting the implementation of LC techniques in some organizations in the UK is that the workers are not given any incentives besides their normal wages for being more smart and efficient. However, only one organization among the interviewed identified this barrier.

To overcome this barriers, the top management should motivate its employees by incentives to effectively participate LC program and changes their behavior towards using LC techniques from negative to positive. They should involve them in decision making and planning to motivate them to participate in LC implementation.

5.4.1.3 Educational Barriers

Despite the continuous efforts to raise the awareness of LC in several countries, it seems that educational barriers could pose a great threat to the implementation of LC (Bashir et al., 2015, Bashir, 2013, Wandahl, 2014, Ogunbiyi et al., 2013, Bashir et al., 2010). According to the findings of second section of this questionnaire, the respondents are not aware of LC tools as expressions around Gaza Strip. This section specialized to identify the significant educational barriers to the application of LC techniques to improve safety in construction projects in Gaza Strip. It contains six barriers related to education and awareness. The results indicated that the highest effect indices are related to *"Lack of LC concept understanding"* and *"Lack of knowledge to apply LC techniques in safety improvement",* with (EI=80.607 and 78.972), respectively.

The barrier of *"Lack of LC concept understanding"* is ranked as the highest barrier within the educational barriers and among the 39 listed barriers. Lean Construction concept is unfamiliar to the construction participants in Gaza Strip, so they did not put it in practice or incorporating it in their projects. Construction participants don't have the skills, knowledge and experience to apply LC in their projects LC. This is because LC is not incorporated in the school's curriculum to fully understand the benefits of LC to encourage them to adopt it in their projects.

Adegbembo et al. (2016) in Nigeria concluded that lack of Lean awareness and understanding was ranked the highest barrier. This was in concordance with the research studies carried out by Sarhan and Fox (2013) and Alarcón et al. (2011) that lack of Lean awareness and understanding was a major barrier to apply LC in UK and Chili, respectively. In the UAE, Small et al. (2017) found that lack of Lean understanding is ranked high as the fourth most important barrier among 34 barriers. Awada et al. (2016) and Hamzeh et al. (2016) validated that one of the most important barriers hindered the application of LC in Lebanon is lack of Lean concept understanding.

The second rank in the educational barriers was for the barrier of *“Lack of knowledge to apply LC techniques in safety improvement”*. It was the in the third position in the overall barriers. LC is not adequately known among the construction practitioners in Gaza Strip which is reflected by the second section of the research questionnaire. This returned back to the weakness of the learning environment and lack of budget to provide training in Gaza Strip regarding the LC to recognize the benefits of LC. Without proper knowledge they will not be aware of the strategies can be used to apply LC techniques in safety improvement and many misconceptions will be in their mind without training. This is consistent with the result which has been found by Enshassi and Abu Hamra (2017) and Enshassi and Abu Zaiter (2014) that lack of education or training on the use of innovative strategies, whether in the university or any governmental or private training centers hindered the application of them

Wandahl (2014) in Denmark demonstrated that lack of knowledge of LC seems to be the main challenge to the application of LC. Likewise, Zhou (2012) in the USA found that among the companies who are not Lean, lack of knowledge was between the first five barriers hindered the application of LC. Awada et al. (2016) concluded that most of the respondents indicated that the lack of knowledge of the lean philosophy hindered the application of LC techniques in the Lebanese construction projects that ultimately impact site safety. In Abu Dhabi, Al-Aomar (2012) stated that construction managers were less capable of linking LC techniques to their projects due to lack of knowledge and experience in LC techniques. Similarly in Qatar, Salem et al. (2016) showed that the limited knowledge of Lean hindered that application of its techniques in the industries.

These barriers can be mitigated through increasing the public awareness of Gazan Construction projects with Lean concepts and techniques; incorporation the LC in the school‘s curriculum so that students can have better knowledge; developing a long term training programs to improve the technical skills of employees; and sharing experiences and information among the companies and employees.

5.4.1.4 Governmental Barriers

Government barriers affect the project's development and the LC's implementation due to its attitudes and support towards the construction industry. It is considered as external barrier in construction projects (Bashir et al., 2015, Cano et al., 2015, Bashir, 2013, Bashir et al., 2010). (Shang and Pheng, 2014). This section specialized to identify the critical governmental barriers to the application of LC techniques to improve safety in construction projects in Gaza Strip. It contains four barriers related to government.

The results indicated that the highest effect index was for *“Lack of government support towards the construction projects to apply any innovative strategy”* with EI=79.439. It is ranked in the first position within the governmental barriers and in the second position in the overall barriers. The local government in Gaza Strip does not prioritize Lean in their national agenda. It doesn’t provide a clear direction for the construction firms to support the application of LC techniques in safety improvement in their projects. The unstable political conditions, lack of funds and lack of awareness regarding the benefits of LC techniques might be main reasons prevented the local government to support the application of LC. This is consistent with the result which has been found by Enshassi et al (2016a).

Cano et al. (2015) demonstrated that lack of the government support is an external factor that impact the implementation of LC in the Colombian Construction Projects. Al-Najem et al. (2013) stated that the Kuwaiti Government doesn’t pay any attention for using any innovative strategy in the industrial sectors which prevented the application of LC techniques. Conversely, Shang and Pheng (2014) in China found that lack of support from government was ranked as 13th among 22 barriers which is slightly late comparing with the remaining barriers. Similarly, Bashir et al. (2015) and Bashir (2013) concluded that government support had minor effects on the application of LC techniques in safety improvement in the UK.

To overcome this barrier, government should prioritize Lean in the national agenda and provide a clear direction for the construction firms apply LC techniques in safety improvement. In addition, government should integrate with local universities and LC professional to socialize the benefits of using LC techniques. A regular training should be provided for all construction practitioners to provide them with the most appropriate techniques that can be used in Gaza Strip to improve safety.

5.4.1.5 Technical Barriers

Technical barriers have a direct impact on the application of certain LC techniques (Koskela, 1992). This section identified the technical barriers to the application of LC techniques to improve safety in construction projects in Gaza Strip which are six barriers. The results indicated that the lowest rank was for *"Fragmented nature of the construction industry"* with EI=63.084. It is ranked as in the 6th position within the technical barriers and 39th position in the overall barriers which both were the last ranks. Despite this barriers is ranked as the lowest, it had a strong effect on the application of LC techniques to improve safety in the Gazan Construction projects.

In Gaza Strip, construction process is still traditional by fragmented nature characteristic with loosely coupled actors who only take part in some of the phases of the process. This barrier hindered the success of LC since it is highly dependent on having a cohesive team working towards congruent goals and objectives. The research of the Adegbembo et al. (2016) indicated that fragmented nature of the construction industry was ranked least in Nigeria. Meanwhile, Ayarkwa et al. (2012b) reported that the strongest barrier to implementation of LC in Ghana is the fragmented nature of the construction industry. To overcome this barrier, the project owner should encourage the construction participants to participate in all phases of the projects like involving the contractor in the design phase.

5.4.1.6 Human Attitudinal Barriers

According to Bygballe and Swärd (2014), human attitude is one of the major factors affecting the implementation of LC in construction projects. This section is specialized to investigate the human attitudinal barriers which prevents the application of LC techniques to improve safety in construction projects in Gaza Strip. It contains seven barriers related to attitude. The results indicated that the barrier of *"Cultural issues"* is the least barrier with EI=65.187. It was ranked as the 7th barrier in the human attitudinal barriers and 38th in the overall barriers which are both least positions. Despite the late position of this barrier comparing with the remaining barriers, it has a strong effect on the application of LC techniques in safety improvement among the Gazan Construction Projects. Culture perceptions and attitudes of the workforce are important factors to apply any innovative strategy. In Gaza Strip, cultural problems are mainly from lack of understanding and knowledge of LC which leads to the employee resistance to change. Construction participants believed that any innovative strategy is just a waste of time and money without having a long term vision to the outcomes they can attain using these strategies especially LC techniques on safety. Their cultural problems are related to their limited amount of knowledge about LC tools and their belief that any innovative strategy is just a waste of time and. These results confirmed with Enshassi and Ahu Hamra (2017) and Enshassi et al. (2016a).

The late result in this research confirmed by the study of Fernandez-Solis et al. (2013) in the USA. They concluded that bad work ethics and cultural issues was at late position among the barriers to the implementation of LC especially LPS. Similarly, Alinaitwe (2009) found that the cultural issues is ranked lately comparing with other barriers to the implementation of LC in Uganda. Conversely, Cano et al. (2015) found that lack of proper human attitude and cultural problems are the most influential barriers in the Colombian Construction Projects. Likewise, Sarhan and Fox (2013) in the UK reported that cultural and human attitudinal issues are among the three significant barriers to the implementation of LC. In Saudi Arabia, AlSehaimi et al. (2009) derived that cultural issues is one of the main potential barriers to the LPS implementation.

This can be enhanced by conducting awareness seminars and publications in order to make the construction parties aware of the value of LC. Management must support the cultural transformation by motivating the employees to change their attitude to use new innovative techniques. Projects used LC even partially should socialize of the results of the LC application.

5.4.2 Factor analysis of the barriers to the application of LC techniques to improve safety in construction projects

Factor analysis results of the barriers to the application of LC techniques to improve safety in construction projects will be discussed in this section. Thirty nine barriers are listed in this research to investigate the effect on the application of LC techniques to improve safety in construction projects in Gaza Strip. The 39 barriers are analyzed using factor analysis and reduced to 25 barriers while 14 barriers were removed. The remained barriers are underlined under seven components which are labeled as education related, governmental related, communication, financial related, cultural related, decision making and technical related. The components are discussed below:

5.4.2.1 Component1: Educational related

The first component of the barriers to the application of LC techniques to improve safety in construction projects is labeled as educational related. Naming of this component based on the variables included in it which are all related to education. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. Component 1 (Educational related) constitutes 17.895 % of the total variance of 25 barriers which is the highest variance among the four components extracted from the analysis. Educational component consists of six variables (barriers) which all have a loading value more than 0.727. The variables underlined under this component are as followed:

- Bar17: *"Lack of LC concept understanding"*, with loading value of 0.881
- Bar18: *"Lack of knowledge to apply LC techniques in safety improvement"*, with loading value of 0.855
- Bar21: *"Lack of awareness program to increase knowledge about LC"*, with loading value of 0.850
- Bar20: *"Lack of education and training needed to apply LC techniques in safety improvement"*, with loading value of 0.827
- Bar19: *"Lack of technical skills to apply LC techniques in safety improvement"*, with loading value of 0.816
- Bar22: *"Lack of information and experiences sharing among construction firms"*, with loading value of 0.727

In this component, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Further, it is named as "Educational related", because all the variables (barriers) included in it are closely related to education. Educational related component comprised of six barriers which reflect the effect on the application of LC techniques in construction safety improvement in Gaza Strip. All barriers under this component have loading value more than 0.7 which are considered significant in contributing to the interpretation of this component. It is the most important component since it constitutes the highest percentage of the total variance of the barriers to the application of LC techniques. Thus, component of “Educational related” has the highest effect degree on the application of LC techniques to improve safety in the Gazan Construction Projects.

In Gaza Strip, Lean Construction is considered as a new innovative strategy which needs to be understood by the construction participants to apply it successfully. Enshassi and Abu Zaiter (2014) confirmed that most construction organizations in Gaza Strip are not interested in using new management techniques. This is because the weakness in the learning environment and school‘s curriculum don’t provide the engineers with adequate skills, knowledge and experience to successfully apply LC in their projects. This is consistent with the result which has been found by Enshassi and Abu Hamra (2017) that lack of education or training on the use of innovative strategies, whether in the university or any governmental or private training centers hindered the application of them. The poorly economic conditions; and lack of budget provided to universities in Gaza or any governmental or private training centers impeded them from socializing the concept of LC. Without proper education, project practitioners will not be aware of the benefits of LC and how it can be adopted in their projects with choosing the best techniques to be suitable in Gaza.

Educational barriers are seemed to be the great threat to the sustainable implementation of LC (Adegbembo et al., 2016, Bashir, 2013, Bashir et al., 2010). Without this prior comprehension, it is feared that concerned parties will not be able to fully understand the concept of LC (Ayarkwa et al., 2012b). Bashir (2013) added that LC cannot be practiced without knowledge of the Lean concepts. Construction managers were less capable of linking LC techniques to their projects due to lack of knowledge and experience in LC techniques (Al-Aomar, 2012). Fernandez-Solis et al. (2013) demonstrated that lack of training programs leads to existence of unskilled employees at using LC techniques in construction projects. Also, unskilled employees will find LC hard to apply.

These results highlighted the need for overcoming the educational barriers to apply LC techniques successfully in safety improvement among Gaza Strip by organizing special courses in the universities in LC concept and how to adopt in safety improvement. Construction practitioners should find measures to cope with the barriers with highest effects including: Lack of LC concept understanding, Lack of knowledge to apply LC techniques in safety improvement, Lack of awareness program to increase knowledge about LC, Lack of education and training needed to apply LC techniques in safety improvement, Lack of technical skills to apply LC techniques in safety improvement; and Lack of information and experiences sharing among professional in the construction firms.

5.4.2.2 Component2: Government related

The second component of the barriers to the application of LC techniques to improve safety in construction projects is labeled as government related. Naming of this component based on the variables included in it which are all related to government. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. Component 2 (Government related) constitutes 10.481% of the total variance of 25 barriers. Government related component consists of four barriers which all have a loading value more than 0.713. The variables underlined under this component are as followed:

- Bar23: *“Lack of government support towards the construction projects to apply any innovative strategy”*, with loading value of 0.767
- Bar26: *“Unsteady price of commodities (Ex. PPE, safety signs, etc.)”*, with loading value of 0.767
- Bar24: *“Inconsistency in the government policies”*, with loading value of 0.716
- Bar25: *“Government bureaucracy and instability”*, with loading value of 0.713

In this component, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Given that barriers included in this component are concerned about governmental issues, this group could appropriately be given the heading of “government-related” barriers. Government related component comprised of four barriers which strongly affect the application of LC techniques in construction safety improvement in Gaza Strip. All barriers under this component have loading value more than 0.7 which are considered significant in contributing to the interpretation of this component.

In Gaza Strip, the local government has not taken any step to push the construction industry in the direction of LC. The unstable political situation in Gaza prevented the government from focusing on improving the construction industry and adopting any innovative strategy. The application of any innovative strategy especially LC in the Gazan Construction Projects is remained an individual initiative by academics and construction professionals depending on their awareness and willingness to adopt it. This is consistent with the result which has been found by Enshassi et al. (2016a).

The success of LC implementation rests in part on the shoulders of the government which is considered as external stakeholder (Bashir et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Bashir et al., 2010). Oladiran (2008) found that government related including government bureaucracy and instability is likely hindered the implementation of LC in Nigeria. Government intervention and inconsistency in policies highly affect the application of LC techniques in the construction industry in Dubai (Small et al., 2017). Similarly, Al-Najem et al. (2013) stated that the ignorance of Kuwaiti Government to pay attention for using any innovative strategy in the industrial sectors impeded the application of LC techniques.

These results open the door for construction projects in Gaza Strip to minimize the effect of government related barriers to successfully apply LC techniques in safety improvement including: Lack of government support towards the construction projects to apply any innovative strategy, Unsteady price of commodities (Ex. PPE, safety signs, etc., Inconsistency in the government policies; and Government bureaucracy and instability. Construction practitioners should find measures to cope with the governmental barriers with highest effects Government and decision makers in the construction industry need to support the establishment of a training board that can provide subsidized courses targeting the industry participants to educate them about the role that LC can play in safety management.

5.4.2.3 Component3: Communication

The third component extracted for the barriers to the application of LC techniques to improve safety in construction projects is labeled as communication. Naming of this component based on the variables included in it which are all related to communication between project participants. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. Component 3 (Communication) constitutes 9.221% of the total variance of 25 barriers. Communication component consists of three barriers which all have a loading value more than 0.572. The variables underlined under this component are as followed:

- Bar7: *"Poor communication among project parties (managers, administrators, foremen, etc.)"*, with loading value of 0.910
- Bar8: *"Poor coordination among project parties (managers, administrators, foremen, etc.)"*, with loading value of 0.892
- Bar6: *"Lack of transparency"*, with loading value of 0.572.

In this component, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Given that barriers included in this component are related to communication, this group could appropriately be given the heading of "Communication". Communication component involved three barriers which strongly affect the application of LC techniques in construction safety improvement in Gaza Strip. All barriers under this component have loading value more than 0.5 which are considered significant in contributing to the interpretation of this component.

Construction projects in Gaza strip suffer from lack of communication between different professionals and stakeholders. This result has been confirmed by the findings of Enshassi and Abu Hamra (2017) and Enshassi et al. (2015). Many companies in the Gaza strip involved in projects as subcontractors to achieve a certain percentage of the profits as they look for a secure and fast profit. This behavior gives rise to communication and coordination problems in line with Enshassi et al. (2007). Moreover, weakness in exchanging information between project participants leads to poor communication between them which hindered the application of LC techniques in construction projects to improve safety.

The impact of communication between parties on the success of LC implementation has been reported in the literature (Singh et al., 2014, Alarcón et al., 2011, Bashir et al., 2010). The project participants have different requirements and priorities with a common objective of successfully completing the project (Ayarkwa et al., 2012b, Abdullah et al., 2009). Therefore, a proper communication between all parties in construction project should be established and improved (Abdullah et al., 2009). In implementing LC techniques, lack of communication among the construction participants highly affected the application of LC techniques (Sarhan and Fox, 2013, Zhou, 2012, Alinaitwe, 2009, Kilpatrick, 2003). Lack of communication can lead to lack of coordination, cooperation and team work highly affected the application of LC techniques in the manufacturing industry in India (Attri et al., 2017). Similarly, Small et al. (2017) stated that poor communication among stakeholders hindered the LC implementation in construction in Dubai. Awada et al. (2016) found that communication barriers especially lack of transparency among project participants act as a major constraint against implementing LC in the Lebanese construction industry.

These results assured on the construction parties to overcome the communication barriers in order to successfully apply LC techniques in safety improvement including: Poor communication among project parties (managers, administrators, foremen, etc.); Poor coordination among project parties (managers, administrators, foremen, etc.); and Lack of transparency. The effects of communication barriers can be minimized by allocating enough time and resources to sustain communication channels between different project parties; exchanging information between project participants properly; and conduct periodically meetings for managers, engineers and workers for discussing problems of the project.

5.4.2.4 Component4: Financial related

The fourth component extracted for the barriers to the application of LC techniques to improve safety in construction projects is labeled as communication. Naming of this component based on the variables included in it which are all related to finance. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. Component 4 (Financial related) constitutes 8.951% of the total variance of 25 barriers. Financial related component consists of three barriers which all have a loading value more than 0.702. The variables underlined under this component are as followed:

- Bar12: *“Inadequate funding of the project to provide the required resources and training”*, with loading value of 0.841
- Bar13: *“Low tender prices”*, with loading value of 0.804
- Bar14: *“High cost of LC implementation including cost of training, consultancy fees and cost to conduct workshops”*, with loading value of 0.702.

In this component, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Given that barriers included in this component are all closed to finance, this group could appropriately be given the heading of "Financial related". This component embraced three barriers which strongly affect the application of LC techniques in construction safety improvement in Gaza Strip. All barriers under this component have loading value more than 0.7 which are considered significant in contributing to the interpretation of this component.

Innovative strategies like LC require some funds for its adequate implementation. Conversely, there is a Lack of the financial ability for the firms in Gaza Strip to adopt a new innovative techniques. This result is inconsistent with the findings of Enshassi and Abu Hamra (2017). Gaza Strip has poorly economic conditions because of the blockade, border closure, inadequate project fund; and absence of steady support from the Ministries of Finance and Local Governments. Financial constraints prevented the construction parties from providing the relevant equipment and material to support LC; providing sufficient training to increase knowledge of LC; employing Lean specialists to guide the implementation of LC; and motivating the employees to participate in LC implementation. Likewise, Enshassi and Abu Zaiter (2014) stated that lack of budget for training is an important barriers in using LC tools in Gaza Strip.

The effect of availability of financial resources on the success LC implementation has been well reported in the literature (Wandahl, 2014, Bashir, 2013, Sarhan and Fox, 2013). Bashir et al. (2015) and Ayarkwa et al. (2012b) found that finance related issues are among the most common challenges to lean practice across many organizations across UK and Ghana, respectively. Al-Aomar (2012) reported that the financial barrier of high cost of lean training is an obstacle of adopting LC techniques in Abu Dhabi. Similarly in Palestine, lack of budget for training is an important barriers in using LC tools (Enshassi and Abu Zaiter, 2014).

These results are important to be taken into consideration to successfully apply LC techniques in safety improvement without financial barriers including: Inadequate funding of the project to provide the required resources and training; Low tender prices; and High cost of LC implementation including cost of training, consultancy fees and cost to conduct workshops. To overcome the financial barriers, it is recommended to provide a sufficient funding for the construction projects to submit the projects in an effective and efficient way. Joint efforts are required from international donors and local organizations in order to effectively manage financial resources with the ultimate goal of applying LC techniques in safety improvement. Further, there is a need to be a paradigm shift in selecting contractors based upon lowest price to multi-criteria selection.

5.4.2.5 Component5: Cultural related

The fifth component extracted for the barriers to the application of LC techniques to improve safety in construction projects is labeled as cultural related. Naming of this component based on the variables included in it which are all related to culture. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. Component 5 (Cultural related) accounts for 8.896% of the total variance and is loaded with three variables with a value more than 0.692. The variables underlined under this component are as followed:

- Bar37: *“Resistance to change by employees”*, with loading value of 0.842
- Bar36: *“Cultural issues”*, with loading value of 0.799
- Bar38: *“Lack of self-criticism which limited the capacity to learn from errors”*, with loading value of 0.692.

In this component, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Given that barriers included in this component are all closed to culture, this group could appropriately be given the heading of “Cultural related”. This component comprised of three barriers which strongly affect the application of LC techniques in construction safety improvement in Gaza Strip. All barriers under this component have loading value more than 0.6 which are considered significant in contributing to the interpretation of this component.

In Gaza Strip, engineers are unwillingness to learn new applications because it is unfamiliar to them and there is no motivation. Moreover, companies are resistance for any change and they refuse to adopt a new technology. The study results of Enshassi and Abu Zaiter (2014) indicated that most construction organizations are not interested in using new management techniques. Their refusal to change is related to their limited amount of knowledge about LC tools and their belief that any innovative strategy is just a waste of time and. These results confirmed with Enshassi and Ahu Hamra (2017) and Enshassi et al. (2016a).

Cultural related issues are the most important barriers that prevented LC implementation in construction projects (Sandeep and Panwar, 2016, Fernandez-Solis et al., 2013, Ayarkwa et al., 2012a,b, Zhou, 2012). Cano et al. (2015) concluded that cultural problems is the most influential barrier impeded the application of LC techniques in Colombian Construction Projects. Similarly, Sarhan and Fox (2012, 2013) identified cultural barrier as a significant barrier to the implementation of LC which emphasizes the importance of establishing a Lean culture among the UK construction industry to support Lean transformations in construction projects. In Dubai, inadequate organizational culture is also considered as barrier to Lean implementation (Small et al., 2017). According to AlSehaimi et al. (2009) in Saudi Arabia, cultural issues is one of the main potential barriers to the LPS implementation.

Cultural barriers to the application of LC techniques to improve safety in construction projects are: Resistance to change by employees; Cultural issues; and Lack of self-criticism which limited the capacity to learn from errors. To overcome the cultural barriers, it is recommended to shift the employees and firms culture by educating the employees at all levels of the firms about the goals of LC implementation; and motivating the employees to change by recognitions and rewards.

5.4.2.6 Component6: Decision making

This component for the barriers to the application of LC techniques to improve safety in construction projects is labeled as decision making. Naming of this component based on the variables included in it which are all related to decision making. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. Component 6 (Decision making) accounts for 8.088% of the total variance and is loaded with three variables with a value more than 0.628. The variables underlined under this component are as followed:

- Bar2: *“Poor project definition which explain the vision, mission and main objectives of the project and its stakeholders”*, with loading value of 0.732
- Bar3: *“Centralization of decision making”*, with loading value of 0.709
- Bar4: *“Lengthy approval procedure from top management to take any step”*, with loading value of 0.628.

In this component, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Given that barriers included in this component are all closed to decision making, this group could appropriately be given the heading of "Decision making". This component contains three barriers which strongly affect the application of LC techniques in construction safety improvement in Gaza Strip. All barriers under this component have loading value more than 0.6 which are considered significant in contributing to the interpretation of this component.

In Gaza Strip, decision making affected the application of LC techniques to improve safety in construction projects. The process of decision making is usually structured in a hierarchical order in the Gazan Construction Projects in line with (Enshassi et al., 2014b). The traditional hierarchical decision-making is too slow which causes construction delays which ultimately costly claims. Hence, delay in construction projects interrupted the workflow and prevented the application of LC techniques.

Management centralization of decision making hindered the application of LC techniques in construction projects (Oladiran, 2008). The traditional hierarchical decision-making is returned to the unclear definition of roles and responsibilities within the team before project start (Camuffo et al., 2017). Moreover, lengthy approval procedure from client and top management is reported as a barrier prevented the implementation of LPS in USA which is related to the hierarchical decision-making (Fernandez-Solis et al., 2013). Similarly AlSehaimi et al. (2009) concluded that lengthy approval procedure by client hindered the achievement of full potentials of LPS in the Saudi construction industry.

These results highlighted the need for overcoming the barriers related to the decision making to apply LC techniques successfully in safety improvement among Gaza Strip. Construction practitioners should find measures to cope with the barriers with highest effects by involvement of all stakeholders in decision making to minimize the responsibilities on management and speed the approval procedure. Moreover, a clear definition of roles and responsibilities within the team before project start is essential.

5.4.2.7 Component7: Technical related

The last component extracted from the EFA of the barriers to the application of LC techniques to improve safety in construction projects is labeled as technical related. Naming of this component based on the variables included in it which are all related to technical issues. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. Component 7 (Technical related) accounts for 7.772% of the total variance and is loaded with three variables with a value more than 0.640. The variables underlined under this component are as followed:

- Bar29: *“Long implementation period needed for LC techniques application in safety improvement”*, with loading value of 0.805
- Bar32: *“Fragmented nature of the construction industry”*, with loading value of 0.707
- Bar27: *“Lack of agreed implementation methodology to implement LC techniques”*, with loading value of 0.640.

In this component, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Given that barriers included in this component are all closed to decision making, this group could appropriately be given the heading of “Technical related”. This component contains three barriers which strongly affect the application of LC techniques in construction safety improvement in Gaza Strip. It is the lowest important component since it constitutes the least percentage of the total variance of the barriers to the application of LC techniques. However, it is still important because all barriers under it have loading value more than 0.6 which are considered significant in contributing to the interpretation of this component.

In Gaza Strip, LC is a new innovative strategy which take a long period to be implemented. Time is needed to train the employees, select the appropriate techniques to use and implement on site, manage change to working culture; and carry out an evaluation to identify areas for improvement. Enshassi et al. (2016a) confirmed that applying any innovative strategy in Gaza Strip need a long time for training.

The effect of technical capabilities on the success of LC has been well documented (Bashir et al., 2015, Marhani et al., 2013, Alinaitwe, 2009). These issues relate to certain tools, they could hinder a holistic implementation of the concept (Bashir, et al., 2010). Lean construction is a continuous improvement process with an endless journey that may take a long period to be fully implemented (Sandeep and Panwar, 2016, Ayarkwa et al., 2012b). Kim and Park (2006) in USA discovered that the implementation of LC in construction projects had resulted in too many meetings and information needed for discussions. Moreover, these meetings had to be held regularly and took up too much time when poorly managed. Small et al. (2017) concluded that lack of agreed implementation methodology, Long implementation periods and fragmented nature of construction are identified as barriers to LC implementation in Dubai.

These results assured on the construction parties to overcome the technical related barriers in order to successfully apply LC techniques in safety improvement including: Long implementation period needed for LC techniques application in safety improvement; Fragmented nature of the construction industry; and lack of agreed implementation methodology to implement LC techniques. Technical barriers can be mitigated by involvement of construction participants in all phases of the projects; and integration between construction participants.

5.5 Critical success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

The fourth objective of this research is to investigate the critical success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects. Section F in the questionnaire specialized to collect the respondents' perspectives regarding the critical success factors to overcome the barriers to the application of LC techniques to improve safety in the Gazan Construction Projects. Discussion of the results attained by questionnaires will be in the two following sections in order to illustrate the ranks of barriers according to Relative Importance Index (RII) and to discuss the labelling and the extracted components that resulted from factor analysis of the barriers.

5.5.1 Ranks of the critical success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

Ranking results of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects will be discussed in this section. Findings of the success factors presents that the overall mean for the 26 listed success factor is 3.08 which is greater than the hypothesized mean (equal to 2 for five-point scale where A_{min}=0 and A_{max}=4) (Holt, 2014). Thus, all of the listed success factors have a significant influence on overcoming the barriers to the application of LC techniques to improve safety in construction projects. Further, the standard deviations for all benefits are small which reflects that there was a little variability in the data and consistency in agreement among the respondents was existed (Neuman, 2013).

The findings shows that the success factors have *p*-value equal 0.000 which is less than 0.05, and *t*-value for all of the success factors are more than the critical *t*-value (1.98). Hence, there is a statistically significant differences attributed to the respondents opinions at the level of $\alpha \leq 0.05$ between the statistical mean of the success factors and average mean (2).

Findings revealed that the highest average mean of success factors is related to the group of government success factors followed by management then educational factors. Whilst, the lowest average mean is related to operation success factors group. In Gaza Strip, inadequate application of LC techniques in safety improvement among construction projects rests partly on the shoulder of government. There is lack of governmental regulations; lack of governmental lead; and lack of standards to encourage the application of any innovative strategy which is consistent with Enshassi and Abu Hamra (2017); and Enshassi et al. (2016a). The most three influential success factors to apply LC techniques successfully in construction safety improvement are related to the management success factors which are:

- *"Good leadership"*, with MS=3.31, SD=0.782, RII=82.75 and rank =1
- *"Management support and commitment to the application of LC techniques in safety improvement"*, with MS=3.26, SD=0.744, RII=81.5 and rank =2
- *"Establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety"*, with MS=3.22, SD=0.756, RII=80.5 and rank =3.

The results indicated that the highest rank within the management factors and in the overall 26 success factors is for *"Good leadership"*. In Gaza Strip, construction managers don't have the leadership skills including the oversight and long term vision to expect the impact of using LC techniques on safety improvement. Therefore, they can't involve the employees in decision making in order to motivate them to change and implement any new innovative strategies. Good leaders are needed to focus on improving the employees' skills and enhancing their knowledge regarding LC. Therefore, the barriers regarding the understanding and knowledge of LC in Gaza Strip could be overcome. In Colombia, Cano et al. (2015) found that the most influential critical success factor is the effective leadership. Similarly, Brady et al. (2011) concluded that satisfactory leadership is appeared to be one of the common factors that are important for the success of Lean initiatives. Sarhan et al. (2016) in Saudi Arabia stated that most of the experts validated that leadership is very critical to the successful implementation of LC in construction industry.

"Management support and commitment to the application of LC techniques in safety improvement" was ranked as the second critical success factor within the management factors and in the overall success factors with (MS=3.26, SD=0.744; and RII=81.5). In Gaza Strip, management of the construction firms isn't supportive and don't have a strong attitude to use LC techniques in their projects. With no management support, the firms will not achieve any tangible benefits. Management support and commitment affects the employee performance behavior by providing all the necessary facilities and incentives required to support cultural transformation and active participation of all employees. Azyan et al. (2017) in Malaysia concluded that management commitment and support emerged as key factors to overcome the barriers to the application of LC techniques in the printing industry. Similarly, respondents in the study of Oladiran (2008) suggested the management support and commitment as an appropriate strategy to take-up lean in Nigerian Construction. In Saudi Arabia, AlSehaimi et al. (2009) confirmed that top management support is the most important critical success factor to overcome the barriers to the application of LC. Likewise, Belhadi and Touriki (2016) concluded that management commitment and support is a critical success factor for an effective implementation of Lean Production in small and medium-sized enterprises in Morocco. Conversely, Bashir (2013) found that only two organizations proposed top management involvement and support is needed to overcome the challenges to the application of LC techniques in safety improvement.

The third rank in both within the management factors and in the overall success factors was *"Establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety"*, with (MS=3.22, SD=0.756, RII=80.5). Employees in Gaza Strip are usually pessimistic and have resistance to change their work method which is mainly returned to the poor economic situation. In order to apply LC techniques in safety improvement around Gaza Strip, management should provide the employees recognitions and rewards the real improvement to promote behavioral change. Establishing a recognition and reward system will encourage the employees to participate in the application of LC techniques to improve safety in the Gazan Construction Projects. Antony et al. (2012) in UK stated that reward and recognition system should be considered to take the Lean initiative. Salem et al. (2005) offered providing recognition and rewarding to overcome the barriers to the application of LC techniques. Netland (2016) ranked the success factors of using rewards and recognition in the 12th position within 24 factors.

On the other hand, *"Construction managers should be proactive in decision-making"* with (MS=2.80, SD=0.916 and RII=70%) was a late rank. It is ranked in 11th position within the management success factors and in 25th position in the overall success factors. Despite the late position of this barrier, it is considered as an influential factor on LC application. Construction mangers should be proactive to avoid problems occurred along with the life cycle of the project especially in Gaza Strip due to the political and economic conditions. Project managers should have an oversight to expect the impacts of using LC techniques on safety improvement which affect time, cost and quality of the project. In Uganda, Ayarkwa et al. (2012b) ensured that the successful implementation of lean construction is needed to establish proactive measures to prevent defective production. In UK, Brady (2014) stated that among construction projects, it appeared to be no proactive means to avoid problems but it is very important to deal with the barriers of the application visual management tool. Similarly in China, Shang and Pheng (2014) concluded that having a long term vision and proactivity should be implemented in the Chinese context to overcome the barriers to the application of LPS. Likewise, Belhadi and Touriki (2016) found that that Long term vision is a critical success factor for an effective implementation of Lean Production in small and medium-sized enterprises in Morocco

The last rank was for the success factor of *"Decentralization of construction management"*, with (MS=2.79, SD=0.922 and RII=69.75%). It was not only the last rank (12th) in management success factors but also in the overall success factors (26th). This factor is also considered as influential factor as its mean is larger than the threshold value of 2. In Gaza Strip, low speed of decision making within the project is related to the centralization of management within the project which interrupt the workflow and as a result impede the application of LC. It is important to decentralize the construction management to enhance the workflow and involve the employees in decision making in order to facilitate the application of LC techniques in safety improvement. Oladiran (2008) confirmed that decentralization of construction management to enhance workflow was a critical success factor to apply Lean in Nigerian Construction. Likewise, Achanga et al. (2006) in UK sated that permitting a flexible organizational structure is crucial to implement the concept of lean manufacturing successfully. Cano et al. (2015) suggested the reduction of hierarchical levels in the organization and decentralization to overcome or minimize the impact of the barriers on the LC's implementation in construction projects. However, they concluded that this factor was not critical success factor among the Colombian Construction Projects.

5.5.2 Factor analysis of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

Factor analysis results of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects will be discussed in this section. Twenty six success factors are listed in this research to investigate the influence of these factor on the barriers to the application of LC techniques to improve safety in construction projects in Gaza Strip. The 26 success factors were analyzed using factor analysis and reduced to 17 success factors while 9 success factors were removed. The remained success factors are underlined under four components which are labeled as governmental factors, educational factors, management factors; and financial factors. The components are discussed below:

5.5.2.1 Component1: Governmental factors

The first component of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects is labeled as governmental factors. Naming of this component based on fundamental relationships among the variables under each component.

All variables included in this component are all related to government. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. Component 1 (Governmental factors) constitutes 19.576% of the total variance of 17 remained success factors which is the highest variance among the four components extracted from the analysis. Governmental factors component comprised of five success factors which all have a loading value more than 0.536. The variables underlined under this component are as followed:

- SF20: *“Government should provide the basic infrastructure and standards to apply LC techniques”*, with loading value of 0.863
- SF21: *“Government should work closely with professional bodies to introduce LC to improve construction safety”*, with loading value of 0.812
- SF19: *“Legislation bodies should introduce laws to facilitate the full application of LC techniques among construction firms”*, with loading value of 0.762
- SF18: *“Government should provide a clear direction for the construction firms to apply LC techniques in safety improvement through introducing policies to encourage construction firms to engage in the application of LC techniques to improve construction safety”*, with loading value of 0.746
- SF24: *“Application of LC techniques gradually step-by-step in improving safety to decrease the complexity of LC implementation”*, with loading value of 0.536.

In this component, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Further, it is named as “Governmental factors”, because all the variables (success factors) included in it are closely related to government. Governmental factors component comprised of five success factors which reflect the influence on the barriers to the application of LC techniques in construction safety improvement in Gaza Strip. All success factors under this component have loading value more than 0.5 which are considered significant in contributing to the interpretation of this component. It is the most important component since it constitutes the highest percentage of the total variance of the success factors. Thus, component of “Governmental factors” has the highest influence degree on the barriers to the application of LC techniques to improve safety in the Gazan Construction Projects.

In Gaza Strip, inadequate application of LC techniques in safety improvement among construction projects rests partly on the shoulder of government. There is lack of governmental regulations; lack of governmental lead; and lack of standards to encourage the application of any innovative strategy which is consistent with Enshassi and Abu Hamra (2017); and Enshassi et al. (2016a). As LC is a new innovative strategy in Gaza, it needs to be supported by government. The local government in Gaza Strip should prioritize Lean in their national agenda and provide a clear direction for the construction firms to support the application of LC techniques in safety improvement in their projects. Government should integrate with professional in LC to enlighten the construction practitioners about LC concept and its benefits.

Small et al. (2017) indicated that government agencies have a major role to incentivize lean application in construction projects in Dubai. Likewise, Oladiran (2008) confirmed the government highly influenced the LC introduction in Nigerian Construction. Bashir et al. (2015) and Bashir (2013) concluded that the UK government could introduce a policy that will encourage construction companies to engage in continuous improvement practices like LC. In the same line, Belhadi and Touriki (2016) stated that Moroccan Government should establishment of policies for Lean implementation.

These results highlighted the influence of governmental factors on overcoming the barriers to the application of LC techniques in safety improvement among Gazan Construction Projects. Government should provide the basic infrastructure and standards to apply LC techniques. It should work closely with professional bodies to introduce LC to improve construction safety. Legislation bodies should introduce laws to facilitate the full application of LC techniques among construction firms. Government should provide a clear direction for the construction firms to apply LC techniques in safety improvement through introducing policies to encourage construction firms to engage in the application of LC techniques to improve construction safety. Finally, Application of LC techniques should be gradually step-by-step to decrease the complexity of LC implementation.

5.5.2.2 Component2: Educational factors

This component of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects is labeled as educational factors based on fundamental relationships among the underlined variables. All variables included in this component are all related to education. In addition, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Component 2 (Educational factors) constitutes 18.497% of the total variance of 17 remained success factors. Educational factors component comprised of five success factors which all have a loading value more than 0.548. The variables underlined under this component are as followed:

- SF17: *“Engagement of skillful site operatives and skillful professionals to guide the application of LC techniques in safety improvement”*, with loading value of 0.820
- SF15: *“Establishing awareness programs to increase the understanding of the LC using workshops and research conferences to guide the application of LC techniques in safety improvement”*, with loading value of 0.775
- SF16: *“Promotion of the LC concept to the stakeholders of construction projects”*, with loading value of 0.698
- SF13: *“Providing adequate education and training for employees at all levels on the LC concept and techniques”*, with loading value of 0.640
- SF25: *“Constitution of an improvement committee to be responsible for the application of LC techniques in safety improvement”*, with loading value of 0.548.

In this component, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Further, it is named as “Educational factors”, because all the variables (success factors) included in it are closely related to education. Educational factors component comprised of five success factors which reflect the influence on the barriers to the application of LC techniques in construction safety improvement in Gaza Strip. All success factors under this component have loading value more than 0.5 which are considered significant in contributing to the interpretation of this component.

LC is not adequately known among the construction practitioners in Gaza Strip. Construction participants don’t have the skills, knowledge and experience to apply LC in their projects LC. In order to overcome the barriers to the application of LC techniques in safety improvement, learning environment in Gaza should be improved. Construction participants should provide a separate budget for training to recognize the benefits of LC. Construction firms should integrate with professional bodies to benefit from their experience.

The influence of educational success factors on the success LC implementation has been well reported in the literature (Azyan et al., 2017, Small et al., 2017, Netland, 2016, Cano et al., 2015). Top management of the organization should conduct proper education & training programs for the employees to succeed with Lean implementation (Sandeep and Panwar, 2016, Netland, 2016). Bashir et al. (2015) and Bashir (2013) confirmed that organizations should engage their staff in a learning process to acquire all the necessary knowledge and skills required to achieve a smooth and full implementation of LC. Enshassi and Abu Zaiter (2014) stated that training will be a key aspect of implementation and success of the LC techniques to increase safety conditions at the site. Similarly, (Azyan et al., 2017) concluded that knowledge and understanding on the lean concepts can further increased with continuous training.

These results assured on the influence of educational factors on overcoming the barriers to the application of LC techniques in safety improvement among Gazan Construction Projects. Construction firms should engage skillful site operatives and skillful professionals to guide the application of LC techniques in safety improvement. They should establish awareness programs to increase the understanding of the LC using workshops and research conferences to guide the application of LC techniques in safety improvement. LC concept should be promoted among the stakeholders of construction projects. Construction firms should organize a training session with Lean consultant for employees at all levels on the LC concept and techniques. An improvement committee should be constituted to be responsible for the application of LC techniques in safety improvement.

5.5.2.3 Component3: Effective planning

This component of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects is labeled as effective planning based on fundamental relationships among the underlined variables. All variables included in this component are all related to planning. In addition, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Component 3 (Effective planning) constitutes 15.490% of the total variance of 17 remained success factors. It contained four success factors which all have a loading value more than 0.692. The variables underlined under this component are as followed:

- SF2: *"Developing and implementing an effective plan to apply LC techniques in safety improvement"*, with loading value of 0.803
- SF3: *"Ensuring the culture of continuous improvement in construction projects to obtain the reduction of costs, increase quality and productivity"*, with loading value of 0.774
- SF4: *"A clear definition of roles, responsibilities, functions and levels of authority before the application of LC techniques"*, with loading value of 0.730
- SF1: *"Management support and commitment to the application of LC techniques in safety improvement"*, with loading value of 0.692

In this component, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Further, it is named as "Effective planning", because all the variables (success factors) included in it are closely related to planning. This component comprised of four success factors which reflect the influence on the barriers to the application of LC techniques in construction safety improvement in Gaza Strip. All success factors under this component have loading value more than 0.6 which are considered significant in contributing to the interpretation of this component.

Sawalhi and Enshassi (2004) found that Gazan Construction Management suffered from lack of planning in the Gaza Strip. Effective planning is required in Gaza to set appropriate and achievable targets from implementing LC techniques. It is necessary to develop a vision and roadmap of how these techniques can be incorporated in Gazan Construction Projects to improve safety.

Cano et al. (2015) in Colombia confirmed that effective planning and selection the right people are highly influenced the application of LC techniques. Similarly, Bashir et al. (2015) concluded that the organizations must develop a very rich and strong program to achieve a smooth implementation of LC. Hamzeh et al. (2016) stated that improvements of planning is a key factor affecting the implementation of LC in Lebanon. In Saudi Arabia, AlSehaimi et al. (2009) validated that facilitation of planning contributed significantly to the success of LC especially LPS. In the same line, Belhadi and Touriki (2016) demonstrated that proper planning before implementation is required to successfully apply Lean in Morocco.

Construction participants should efficiently plan for their projects to successfully apply LC techniques in safety improvement among Gazan Construction Projects. They should ensuring the culture of continuous improvement in construction projects to obtain the reduction of costs, increase quality and productivity. Construction mangers should clearly define the roles, responsibilities, functions and levels of authority before the application of LC techniques. Management support and commitment is a must to successfully apply LC techniques in safety improvement.

5.5.2.4 Component4: Financial factors

This component of the success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects is labeled as financial factors based on fundamental relationships among the underlined variables. All variables included in this component are all related to finance. In addition, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Component 4 (Financial factors) constitutes 12.959% of the total variance of 17 remained success factors. It comprised of three success factors which all have a loading value more than 0.711. The variables underlined under this component are as followed:

- SF11: *"Adequate funding of projects to cover the provisions of consultancy and training"*, with loading value of 0.757
- SF123: *"Invest time as much as money to successfully apply LC techniques"*, with loading value of 0.746
- SF10: *"Establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety"*, with loading value of 0.711

In this component, variables with higher loadings are used to identify the nature of the underlying latent variable represented by the factor. Further, it is named as "Financial factors", because all the variables (success factors) included in it are concerned about finance. This component involved three success factors which reflect the influence on the barriers to the application of LC techniques in construction safety improvement in Gaza Strip. All success factors under this component have loading value more than 0.7 which are considered significant in contributing to the interpretation of this component. This component has the lowest percentage of the total variance of the barriers to the application of LC techniques. Thus, component of "Financial factors" has the lowest influence degree on the barriers to the application of LC techniques to improve safety in the Gazan Construction Projects comparing with other factors.

In order to apply LC techniques in safety improvement around Gaza Strip, donors should provide sufficient fund for developing and sustaining new tools and programs. This result is in line with the study of Enshassi et al. (2016b). In addition, the local government should specialize adequate fund to encourage the application of new innovative techniques. Top managers should establish a recognition and reward system to encourage the employees to participate in the application of LC techniques to improve safety in the Gazan Construction Projects.

The effect of availability of financial resources on the success LC implementation has been well reported in the literature (Netland, 2016, Antony et al., 2012, Bashir et al., 2010, Mossman, 2009, Oladiran, 2008, Achanga et al., 2006). Adequate funding is needed to motivate workers, provide relevant equipment and employ lean specialists to guide the implementation of LC techniques (Ayarkwa et al., 2012b). Azyan et al. (2017) validated that management should provide adequate financial resources to find a competent consultant to take their help.

The findings encourage the construction participant to incorporate the financial factors to successfully apply LC techniques in safety improvement among Gazan Construction Projects. They should look for an adequate funding of projects to cover the provisions of consultancy and training, invest time as much as money to successfully apply LC techniques; and establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety. They should ensure the culture of continuous improvement in construction projects to obtain the reduction of costs, increase quality and productivity. Top managers should allocate enough time and resources to successfully apply LC techniques.

Chapter 6

Conclusion and Recommendations

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The sixth chapter of the research is to draw conclusions on the application of LC techniques in safety improvement in Gaza Strip, and make recommendations to construction practitioners and for future research. The chapter begins with the research findings, across the objectives, on the basis of which conclusions are drawn. Following the conclusions, the chapter summarized the originality of this research, then limitations related to the research. The chapter also makes recommendations future researchers and practitioners.

6.1 Conclusions

This research aimed to develop a clear understanding about safety improvement in construction projects through the implementation of Lean Construction techniques. The main conclusions drawn from the research study are presented in the following sections. The research conclusions is divided according to research objectives.

6.1.1 Applicability level of LC techniques to reduce the causes of accidents in construction projects

A variety of LC techniques are being implemented on construction projects. The extent to which LC techniques are implemented varies from company to company. The first objective investigate the extent of using LC techniques to reduce the causes of accidents in the Gazan Construction Projects. The LC techniques measured in this research are related to the tools of Last Planner System, Increased visualization, 5S, Fail safe for quality and safety, Daily Huddle Meetings, First Run Studies, Continuous improvement; and Accident investigation. A quantitative approach was used to collect data related to this section using questionnaire. The questionnaire requested the respondents to rate the applicability level of twenty five techniques in reducing the causes of accidents in construction projects. Descriptive analysis was used to analyze the collected data using Relative Importance Index and Exploratory Factors Analysis

Results obtained by RII were ordered regarding their applicability from largest to smallest level. The overall results of this section indicated that construction practitioners are unfamiliar of

LC tools; and LC techniques are poorly implemented in construction projects to reduce the causes of accidents among Gaza Strip. The top three techniques that were applicable among Gaza Strip to reduce the causes of accidents were: Cleaning the workplace and removing materials and machines that are not required; Conducting accident investigation and root-cause analysis program; and using safety signs and labels on site. On the other hand, the lowest applicable techniques were: Using Alarms and warning gadgets to warn workers from crossing the unsafe boundaries; and using camera connected with computer algorithm to warn safety officer when workers violate safety conditions.

Additionally, data collected using questionnaire was analyzed using EFA to reduce the twenty five techniques into smaller sets. By EFA, the twenty five techniques were reduced to thirteen while twelve techniques were removed. The remained thirteen techniques were underlined in three components which are interpreted based on the fundamental relationships among the variables under each component and based on variable with higher loadings. The three extracted components including: Communication and planning; workers' involvement; and using safety equipment. The highest component which is applied in construction projects to reduce the causes of accidents in Gaza Strip was "Communication and planning". On the other hand, component of "using safety equipment" was the lowest.

Findings of this research aid professionals and companies in the Gazan construction projects to shift their attention and resources towards implementing LC techniques to reduce the causes of accidents. It would guide the construction practitioners to improve the techniques related to communication and planning, workers' involvement; and using safety equipment in order to raise the level of using LC techniques to reduce the causes of accidents in construction projects.

6.1.2 Benefits of implementing LC techniques related to safety improvement in construction projects

The introduction of the LC concept and its application within the construction industry is reported to have a lot of benefits. This section is specialized to identify the benefits of implementing LC techniques which is related to safety improvement in construction projects in Gaza Strip. The questionnaire is used to ask the respondents to rate the importance degree of twenty two benefits which are expected to be gained by applying the LC techniques which are all related to safety. RII and EFA were used to analyze the collected data from questionnaire.

RII results were ordered regarding their importance level. The main finding of this section was that all identified benefits in the questionnaire were important from the respondents' perspective. Majority of respondents indicated that improving the rate of workflow on site was the primary benefit of implementing LC techniques. Further, implementing LC techniques helped to improve the work plan and improve the safety management plan. However, most respondents did not find significant benefit in increasing profit and controlling the construction site environmentally.

By using EFA, the twenty two benefits were reduced to fifteen benefits while seven benefits were removed. The fifteen benefits were underlined into four components which are interpreted based on the variables with higher loadings. The four extracted components are communication and trust, time and quality, safety management plan and reducing site hazards. The most important component in this section was "communication and trust". Conversely, component of "Reducing site hazards" was the least important.

Implementing LC techniques resulted in many significant benefits in the construction projects. The findings of the research drive the project practitioners in Gaza Strip to adopt LC in construction projects and encourage them to implement the appropriate LC techniques to gain all of the listed benefits especially improving the rate of workflow and enhancing the work plan and safety plan of the projects. By the research findings, construction participants will recognize the importance of all benefits especially the communication and trust related benefits.

6.1.3 Barriers to the application of LC techniques to improve safety in construction projects

To integrate Lean philosophy in a construction organization, it is recommended to understand and anticipate the barriers that might hinder the proper implementation of LC in construction projects. The third objective of this research is to investigate the barriers to the application of LC techniques to improve safety in the Gazan Construction Projects. The questionnaire asked the respondents to rate the effect degree of thirty nine barriers on the application of LC techniques to improve safety in construction projects among Gaza Strip. Effect Index and EFA were used to analyze the collected data.

EI was used to order the barriers regarding their effects. Findings indicated that all identified barriers in the questionnaire had strong effects on the application of LC techniques to improve safety from the respondents' perspective. The strongest barriers to the application of LC techniques to improve safety in Gaza Strip were lack of LC concept understanding; lack of government support towards the construction projects to apply any innovative strategy; and lack of knowledge to apply LC techniques in safety improvement. However, the lowest effect barriers were cultural issues followed by fragmented nature of the construction industry.

By using EFA, the thirty nine barriers were reduced to twenty five barriers, while fourteen barriers were eliminated. Seven components were extracted to underline the twenty five barriers which are interpreted based on the fundamental relationship between the variables and based on the variables with higher loadings. The seven extracted components were education related, governmental related, communication, financial related, cultural related, decision making and technical related. The highest effect component of barriers on the application of LC techniques to improve safety was "Educational related". On the contrary, "Technical related" has the lowest effect.

The findings of this section stress the construction participants in Gaza Strip to cope with the strongest barriers affected the implementation of LC techniques in order to identify proper measures to overcome them. Additionally, findings helped the respondents to recognize the highest effect components on the application of LC techniques to improve safety like educational related barriers. Appropriate strategies should be taken to address the barriers especially training the construction participant to enlighten them on the benefits of LC and recognize the value of LC implementation.

6.1.4 Critical success factors to overcome the barriers to the application of LC techniques to improve safety in construction projects

The success factors should be addressed to overcome the barriers to the application of LC techniques in order to improve safety in construction projects. The fourth objective of this research is the critical success factors to overcome the barriers to the application of LC techniques to improve safety in the Gazan Construction Projects. The questionnaire asked the respondents to rate the influence degree of twenty six success factors to overcome the barriers to the application of LC techniques in construction safety improvement. Data collected was analyzed using RII and EFA.

RII analysis was used to order the success factors regarding their influence and determine the critical success factors. The overall findings indicated that all identified success factors in the questionnaire had high influence on overcoming the barriers to the application of LC techniques to improve safety in construction projects. The most three critical success factors that should be taken to overcome the barriers to the application of LC techniques to improve safety in Gaza Strip were: Good leadership; Management support and commitment to the application of LC techniques in safety improvement; and Establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety. On the other hand, the lowest influent factors were: Construction managers should be proactive in decision-making; and Decentralization of construction management.

By using EFA, the twenty six success factors were reduced to seventeen success factors while nine factors were removed. The remained factors which are seventeen success factors were underlined into four components. Components were interpreted based on the fundamental relationship between the variables and based on the variables with higher loadings. The four extracted components were Governmental factors; Educational factors; Effective planning; and Financial factors. The highest influence component of on overcoming the barriers to the application of LC techniques to improve safety was “Governmental factors”. However, “Financial factors” has the lowest influence.

The results offer several strategies for construction managers striving to implement LC in their firms. In addition, the findings enable construction participants implement the measures suggested to remove or eliminate the potential barriers to the implementation of LC techniques to improve safety in construction projects among Gaza Strip. Government should take steps to encourage the construction participants to apply LC techniques in safety improvement.

6.2 Originality/ value

The research value can be summarized in the following points:

- It is considered as one of the first studies among the Middle East which links between LC techniques and safety improvement.
- The findings of this study will aid professionals and companies in the Gaza Strip to shift their attention and resources towards implementing LC techniques in order to reduce the causes of accidents.
- The findings would guide the selection of appropriate LC techniques on the construction projects to reap the full benefits of LC techniques.
- The findings would guide the construction practitioners to the main barriers affect the implementation of LC techniques in safety improvement around he construction projects.
- The identified critical success factors provides a useful insight for the enhancement of critical decision-making process which is needed for the delivery of corporate strategic ambitions towards the implementation of LC techniques in construction projects to improve safety in Gaza Strip.
- The roadmap gained by the research helps the construction participants of the critical barriers prevented the application of LC techniques in safety improvement and how to overcome or mitigate them.

6.3 Limitations

The main limitations related to this research are:

- Lack of information and published studies regarding the linkage between Lean and safety especially in the Middle East.
- Scarcity of information and published studies regarding the benefits, barriers and success factors of implementing LC techniques which are related to safety improvement especially in the Middle East.
- The research focused on studying the implementation of the LC techniques in the construction phase only.

- Findings in this research were dependent on the accuracy and reliability of the collected data from construction projects by questionnaire.
- The study has its limitations as the results were obtained based upon a questionnaire survey that has a limited number of samples.
- The questionnaire was conducted for a specific period with professionals working in construction projects funded externally (like Qatar Committee), so results may not represent the whole Gazan construction projects.
- In Scree plot, the researcher is tasked with finding a visual "elbow" in the plot where there is a distinct transition from large to small eigenvalues; unfortunately, a clear elbow is not always obvious. Consequently, the researcher is forced to make an ambiguous subjective judgment about the number of factors to retain.

6.4 Recommendation

To successfully implement the LC techniques to reduce the causes of accidents as well as to gain the benefits from LC implementation in Gaza Strip. The study recommendations includes:

- Foreman should prepare daily and weekly work plans and define tools that should be used to ensure safety.
- Employees should be provided with appropriate safety equipment to each task.
- The workplace should be provided with adequate quantity of safety signs and labels to keep workers safe.
- A safety engineer at site is necessary to periodically inspect the commitment of employees to safety conditions.
- Managers, engineers and supervisors must be a good example for workers in using the PPE.
- Workers involvement in:
    - Task scheduling to develop the schedule based on their abilities.
    - Decision making and planning to motivate them to participate in LC implementation.
    - Discussing the good and bad aspects of their tasks and to suggest ways to solve these problems together in order to increase the communication.

- Periodic inspection should be conducted to assure that all employees are committed to the safety standards and regulations; and to check the quality of completed works.
- Conduct periodic meetings with all employees to review the work progress.
- An adequate fund should be specialized to the safety equipment in the project to provide the sites with appropriate equipment.
- Safety planner should prepare check lists with the expected causes of accidents in all of project tasks to specifically determine the causes of accidents.
- Requiring contractors to prepare and submit safety plan and acceptable project hazard prevention plan.
- In order to reap the full benefits of LC techniques, construction practitioners have to implement the techniques properly; not just implement one or two techniques of LC.
- Conducting training programs:
    - On carrying out works properly and dealing with changes in working conditions, such as extreme heat, rain and slippery surfaces to prevent injuries.
    - On wearing the appropriate clothing for each task.
    - On preparing plans before starting the project
    - On safety planning before starting the project
    - On identifying the job hazards before starting work to prevent accidents from occurring.
    - To improve the leadership skills of construction managers
    - To enhance the long term vision and proactivity of construction managers

6.5 Future studies

Directions for future researchers include:

- Conduct a case study based research to provide an integrated comprehensive understanding of the LC techniques that are implemented with their benefits, barriers and success factors.
- Study the implementation of LC techniques in design phase and compare it with construction phase.
- A practical framework is highly needed to guide construction projects in creating a Lean culture and adopting lean techniques in the Gazan Construction Industry.

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Appendices

Appendix (A): Draft English Questionnaire

The Islamic University–Gaza

Research and Postgraduate Affairs

Faculty of Engineering

Civil Engineering Department

الجامعـــــــــة الإســــلاميــةـ غـزة

شئون البحث العلمي والدراسات العليا

كـليــــة الـهندسة

قسم الـهندسة المدنية

Subject: questionnaire survey about: **"Safety improvement through the application of Lean Construction (LC) techniques in construction projects"** for submitting a thesis in partial fulfillment of the requirements for the Master degree in Construction Management

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Research Aim: Developing a clear understanding of the relation between Lean Construction and safety improvement and exploring the current state of using Lean Construction techniques to promote safety in construction projects in Gaza Stip.

Target Group: Engineers who work in the field of construction supervision ***(Project manager, site engineers, site supervisors and safety engineers).***

The questionnaire consists of six main sections. ***Filling in the questionnaire does not require a prior knowledge about Lean Construction***, but what is required is the answer and evaluation of certain points with precision and objectivity according to your point of view and expertise in the field of construction. The validity of the questionnaire results depends on your answer's accuracy. Thank you in advance for your valuable time and contribution to this research work.

Best Regards,

Nour Maher Saleh

M.Sc. Candidate in Construction Management, IUG

(2017)

Section A: **Profile of respondent**

- Please tick (√) the appropriate option in the following questions

1.	**Educational qualification**	☐ Bachelor's	☐ Master's	☐ Ph.D.	
2.	**Specialization**	☐ Architect engineer	☐ Civil engineer	☐ Other ……………………….	
3.	**Type of organization**	☐ Consultant	☐ Contractor	☐ Governmental sector	☐ NGO
4.	**Job title**	☐ Project manager	☐ Site engineer	☐ Site supervisor	☐ Safety engineer
5.	**Years of experience**	☐ Less than 5 years	☐ From 5 to less than 10 years	☐ 10 years and more	

Section B: **Awareness level of Lean Construction (LC) tools**

- Please rate your awareness level regard the following Lean Construction (LC) tools

#	**Lean Construction (LC) tool**	Degree of awareness				
		Low		⇔		High
		1	2	3	4	5
		Never	Little	Somewhat	Much	Very much
1.	Last Planner System (LPS)					
2.	Increased visualization (IV)					
3.	5S process					
4.	Fail safe for quality and safety (Poka yoke)					
5.	Daily Huddle Meetings (DHM)					
6.	First Run Studies (FRS)					
7.	Continuous improvement (Kaizen)					
8.	Accident investigation (5 Why’s)					

Section C: **Applicability level of LC techniques to reduce the causes of accidents on the construction projects**

- Please rate the applicability extent of the following statements among your firm

#	**LC tools and techniques application to reduce the causes of accidents on the construction projects**	Degree of applicability				
		Low		⇔		High
		1	2	3	4	5
		Never	Seldom	Often	Frequent	Always
Last Planner System (LPS)						
1.	Providing employees with safety equipment					
2.	Developing a plan for supervision					
3.	Developing a schedule based on worker's abilities					
4.	Worker's empowerment and involvement in assignment planning and scheduling					
5.	Correlating work methods with worker's skills and abilities					
6.	Involvement of all employees in safety planning					
7.	Conducting pre task hazard analysis to identify risks predicted at activity and reducing it					
8.	Conducting weekly work planning					
Increased visualization						
9.	Using camera connected with computer to warn safety officer when workers violate the safety issues on site					
10.	Using visual demarcations and boards on site					
11.	Using safety signs and labels on site					
5S						
12.	Cleaning the workplace and removing materials and machines that are not required					
13.	Organizing material and plant					
14.	Separating needed tools from unneeded materials and clearing the unwanted materials					
15.	Defining standard procedures to maintain the working environment clean and organized and improve safety culture					
16.	Creating continuous improvement in safety culture to increase safety culture among the workforce					
Poka yoke						
17.	Conducting visual inspection					
18.	Using Alarms and warning gadgets to warn workers from crossing the unsafe boundaries					

#	**LC tools and techniques application to reduce the causes of accidents on the construction projects**	Degree of applicability				
		Low		⇔		High
		1	2	3	4	5
		Never	Seldom	Often	Frequent	Always
19.	Using safe guards and Personal Protective Equipment (PPE)					
Daily Huddle Meeting (DHM)						
20.	Conducting daily meeting to increase communication between teamwork, increase workers awareness of safety to make them identify risks and reduce it					
21.	Conducting daily meeting to increase workers awareness of safety to make them identify risks and reduce it					
First Run Studies (FRS)						
22.	Make a plan for the critical tasks					
23.	Illustration of work methods using videos, photos, etc.					
Continuous improvement (Kaizen)						
24.	Involvement of all employees in improvement process					
25.	Conducting pre task hazard analysis to identify risks predicted at activity and reducing it					
5 whys						
26.	Conducting accident investigation and root-cause analysis program					

Section C: **Benefits of LC techniques related to safety improvement in construction projects**

- Please rate the importance degree of the following benefits to the application of LC techniques' which is related to safety improvement among your firm

#	**Benefits of LC techniques related to safety improvement in construction projects**	Degree of importance				
		Low		⇔		High
		1	2	3	4	5
		Not important at all	Slightly important	Important	Very important	Extremely important
1.	Better work plan					
2.	Better safety management plan					
3.	Improving the rate of workflow on-site					

#	**Benefits of LC techniques related to safety improvement in construction projects**	Degree of importance				
		Low		⇔		High
		1	2	3	4	5
		Not important at all	Slightly important	Important	Very important	Extremely important
4.	Delivering the projects on time or in some cases ahead of schedule					
5.	Submit works with high quality and less defects					
6.	Maximizing workers' productivity and work efficiency					
7.	Reducing the additional costs					
8.	Increased profit					
9.	Reducing wastes on site					
10.	Site organization to reduce clutter and congestion on workspace to create a space and convenience for employees					
11.	Facilitating coordination in tools' handling					
12.	Distinguishing dangerous places from safe ones					
13.	Reducing site hazards such as noise and dust					
14.	Control the construction site environmentally (less weather effects)					
15.	Creating a trust bond and enhancing transparency among project parties					
16.	Increasing communication and collaboration between project parties					
17.	Enhancing employees' sense of belonging and their problem-solving ability					
18.	Employees can clearly know the critical work areas and durations of these					
19.	Improving employees' self- disciplined					
20.	Stakeholders satisfaction					
21.	Reducing stress level on management and conflicts on projects					
22.	Promoting free flow of information on-site					

Section D: **<u>Barriers to the application of LC techniques regarding safety improvement</u>**

- Please indicate the effect level of the following barriers which face the application of LC techniques in safety improvement among your firm

#	**Barriers to the application of LC techniques regarding safety improvement**	Degree of effect				
		Low		⇔	High	
		0	1	2	3	4
		No effect	Slight effect	Moderate effect	Strong effect	Extreme effect
Management barriers						
1.	Lack of management support and commitment					
2.	Poor project definition					
3.	Centralization of decision					
4.	Lengthy approval procedure from top management					
5.	Lack of time for innovation					
6.	Lack of transparency					
7.	Poor communication among construction participants					
8.	Poor coordination among construction participants					
9.	Absence of long term forecast and investment					
10.	Inadequate planning					
11.	Logistics' problems					
Financial barriers						
12.	Inadequate funding					
13.	Low tender prices					
14.	High cost of LC implementation					
15.	Poor salaries of professionals					
16.	Lack of incentives and motivation					
Educational barriers						
17.	Lack of LC concept understanding					
18.	Lack of knowledge and skills					
19.	Lack of technical skills					
20.	Lack of education and training					
21.	Lack of awareness programs					
22.	Lack of information sharing					
Governmental barriers						
23.	Lack of government support					
24.	Government bureaucracy and instability					
25.	Inconsistency in the government policies					
26.	Unsteady price of commodities					
Technical barriers						
27.	Lack of agreed implementation methodology					

#	Barriers to the application of LC techniques regarding safety improvement	Degree of effect				
		Low		⇔		High
		0	1	2	3	4
		No effect	Slight effect	Moderate effect	Strong effect	Extreme effect
28.	Complexity of LC implementation					
29.	Long implementation period					
30.	Incomplete designs					
31.	Poor performance measurement strategies					
32.	Fragmented nature of the construction industry					
Human attitudinal barriers						
33.	Selfishness among professionals					
34.	Poor leadership					
35.	Resistance to change by employees					
36.	Cultural issues					
37.	Lack of self-criticism					
38.	Fear of unfamiliar practices					
39.	Lack of teamwork					

Section E: **Success factors to apply LC techniques in safety improvement successfully**

- Please indicate the level of influence of the following success factors that should be taken to apply LC techniques successfully in safety improvement among your firm

#	Success factors to apply LC techniques in safety improvement successfully	Degree of influence				
		Low		⇔		High
		1	2	3	4	5
		Not influential at all	Slightly influential	Influential	Very influential	Extremely influential
Management success factors						
1.	Management support and commitment					
2.	Developing and implementing an effective plan					
3.	Ensuring the culture of continuous improvement					
4.	A clear definition of roles, responsibilities, functions and levels of authority					
5.	Decentralization of construction management					
6.	Good leadership					
7.	Constructing transparency					
8.	Construction managers should be proactive					

#	**Success factors to apply LC techniques in safety improvement successfully**	Degree of influence				
		Low		⬄	High	
		1	2	3	4	5
		Not influential at all	Slightly influential	Influential	Very influential	Extremely influential
9.	Improving communication skills cooperation, coordination and promoting integration					
10.	Establish a recognition and reward system					
11.	Adequate funding of projects					
12.	Invest time as much as money					
Education and skill development success factors						
13.	Providing adequate education and training					
14.	Simplifying the language of Lean					
15.	Enlighten the employees on the benefits of LC techniques					
16.	Establishing awareness programs					
17.	Promotion of the LC concept to the stakeholders of construction projects					
18.	Engagement of skillful site operatives					
19.	Engagement of skillful professionals					
Government success factors						
20.	Government should provide a clear direction to apply LC techniques by introducing policies					
21.	Legislation bodies should introduce laws					
22.	Government should provide the basic infrastructure and standards to apply LC techniques					
23.	Government should work closely with professional bodies					
Operational success factors						
24.	Standardize and ensure complete designs					
25.	Workers empowerment and involvement					
26.	Application of LC techniques gradually step-by-step					
27.	Constitution of an improvement committee					
28.	Establishing appropriate performance measurement approaches					

Appendix (B): Main English Questionnaire

The Islamic University–Gaza

Research and Postgraduate Affairs

Faculty of Engineering

Civil Engineering Department

الجامعـــــــة الإســـلاميـةـ غـزة

شئون البحث العلمي والدراسات العليا

كـليـــة الـهندسة

قسم الهندسة المدنية

Subject: questionnaire survey about: **“Safety improvement through the application of Lean Construction (LC) techniques in construction projects”** for submitting a thesis in partial fulfillment of the requirements for the Master degree in Construction Management

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Research Aim: Developing a clear understanding of the relation between Lean Construction and safety improvement and exploring the current state of using Lean Construction techniques to promote safety in construction projects in Gaza Stip.

Target Group: Engineers who work in the field of construction supervision ***(Project manager, site engineers, site supervisors and safety engineers).***

The questionnaire consists of six main sections. ***Filling in the questionnaire does not require a prior knowledge about Lean Construction***, but what is required is the answer and evaluation of certain points with precision and objectivity according to your point of view and expertise in the field of construction. The validity of the questionnaire results depends on your answer’s accuracy. Thank you in advance for your valuable time and contribution to this research work.

Best Regards,

Nour Maher Saleh

M.Sc. Candidate in Construction Management, IUG

(2017)

Section A: Profile of respondent

- **Please tick (√) the appropriate option in the following questions**

Q1.	**Educational qualification**	☐ Bachelor's	☐ Master's	☐ Ph.D.	
Q2.	**Specialization**	☐ Architect	☐ Civil	☐ Others……………….	
Q3.	**Type of organization**	☐ Consultant	☐ Contractor	☐ NGO	☐ Governmental organization
Q4.	**Job title**	☐ Project manager	☐ Site engineer	☐ Site supervisor	☐ Safety engineer
Q5.	**Years of experience in construction firms**	☐ Less than 5 years	☐ From 5 to less than 10 years		☐ 10 years and more

Section B: Awareness level of Lean Construction (LC) tools

- **Please rate your awareness level regard the following Lean Construction (LC) tools**

#	**Lean Construction (LC) tool**	Degree of awareness				
		Low		⇔		High
		1	2	3	4	5
		Never	Little	Somewhat	Much	Very much
AL1	Last Planner System (LPS)					
AL2	Increased visualization (IV)					
AL3	5S process					
AL4	Fail safe for quality and safety (Poka yoke)					
AL5	Daily Huddle Meetings (DHM)					
AL6	First Run Studies (FRS)					
AL7	Continuous improvement (Kaizen)					
AL8	Accident investigation (5 Why’s)					

Section C: **Applicability level of LC techniques to reduce the causes of accidents on the construction sites**

- Please rate the applicability extent of the following statements among your firm to decrease the accidents on construction sites

#	**LC techniques application to reduce the causes of accidents on the construction sites**	Degree of applicability				
		Low		⇔		High
		1	2	3	4	5
		Never	Seldom	Often	Frequent	Always
Last Planner System (LPS)						
App1	Providing employees with safety equipment					
App2	Developing a plan for supervision					
App3	Developing a schedule based on worker's abilities					
App4	Worker's empowerment and involvement in task planning and scheduling					
App5	Correlating work methods with worker's skills and abilities					
App6	Involvement of all employees in safety planning					
App7	Conducting pre task hazard analysis to identify risks predicted at activity and reducing it					
App8	Conducting weekly work planning					
Increased visualization						
App9	Using camera connected with computer algorithm to warn safety officer when workers violate safety conditions					
App10	Using visual demarcations and boards on site					
App11	Using safety signs and labels on site					
5S						
App12	Cleaning the workplace and removing materials and machines that are not required					
App13	Organizing material and plant					
App14	Separating needed tools from unneeded materials and clearing the unwanted materials					
App15	Defining standard procedures to maintain the working environment clean and organized and improve safety culture					
App16	Creating continuous improvement in safety culture to increase safety culture among the workforce					
Poka yoke						
App17	Conducting visual inspection					

#	LC techniques application to reduce the causes of accidents on the construction sites	Degree of applicability				
		Low		⇔		High
		1	2	3	4	5
		Never	Seldom	Often	Frequent	Always
App18	Using Alarms and warning gadgets to warn workers from crossing the unsafe boundaries					
App19	Using safe guards and Personal Protective Equipment (PPE)					
Daily Huddle Meeting (DHM)						
App20	Conducting daily meeting to increase communication between teamwork, increase workers awareness of safety to make them identify risks and reduce it					
First Run Studies (FRS)						
App21	Make a plan for the critical tasks					
App22	Illustration of work methods using videos, photos, etc.					
Continuous improvement (Kaizen)						
App23	Involvement of all employees in improvement process					
App24	Conducting pre task hazard analysis to identify risks predicted at activity and reducing it					
Accident investigation (5Whys)						
App25	Conducting accident investigation and root-cause analysis program					

Section D: **Benefits of implementing LC techniques related to safety improvement in construction projects**

- Please rate the importance degree of the following benefits to the application of LC techniques' which is related to safety improvement among your firm

#	Benefits of LC techniques related to safety improvement in construction projects	Degree of importance				
		Low		⇔		High
		1	2	3	4	5
		Not important at all	Slightly important	Important	Very important	Extremely important
Ben1	Better work plan					
Ben2	Better safety management plan					
Ben3	Improving the rate of workflow on-site					

#	**Benefits of LC techniques related to safety improvement in construction projects**	Degree of importance				
		Low		⇔		High
		1	2	3	4	5
		Not important at all	Slightly important	Important	Very important	Extremely important
Ben4	Delivering the projects on time or in some cases ahead of schedule					
Ben5	Submit work with high quality and less defects to minimize the rework					
Ben6	Maximizing the workers productivity and work efficiency					
Ben7	Reducing the additional costs resulting from accidents					
Ben8	Increasing profit					
Ben9	Reducing wastes on site					
Ben10	Site organization to reduce clutter and congestion on workplace to create space and convenience for employees					
Ben11	Facilitating coordination in tools' handling					
Ben12	Distinguishing dangerous places from safe ones					
Ben13	Reducing site hazards such as noise and dust					
Ben14	Control the construction site environmentally (less weather effects)					
Ben15	Creating a trust bond and enhancing transparency between the project parties					
Ben16	Increasing communication and collaboration between project parties					
Ben17	Enhancing employees' sense of belonging and their problem-solving ability					
Ben18	Employees can clearly know the critical work areas and durations of these					
Ben19	Improving employees' self- disciplined					
Ben20	Stakeholders satisfaction					
Ben21	Reducing stress level on management and conflicts in projects					
Ben22	Promoting free flow of information on-site between project practitioners					

Section E: <u>Barriers to the application of LC techniques regarding safety improvement</u>

- **Please indicate the effect level of the following barriers which face the application of LC techniques in safety improvement among your firm**

#	Barriers to the application of LC techniques regarding safety improvement	Degree of effect				
		Low		⇔		High
		0	1	2	3	4
		No effect	Slight effect	Moderate effect	Strong effect	Extreme effect
Management barriers						
Bar1	Lack of management support and commitment to the application of LC techniques in safety improvement					
Bar2	Poor project definition which explain the vision, mission and main objectives of the project and its stakeholders					
Bar3	Centralization of decision making					
Bar4	Lengthy approval procedure from top management to take any step					
Bar5	Lack of time in construction firms for innovation and application of any innovative strategy					
Bar6	Lack of transparency					
Bar7	Poor communication among project parties (managers, administrators, foremen, etc.)					
Bar8	Poor coordination among project parties (managers, administrators, foremen, etc.)					
Bar9	Absence of long term forecast of safety improvement					
Bar10	Inadequate planning to apply of LC techniques in safety improvement					
Bar11	Logistics' problems (Ex. poor management of materials, equipment and tools and short supply of material)					
Financial barriers						
Bar12	Inadequate funding of the project to provide the required resources and training					
Bar13	Low tender prices					
Bar14	High cost of LC implementation including cost of training, consultancy fees and cost to conduct workshops					
Bar15	Poor salaries do not encourage employees to apply any innovative strategies					
Bar16	Lack of incentives and motivation					

#	**Barriers to the application of LC techniques regarding safety improvement**	Degree of effect				
		Low		⇔		High
		0	1	2	3	4
		No effect	Slight effect	Moderate effect	Strong effect	Extreme effect
Educational barriers						
Bar17	Lack of LC concept understanding					
Bar18	Lack of knowledge to apply LC techniques in safety improvement					
Bar19	Lack of technical skills to apply LC techniques in safety improvement					
Bar20	Lack of education and training needed to apply LC techniques in safety improvement					
Bar21	Lack of awareness program to increase knowledge about LC					
Bar22	Lack of information and experiences sharing among construction firms					
Governmental barriers						
Bar23	Lack of government support towards the construction projects to apply any innovative strategy					
Bar24	Inconsistency in the government policies					
Bar25	Government bureaucracy and instability					
Bar26	Unsteady price of commodities (Ex. PPE, safety signs, etc.)					
Technical barriers						
Bar27	Lack of agreed implementation methodology to implement LC techniques					
Bar28	Complexity of LC implementation since LC does not just involve applying LC techniques on site, but also involves developing a culture among the staff for a continuous improvement					
Bar29	Long implementation period needed for LC techniques application in safety improvement					
Bar30	Incomplete designs which leads to increases the probability of re-work					
Bar31	Poor performance measurement strategies					
Bar32	Fragmented nature of the construction industry					
Human attitudinal barriers						
Bar33	Selfishness among professionals to provide their experience in using LC techniques to improve safety					
Bar34	Lack of teamwork					
Bar35	Poor leadership					
Bar36	Cultural issues					

#	Barriers to the application of LC techniques regarding safety improvement	Degree of effect				
		Low		⇔		High
		0	1	2	3	4
		No effect	Slight effect	Moderate effect	Strong effect	Extreme effect
Bar37	Resistance to change by employees					
Bar38	Lack of self-criticism which limited the capacity to learn from errors					
Bar39	Fear of unfamiliar practices due to the misconceptions and misunderstandings of LC					

Section F: Success factors to apply LC techniques in safety improvement successfully

- **Please indicate the level of influence of the following success factors that should be taken to apply LC techniques successfully in safety improvement among your firm**

#	Success factors to apply LC techniques in safety improvement successfully	Degree of influence				
		Low		⇔		High
		1	2	3	4	5
		Not influential at all	Slightly influential	Influential	Very influential	Extremely influential
Management success factors						
SF1	Management support and commitment to the application of LC techniques in safety improvement					
SF2	Developing and implementing an effective plan to apply LC techniques in safety improvement					
SF3	Ensuring the culture of continuous improvement in construction projects to obtain the reduction of costs, increase quality and productivity					
SF4	A clear definition of roles, responsibilities, functions and levels of authority before the application of LC techniques					
SF5	Decentralization of construction management					
SF6	Construction managers should be proactive in decision-making					
SF7	Good leadership					
SF8	Constructing transparency between project participants					

#	**Success factors to apply LC techniques in safety improvement successfully**	Degree of influence				
		Low		⇔		High
		1	2	3	4	5
		Not influential at all	Slightly influential	Influential	Very influential	Extremely influential
SF9	Effective communication, cooperation, coordination and promoting integration between stakeholders					
SF10	Establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety					
SF11	Adequate funding of projects to cover the provisions of consultancy and training					
SF12	Invest time as much as money to successfully apply LC techniques					
Education and skill development success factors						
SF13	Providing adequate education and training for employees at all levels on the LC concept and techniques					
SF14	Simplifying the language of Lean to enlighten the employees on the benefits of LC techniques application to achieve their compliance to the LC application					
SF15	Establishing awareness programs to increase the understanding of the LC using workshops and research conferences to guide the application of LC techniques in safety improvement					
SF16	Promotion of the LC concept to the stakeholders of construction projects					
SF17	Engagement of skillful site operatives and skillful professionals to guide the application of LC techniques in safety improvement					
Government success factors						
SF18	Government should provide a clear direction for the construction firms to apply LC techniques in safety improvement through introducing policies to encourage construction firms to engage in the application of LC techniques to improve construction safety					
SF19	Legislation bodies should introduce laws to facilitate the full application of LC techniques among construction firms					

#	**Success factors to apply LC techniques in safety improvement successfully**	Degree of influence				
		Low		⇔	High	
		1	2	3	4	5
		Not influential at all	Slightly influential	Influential	Very influential	Extremely influential
SF20	Government should provide the basic infrastructure and standards to apply LC techniques					
SF21	Government should work closely with professional bodies to introduce LC to improve construction safety					
Operation success factors						
SF22	Standardize and ensure complete designs					
SF23	Workers empowerment and involvement in the application of LC techniques in safety improvement					
SF24	Application of LC techniques gradually step-by-step in improving safety to decrease the complexity of LC implementation					
SF25	Constitution of an improvement committee to be responsible for the application of LC techniques in safety improvement					
SF26	Establishing appropriate performance measurement approaches to measure the effectiveness of implemented LC techniques in safety improvement and identifying the mistakes to improve their weak links					

Thank you very much for your valuable time and effort on this survey

Appendix (C): Arabic Questionnaire

The Islamic University– Gaza
Research and Postgraduate Affairs
Faculty of Engineering
Civil Engineering Department
Master of Construction Management

الجامعة الإسلامية_ غزة
شئون البحث العلمي والدراسات العليا
كلية الهندسة
قسم الهندسة المدنية
ماجستير إدارة المشروعات الهندسية

الموضوع: استبانة حول **" تحسين السلامة من خلال استخدام تقنيات البناء السلس (Lean Construction) في مشاريع البناء"** استكمالاً لمتطلبات الحصول على درجة الماجستير في إدارة المشاريع الهندسية.

- **الهدف الرئيسي من البحث:** تطوير فهم واضح حول اعتماد تقنيات Lean Construction فى تحسين السلامة فى مشاريع البناء من خلال دراسة مدى تطبيق تقنيات Lean Construction في تحسين السلامة في مشاريع البناء في قطاع غزة واقتراح منهجية عملية توضح كيفية تطبيق تقنيات LC من أجل تحسين السلامة في مشاريع البناء.
- **ماهية الاستبانة:** تتكون الاستبانة من ستة أقسام رئيسية، **لا تتطلب تعبئة الاستبانة معرفة مسبقة عن تقنيات LC** ، وانما المطلوب هو التقييم لنقاط معينة بكل دقة وموضوعية وفقا لوجهة نظرك، والخبرة في مجال العمل الهندسي الخاص بالبناء في ضوء الواقع الفعلي في قطاع غزة .مدى صحة نتائج الاستبانة يعتمد اعتماداً كلياً على دقة إجابتك.

لكم كل الشكر مقدما على المساهمة في هذا العمل البحثي.

أطيب التحيات،
نور ماهر صالح، مهندسة مدنية/ وباحثة للحصول على درجة الماجستير في إدارة المشاريع الهندسية (الهندسة المدنية)،
الجامعة الإسلامية _ غزة

نبذة تعريفية عن Lean Construction (LC) و علاقته بالسلامة (Safety):

: نظام يهدف إلى التحسين المتزامن والمستمر لمشروع البناء عن طريق الحد من هدر الموارد و زيادة LC
الإنتاجية و تحسين السلامة من أجل تلبية متطلبات العملاء.

تعتبر الحوادث في مشاريع البناء هدر للمال و الوقت و العمال، ولذلك يجب القضاء على LCبناء على مفهوم
و تشمل هذه الأدوات: LC الحوادث و بالتالي تحسين السلامة في مشاريع البناء باستخدام مجموعة من أدوات

- Last planner system, increased visualization, 5S process, fail safe for quality and safety, daily huddle meetings, first run studies, Continuous improvement and accident investigation

الجزء الأول: **معلومات شخصية**

يرجى وضع علامة (√) أمام الخيار المناسب في الأسئلة التالية:

1.	**المؤهل العلمي**	☐ بكالوريوس	☐ ماجستير	☐ دكتوراة	
2.	**التخصص**	☐ مهندس معماري	☐ مهندس مدني	☐ أخرى	
3.	**طبيعة مكان العمل**	☐ استشارات هندسية	☐ مقاولات	☐ مؤسسات دولية	☐ قطاع حكومي
4.	**الوظيفة الحالية**	☐ مدير مشروع	☐ مهندس موقع	☐ مهندس مشرف	☐ مهندس أمن و سلامة
5.	**سنوات الخبرة**	☐ أقل من 5 سنوات	☐ من 5 الى اقل من 10 سنوات	☐ 10 سنوات فأكثر	

الجزء الثاني: **درجة الوعي بأدوات Lean Construction (LC)**

إلى أي درجة تقيم درجة الوعي الخاصة بك لأدوات LC التالية، يرجى وضع علامة √ أمام التقييم الذي تراه مناسبا

#	**أدوات Lean Construction**	درجة الوعي				
		5	4	3	2	1
		درجة كبيرة جدا	درجة كبيرة	درجة متوسطة	درجة قليلة	درجة قليلة جدا
1.	Last Planner System (LPS)					
2.	Increased visualization (IV)					
3.	5S process					
4.	Fail safe for quality and safety (Poka yoke)					
5.	Daily Huddle Meetings (DHM)					
6.	First Run Studies (FRS)					
7.	Continuous improvement (Kaizen)					
8.	Accident investigation (5 Why’s)					

الجزء الثالث: **تطبيق تقنيات LC للحد من أسباب الحوادث في مشاريع البناء**

من وجهة نظركم، إلى أي درجة يتم تطبيق التقنيات التالية **لتقليل حوادث البناء** في مشاريع البناء؟ يرجى وضع علامة √ أمام التقييم الذي تراه مناسبا

#	**تقنيات Lean Construction**	درجة التطبيق				
		5	4	3	2	1
		بدرجة كبيرة جدا	بدرجة كبيرة	بدرجة متوسطة	بدرجة قليلة	بدرجة قليلة جدا
	Last Planner System (LPS)					
.1	تزويد العاملين بأدوات الأمن و السلامة					
.2	إعداد خطة للإشراف على تطبيق إجراءات الأمن و السلامة في الموقع					
.3	إعداد جدول زمني مبنى على قدارات العمال					
.4	تمكين و مشاركة العمال في تخطيط و جدولة الأعمال					
.5	موائمة طرق تنفيذ الأعمال مع قدرات و مهارات العمال					
.6	مشاركة كافة العاملين في إعداد خطة الأمن و السلامة					
.7	تحليل المخاطر المتوقعة في الأعمال قبل تنفيذها					
.8	إعداد خطة أسبوعية لتنفيذ الأعمال					
	Increased visualization (IV)					
.9	تزويد الموقع بكاميرات متصلة بكمبيوتر لتحذير مهندس الأمن و السلامة عند انتهاك أحد العاملين لشروط السلامة					
.10	استخدام الحواجز المرئية في الموقع لتنبيه العمال من الأماكن الخطرة					
.11	استخدام الإشارات المتعلقة بالأمن و السلامة في الموقع					
	5S process					
.12	تنظيف موقع العمل و إزالة المواد و الأدوات غير اللازمة للعمل					
.13	تنظيم الأدوات اللازمة للعمل					
.14	فصل الأدوات و المواد اللازمة للعمل عن غير اللازمة للعمل					
.15	اعتماد المعايير المناسبة لتحقيق بيئة عمل نظيفة و مرتبة					
.16	الحفاظ على التحسين المستمر في ثقافة الأمن و السلامة للعاملين					
	Fail safe for quality and safety (Poka yoke)					
.17	إجراء فحص دوري للموقع للتأكد من تطبيق إجراءات الأمن و السلامة					
.18	استخدام أجهزة إنذار في الموقع للتحذير من المخاطر قبل وقوعها					
.19	استخدام أدوات الحماية الشخصية لتقليل نتائج الحوادث على العاملين في الموقع					
	Daily Huddle Meetings (DHM)					
.20	عقد اجتماع يومي لتوضيح ومناقشة العمل الذي يتعين القيام به في ذلك اليوم و تحديد المخاطر المتوقعة فيه و كيفية تجاوزها					
	First Run Studies (FRS)					
.21	إعداد خطة خاصة بالمهام الحرجة و الخطيرة					
.22	توضيح طرق تنفيذ الأعمال باستخدام فيديوهات أو صور					
	Continuous improvement (Kaizen)					

#	**تقنيات Lean Construction**	درجة التطبيق				
		5	4	3	2	1
		بدرجة كبيرة جدا	بدرجة كبيرة	بدرجة متوسطة	بدرجة قليلة	بدرجة قليلة جدا
.23	مشاركة العاملين في عملية التحسين المستمر لتخفيض التكاليف وزيادة الجودة والإنتاجية					
.24	تحليل المخاطر المتوقعة في الأعمال قبل تنفيذها					
	Accident investigation (5 Why's)					
.25	تحديد الأسباب الرئيسية للحوادث في الموقع عند وقوعها					

الجزء الرابع: **فوائد استخدام تقنيات LC المتعلقة بتحسين السلامة في مشاريع البناء**

ما تقييمك لأهمية الفوائد التالية الناتجة من تطبيق تقنيات LC من حيث تأثيرها على تحسين السلامة في مشاريع البناء ؟ يرجى وضع علامة √ أمام التقييم الذي تراه مناسبا

#	**فوائد تقنيات LC المتعلقة بتحسين السلامة في مشاريع البناء**	درجة الأهمية				
		5	4	3	2	1
		أهمية كبيرة جدا	أهمية كبيرة	أهمية متوسطة	أهمية قليلة	أهمية قليلة جدا
.1	إنتاج خطة جيدة للأعمال					
.2	إنتاج خطة جيدة للسلامة					
.3	تحسين سير العمل في الموقع					
.4	تسليم المشروع في الوقت المحدد أو قبل الموعد المحدد					
.5	تسليم الأعمال بجودة عالية و عيوب أقل لتقليل إعادة العمل					
.6	زيادة إنتاجية العمال و كفاءة العمل					
.7	تقليل التكاليف الإضافية الناتجة عن الحوادث					
.8	زيادة الربح					
.9	تقليل النفايات في الموقع					
.10	تنظيم الموقع للحد من الفوضى و الازدحام و خلق مساحة و راحة للعمل في الموقع					
.11	تسهيل الوصول إلى أدوات العمل حسب العمل الحالي					
.12	التمييز بين الأماكن الخطرة و الآمنة في الموقع					
.13	الحد من المخاطر في الموقع كالضوضاء و الغبار					
.14	تقليل آثار الطقس على العاملين في موقع العمل					
.15	تعزيز الثقة و الشفافية بين أطراف المشروع					
.16	زيادة التواصل والتعاون بين أطراف المشروع					
.17	تعزيز شعور العاملين بالانتماء للمشروع و زيادة قدرتهم على حل المشاكل					

#	**فوائد تقنيات LC المتعلقة بتحسين السلامة في مشاريع البناء**	درجة الأهمية				
		5	4	3	2	1
		أهمية كبيرة جدا	أهمية كبيرة	أهمية متوسطة	أهمية قليلة	أهمية قليلة جدا
18.	توعية العاملين بالمهام الحرجة و مدتها					
19.	تحسين الانضباط الذاتي لدى العاملين					
20.	تحقيق رضا أطراف المشروع					
21.	تقليل الضغط على الإدارة العليا و تقليل الصراعات في المشروع					
22.	سلاسة تبادل المعلومات الخاصة بالمشروع في الموقع بين أطراف المشروع					

الجزء الخامس: **<u>عوائق استخدام تقنيات LC فى تحسين السلامة فى مشاريع البناء</u>**

إلى أي درجة يمكن أن تؤثر العوائق التالية على تطبيق تقنيات LC في تحسين السلامة في مشاريع البناء؟ يرجى وضع علامة √ أمام التقييم الذي تراه مناسبا

#	**عوائق استخدام تقنيات LC في تحسين السلامة في مشاريع البناء**	درجة التأثير				
		4	3	2	1	0
		تأثير قوي جدا	تأثير قوي	تأثير متوسط	تأثير ضعيف	تأثير ضعيف جدا
عوائق إدارية						
1.	عدم دعم الإدارة العليا لتطبيق تقنيات LC في تحسين السلامة					
2.	ضعف تعريف المشروع الذي يوضح الرؤية الرسالة والأهداف الرئيسية للمشروع وأصحاب المصلحة فيه					
3.	المركزية في اتخاذ القرارات					
4.	طول إجراءات الموافقة من الإدارة العليا لاتخاذ أي خطوة					
5.	عدم توفر الوقت في شركات البناء للابتكار وتطبيق أي استراتيجية مبتكرة					
6.	انعدام الشفافية					
7.	قلة التواصل بين أطراف المشروع					
8.	قلة التنسيق بين أطراف المشروع					
9.	غياب التوقعات طويلة الأجل لنتائج تحسين السلامة					
10.	عدم كفاية التخطيط لتطبيق تقنيات LC في تحسين السلامة					
11.	المشاكل اللوجستية (سوء إدارة المواد والمعدات)					
عوائق اقتصادية						
12.	عدم ملائمة تمويل المشروع لتوفير الموارد اللازمة و تدريب العاملين لاستخدام تقنيات مبتكرة					
13.	انخفاض أسعار العطاءات					

#	عوائق استخدام تقنيات LC في تحسين السلامة في مشاريع البناء	درجة التأثير				
		4	3	2	1	0
		تأثير قوي جدا	تأثير قوي	تأثير متوسط	تأثير ضعيف	تأثير ضعيف جدا
.14	ارتفاع تكلفة تنفيذ تقنيات LC (تكلفة التدريب، رسوم الاستشارات و ورش العمل)					
.15	سوء الرواتب لا يشجع الموظفين على تطبيق أي استراتيجيات مبتكرة					
.16	نقص الحوافز والمكافآت					
عوائق معرفية						
.17	عدم الوعي بمفهوم LC					
.18	عدم المعرفة بكيفية تطبيق تقنيات LC في تحسين السلامة					
.19	قلة المهارات التقنية لتطبيق تقنيات LC في تحسين السلامة					
.20	نقص التدريب اللازم لتطبيق تقنيات LC في تحسين السلامة					
.21	قلة برامج التوعية بتطبيق تقنيات LC في تحسين السلامة					
.22	قلة تبادل المعلومات و الخبرات بين شركات البناء					
عوائق حكومية						
.23	الافتقار إلى الدعم الحكومي لتطبيق أي استراتيجية مبتكرة في مشاريع البناء					
.24	عدم ملاءمة سياسات الحكومة أي استراتيجية مبتكرة في مشاريع البناء					
.25	عدم الاستقرار الحكومي و البيروقراطية الحكومية					
.26	عدم استقرار أسعار السلع					
عوائق تقنية						
.27	عدم وجود منهجية متفق عليها لتنفيذ تقنيات LC في تحسين السلامة					
.28	تعقيد تطبيق LC حيث أنها لا تشمل تطبيق التقنيات فقط و إنما تطوير ثقافة لدى العاملين بالتحسين المستمر					
.29	طول الفترة اللازمة لتطبيق تقنيات LC في تحسين السلامة					
.30	عدم اكتمال التصاميم قبل بدء العمل مما يؤدي إلى زيادة احتمال إعادة العمل					
.31	ضعف الاستراتيجيات المستخدمة في قياس أداء الأعمال					
.32	طبيعة صناعة البناء والتشييد المجزأة لا تسهل تطبيق تقنيات LC					
عوائق بشرية						
.33	عدم مشاركة الخبراء لخبراتهم في استخدام تقنيات LC لتحسين السلامة					
.34	غياب العمل بروح الفريق					
.35	ضعف القيادة					
.36	عدم تقبل LC ثقافياً					
.37	مقاومة العاملين للتغيير					
.38	افتقار العاملين للنقد الذاتي الذي يحد من قدرتهم على التعلم من الأخطاء					
.39	الخوف من تطبيق التقنيات غير المألوفة					

الجزء السادس: **عوامل نجاح تطبيق تقنيات LC في تحسين السلامة في مشاريع البناء**

ما تقييمك لتأثير العوامل التالية على نجاح تطبيق تقنيات LC في تحسين السلامة في مشاريع البناء من حيث أهميتها؟ يرجى وضع علامة √ أمام التقييم الذي تراه مناسبا

#	**عوامل النجاح لتطبيق تقنيات LC في تحسين السلامة في مشاريع البناء**	درجة التأثير				
		5	4	3	2	1
		قوي جدا	قوي	متوسط القوة	ضعيف	ضعيف جدا
عوامل إدارية						
1.	دعم الإدارة العليا لتطبيق تقنيات LC في تحسين السلامة					
2.	وضع وتنفيذ خطة فعالة لتطبيق تقنيات LC في تحسين السلامة					
3.	تعزيز التحسين المستمر في مشاريع البناء لتخفيض التكاليف وزيادة الجودة والإنتاجية					
4.	تعريف واضح للأدوار والمسؤوليات والوظائف قبل تطبيق تقنيات LC في تحسين السلامة					
5.	اللامركزية في اتخاذ القرارات					
6.	الاستباقية و طول الأجل في اتخاذ القرارات					
7.	القيادة الجيدة					
8.	تعزيز الشفافية بين أطراف المشروع					
9.	التواصل الفعال والتعاون والتنسيق وتعزيز التكامل بين أطراف المشروع					
10.	إنشاء نظام الحوافز والمكافآت لتشجيع العاملين على المشاركة في تطبيق تقنيات LC في تحسين السلامة					
11.	تزويد المشاريع بالتمويل الكافي					
12.	استثمار الوقت بقدر المال لتطبيق تقنيات LC في تحسين السلامة بنجاح					
عوامل معرفية						
13.	تزويد العاملين بالتدريب المناسب حول مفهوم و تقنيات LC					
14.	تبسيط مفهوم LC لتنوير العاملين بفوائد تطبيق تقنيات LC					
15.	إنشاء برامج للتوعية بتطبيق تقنيات LC في تحسين السلامة					
16.	ترويج و نقل مفهوم LC لجميع أطراف المشروع					
17.	إشراك خبراء في LC لتوجيه تطبيق تقنيات LC في تحسين السلامة					
عوامل حكومية						
18.	توفير الحكومة اتجاهاً واضحاً لشركات البناء لتطبيق تقنيات LC في تحسين السلامة من خلال وضع سياسات لتشجيع شركات البناء على الانخراط في تطبيق تقنيات LC في تحسين السلامة					
19.	سن القوانين التي تلزم بتطبيق شركات البناء لتقنيات LC في تحسين السلامة					
20.	توفير الحكومة البنية التحتية والمعايير الأساسية لتطبيق تقنيات LC في تحسين السلامة					
21.	تعاون الحكومة بشكل وثيق مع الخبراء لتطبيق تقنيات LC في تحسين السلامة					

#	**عوامل النجاح لتطبيق تقنيات LC في تحسين السلامة في مشاريع البناء**	درجة التأثير				
		5	4	3	2	1
		قوي جدا	قوي	متوسط القوة	ضعيف	ضعيف جدا
عوامل تشغيلية/ تنفيذية						
.22	توحيد وضمان التصاميم كاملة					
.23	تمكين و مشاركة العمال في تطبيق تقنيات LC في تحسين السلامة					
.24	تطبيق تقنيات LC تدريجياً خطوة بخطوة في تحسين السلامة للحد من تعقيد تنفيذ LC					
.25	تشكيل لجنة للتحسين لتكون مسؤولة عن متابعة تطبيق تقنيات LC في تحسين السلامة					
.26	وضع استراتيجيات مناسبة لقياس فعالية تقنيات LC المطبقة في تحسين السلامة					

شكرا جزيلا على وقتك الثمين والجهد المبذول في هذا الاستطلاع

Appendix (D)

Table (D1): Internal validity results of section (B): Awareness level of Lean Construction tools

#	Item	Pearson correlation	P value	Significant (Sig.) at
AL1	Last Planner System (LPS)	0.878**	0.000	Sig. at 0.01
AL2	Increased visualization (IV)	0.931**	0.000	Sig. at 0.01
AL3	5S process	0.830**	0.000	Sig. at 0.01
AL4	Fail safe for quality and safety (Poka yoke)	0.927**	0.000	Sig. at 0.01
AL5	Daily Huddle Meetings (DHM)	0.886**	0.000	Sig. at 0.01
AL6	First Run Studies (FRS)	0.856**	0.000	Sig. at 0.01
AL7	Continuous improvement (Kaizen)	0.872**	0.000	Sig. at 0.01
AL8	Accident investigation (5 Why's)	0.843**	0.000	Sig. at 0.01

Table (D2): Internal validity results of section (C): Application of LC techniques to reduce the causes of accidents on the construction sites

#	Item	Pearson correlation	P value	Significant (Sig.) at
App1	Providing employees with safety equipment	0.592^{**}	0.001	Sig. at 0.01
App2	Developing a plan for supervision	0.769^{**}	0.000	Sig. at 0.01
App3	Developing a schedule based on worker's abilities	0.601**	0.000	Sig. at 0.01
App4	Worker's empowerment and involvement in task planning and scheduling	0.653**	0.000	Sig. at 0.01
App5	Correlating work methods with worker's skills and abilities	0.443*	0.014	Sig. at 0.05
App6	Involvement of all employees in safety planning	0.499**	0.005	Sig. at 0.01
App7	Conducting pre task hazard analysis to identify risks predicted at activity and reducing it	0.606**	0.000	Sig. at 0.01
App8	Conducting weekly work planning	0.607**	0.000	Sig. at 0.01

Table (D2): Internal validity results of section (C): Application of LC techniques to reduce the causes of accidents on the construction sites

#	Item	Pearson correlation	P value	Significant (Sig.) at
App9	Using camera connected with computer algorithm to warn safety officer when workers violate safety conditions	0.546**	0.002	Sig. at 0.01
App10	Using visual demarcations and boards on site	0.490**	0.006	Sig. at 0.01
App11	Using safety signs and labels on site	0.595**	0.001	Sig. at 0.01
App12	Cleaning the workplace and removing materials and machines that are not required	0.721**	0.000	Sig. at 0.01
App13	Organizing material and plant	0.495**	0.005	Sig. at 0.01
App14	Separating needed tools from unneeded materials and clearing the unwanted materials	0.619**	0.000	Sig. at 0.01
App15	Defining standard procedures to maintain the working environment clean and organized and improve safety culture	0.689**	0.000	Sig. at 0.01
App16	Creating continuous improvement in safety culture to increase safety culture among the workforce	0.746**	0.000	Sig. at 0.01
App17	Conducting visual inspection	0.863**	0.000	Sig. at 0.01
App18	Using Alarms and warning gadgets to warn workers from crossing the unsafe boundaries	0.598**	0.000	Sig. at 0.01
App19	Using safe guards and Personal Protective Equipment (PPE)	0.680**	0.000	Sig. at 0.01
App20	Conducting daily meeting to increase communication between teamwork, increase workers awareness of safety to make them identify risks and reduce it	0.426*	0.019	Sig. at 0.05
App21	Make a plan for the critical tasks	0.554**	0.001	Sig. at 0.01
App22	Illustration of work methods using videos, photos, etc.	0.598**	0.000	Sig. at 0.01

Table (D2): Internal validity results of section (C): Application of LC techniques to reduce the causes of accidents on the construction sites

#	Item	Pearson correlation	P value	Significant (Sig.) at
App23	Involvement of all employees in improvement process	0.609**	0.000	Sig. at 0.01
App24	Conducting pre task hazard analysis to identify risks predicted at activity and reducing it	0.640**	0.000	Sig. at 0.01
App25	Conducting accident investigation and root-cause analysis program	0.390*	0.033	Sig. at 0.05

Table (D3): Internal validity results of section (D): Benefits of LC techniques related to safety improvement in construction projects

#	Item	Pearson correlation	P value	Significant (Sig.) at
Ben1	Better work plan	0.462*	0.01	Sig. at 0.05
Ben2	Better safety management plan	0.417*	0.022	Sig. at 0.05
Ben3	Improving the rate of workflow on-site	0.504**	0.005	Sig. at 0.01
Ben4	Delivering the projects on time or in some cases ahead of schedule	0.605**	0.000	Sig. at 0.01
Ben5	Submit work with high quality and less defects to minimize the rework	0.530**	0.003	Sig. at 0.01
Ben6	Maximizing the workers productivity and work efficiency	0.517**	0.003	Sig. at 0.01
Ben7	Reducing the additional costs resulting from accidents	0.462*	0.01	Sig. at 0.05
Ben8	Increasing profit	0.621**	0.000	Sig. at 0.01
Ben9	Reducing wastes on site	0.535**	0.002	Sig. at 0.01
Ben10	Site organization to reduce clutter and congestion on workplace to create space and convenience for employees	0.463*	0.01	Sig. at 0.05
Ben11	Facilitating coordination in tools’ handling	0.531**	0.003	Sig. at 0.01

Table (D3): Internal validity results of section (D): Benefits of LC techniques related to safety improvement in construction projects

#	Item	Pearson correlation	P value	Significant (Sig.) at
Ben12	Distinguishing dangerous places from safe ones	0.645**	0.000	Sig. at 0.01
Ben13	Reducing site hazards such as noise and dust	0.483**	0.007	Sig. at 0.01
Ben14	Control the construction site environmentally (less weather effects)	0.488**	0.006	Sig. at 0.01
Ben15	Creating a trust bond and enhancing transparency between the project parties	0.734**	0.000	Sig. at 0.01
Ben16	Increasing communication and collaboration among project practitioners	0.735**	0.000	Sig. at 0.01
Ben17	Enhancing employees' sense of belonging and their problem-solving ability	0.643**	0.000	Sig. at 0.01
Ben18	Employees can clearly know the critical work areas and durations of these	0.815**	0.000	Sig. at 0.01
Ben19	Improving employees' self- disciplined	0.502**	0.005	Sig. at 0.01
Ben20	Stakeholders satisfaction	0.809**	0.000	Sig. at 0.01
Ben21	Reducing stress level on management and conflicts in projects	0.638**	0.000	Sig. at 0.01
Ben22	Promoting free flow of information on-site between project practitioners	0.719**	0.000	Sig. at 0.01

Table (D4): Internal validity results of section (E): Barriers to the application of LC techniques regarding safety improvement

#	Item	Pearson correlation	P value	Significant (Sig.) at
Bar1	Lack of management support and commitment to the application of LC techniques in safety improvement	0.367*	0.046	Sig. at 0.05
Bar2	Poor project definition which explain the vision, mission and main objectives of the project and its stakeholders	0.508**	0.004	Sig. at 0.01
Bar3	Centralization of decision making	0.539**	0.002	Sig. at 0.01

Table (D4): Internal validity results of section (E): Barriers to the application of LC techniques regarding safety improvement

#	Item	Pearson correlation	P value	Significant (Sig.) at
Bar4	Lengthy approval procedure from top management to take any step	0.510**	0.004	Sig. at 0.01
Bar5	Lack of time in construction firms for innovation and application of any innovative strategy	0.569**	0.001	Sig. at 0.01
Bar6	Lack of transparency	0.367*	0.046	Sig. at 0.05
Bar7	Poor communication among project parties (managers, administrators, foremen, etc.)	0.505**	0.004	Sig. at 0.01
Bar8	Poor coordination among project parties (managers, administrators, foremen, etc.)	0.374*	0.042	Sig. at 0.05
Bar9	Absence of long term forecast of safety improvement	0.369*	0.045	Sig. at 0.05
Bar10	Inadequate planning to apply of LC techniques in safety improvement	0.443*	0.014	Sig. at 0.05
Bar11	Logistics' problems (Ex. poor management of materials, equipment and tools and short supply of material)	0.412*	0.024	Sig. at 0.05
Bar12	Inadequate funding of the project to provide the required resources and training	0.387*	0.035	Sig. at 0.05
Bar13	Low tender prices	0.367*	0.046	Sig. at 0.05
Bar14	High cost of LC implementation including cost of training, consultancy fees and cost to conduct workshops	0.525**	0.003	Sig. at 0.01
Bar15	Poor salaries do not encourage employees to apply any innovative strategies	0.716**	0.000	Sig. at 0.01
Bar16	Lack of incentives and motivation	0.678**	0.000	Sig. at 0.01
Bar17	Lack of LC concept understanding	0.590**	0.001	Sig. at 0.01

Table (D4): Internal validity results of section (E): Barriers to the application of LC techniques regarding safety improvement

#	Item	Pearson correlation	P value	Significant (Sig.) at
Bar18	Lack of knowledge to apply LC techniques in safety improvement	0.554**	0.001	Sig. at 0.01
Bar19	Lack of technical skills to apply LC techniques in safety improvement	0.455*	0.011	Sig. at 0.05
Bar20	Lack of education and training needed to apply LC techniques in safety improvement	0.532**	0.002	Sig. at 0.01
Bar21	Lack of awareness program to increase knowledge about LC	0.544**	0.002	Sig. at 0.01
Bar22	Lack of information and experiences sharing among construction firms	0.710**	0.000	Sig. at 0.01
Bar23	Lack of government support towards the construction projects to apply any innovative strategy	0.548**	0.002	Sig. at 0.01
Bar24	Inconsistency in the government policies	0.485**	0.007	Sig. at 0.01
Bar25	Government bureaucracy and instability	0.612**	0.000	Sig. at 0.01
Bar26	Unsteady price of commodities (Ex. PPE, safety signs, etc.)	0.612**	0.000	Sig. at 0.01
Bar27	Lack of agreed implementation methodology to implement LC techniques	0.472**	0.008	Sig. at 0.01
Bar28	Complexity of LC implementation since LC does not just involve applying LC techniques on site, but also involves developing a culture among the staff for a continuous improvement	0.625**	0.000	Sig. at 0.01
Bar29	Long implementation period needed for LC techniques application in safety improvement	0.641**	0.000	Sig. at 0.01
Bar30	Incomplete designs which leads to increases the probability of re-work	0.462*	0.010	Sig. at 0.05
Bar31	Poor performance measurement strategies	0.425*	0.019	Sig. at 0.05

Table (D4): Internal validity results of section (E): Barriers to the application of LC techniques regarding safety improvement

#	Item	Pearson correlation	P value	Significant (Sig.) at
Bar32	Fragmented nature of the construction industry	0.412*	0.024	Sig. at 0.05
Bar33	Selfishness among professionals to provide their experience in using LC techniques to improve safety	0.462*	0.010	Sig. at 0.05
Bar34	Lack of teamwork	0.483**	0.007	Sig. at 0.01
Bar35	Poor leadership	0.466**	0.009	Sig. at 0.01
Bar36	Cultural issues	0.425*	0.019	Sig. at 0.05
Bar37	Resistance to change by employees	0.552**	0.002	Sig. at 0.01
Bar38	Lack of self-criticism which limited the capacity to learn from errors	0.568**	0.001	Sig. at 0.01
Bar39	Fear of unfamiliar practices due to the misconceptions and misunderstandings of LC	0.631**	0.00	Sig. at 0.01

Table (D5): Internal validity results of section (F): Success factors to apply LC techniques in safety improvement successfully

#	Item	Pearson correlation	P value	Significant (Sig.) at
SF1	Management support and commitment to the application of LC techniques in safety improvement	0.695^{**}	0.000	Sig. at 0.01
SF2	Developing and implementing an effective plan to apply LC techniques in safety improvement	0.423^{*}	0.02	Sig. at 0.05
SF3	Ensuring the culture of continuous improvement in construction projects to obtain the reduction of costs, increase quality and productivity	0.584**	0.001	Sig. at 0.01
SF4	A clear definition of roles, responsibilities, functions and levels of authority before the application of LC techniques	0.545**	0.002	Sig. at 0.01

Table (D5): Internal validity results of section (F): Success factors to apply LC techniques in safety improvement successfully

#	Item	Pearson correlation	P value	Significant (Sig.) at
SF5	Decentralization of construction management	0.447*	0.013	Sig. at 0.05
SF6	Construction managers should be proactive in decision-making	0.440*	0.015	Sig. at 0.05
SF7	Good leadership	0.398*	0.029	Sig. at 0.05
SF8	Constructing transparency between project participants	0.561**	0.001	Sig. at 0.01
SF9	Effective communication, cooperation, coordination and promoting integration between stakeholders	0.592**	0.001	Sig. at 0.01
SF10	Establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety	0.706**	0.000	Sig. at 0.01
SF11	Adequate funding of projects to cover the provisions of consultancy and training	0.602**	0.000	Sig. at 0.01
SF12	Invest time as much as money to successfully apply LC techniques	0.465**	0.01	Sig. at 0.01
SF13	Providing adequate education and training for employees at all levels on the LC concept and techniques	0.725**	0.000	Sig. at 0.01
SF14	Simplifying the language of Lean to enlighten the employees on the benefits of LC techniques application to achieve their compliance to the LC application	0.660**	0.000	Sig. at 0.01
SF15	Establishing awareness programs to increase the understanding of the LC using workshops and research conferences to guide the application of LC techniques in safety improvement	0.764**	0.000	Sig. at 0.01
SF16	Promotion of the LC concept to the stakeholders of construction projects	0.505**	0.004	Sig. at 0.01

Table (D5): Internal validity results of section (F): Success factors to apply LC techniques in safety improvement successfully

#	Item	Pearson correlation	P value	Significant (Sig.) at
SF17	Engagement of skillful site operatives and skillful professionals to guide the application of LC techniques in safety improvement	0.531**	0.003	Sig. at 0.01
SF18	Government should provide a clear direction for the construction firms to apply LC techniques in safety improvement through introducing policies to encourage construction firms to engage in the application of LC techniques to improve construction safety	0.612**	0.000	Sig. at 0.01
SF19	Government agencies should introduce policies to encourage construction firms to engage in the application of LC techniques to improve construction safety	0.593**	0.001	Sig. at 0.01
SF20	Legislation bodies should introduce laws to facilitate the full application of LC techniques among construction firms	0.699**	0.000	Sig. at 0.01
SF21	Government should provide the basic infrastructure and standards to apply LC techniques	0.595**	0.001	Sig. at 0.01
SF22	Standardize and ensure complete designs	0.414*	0.023	Sig. at 0.05
SF23	Workers empowerment and involvement in the application of LC techniques in safety improvement	0.616**	0.000	Sig. at 0.01
SF24	Application of LC techniques gradually step-by-step in improving safety to decrease the complexity of LC implementation	0.680**	0.000	Sig. at 0.01
SF25	Constitution of an improvement committee to be responsible for the application of LC techniques in safety improvement	0.766**	0.000	Sig. at 0.01

SF26	Establishing appropriate performance measurement approaches to measure the effectiveness of implemented LC techniques in safety improvement and identifying the mistakes to improve their weak links	0.711**	0.000	Sig. at 0.01

Table (D6): Items of awareness level of Lean Construction tools

#	Item	Source	The way that was done to get the item
AL1	Last Planner System (LPS)	Camuffo, et al., 2017, Awada et al., 2016, Gambatese et al., 2016, Pestana and Gambatese, 2016, Enshassi and Abu Zaiter, 2014, Gambetese and Pestana, 2014, Bashir, 2013, Forman, 2013, Bashir et al., 2011, Forman, 2010, Nahmens and Ikuma, 2009, Mitropoulos et al., 2007, Salem et al., 2005	From literature review
AL2	Increased visualization (IV)	Awada et al., 2016, Enshassi and Abu Zaiter, 2014, Bashir, 2013, Salem et al., 2005	From literature review
AL3	5S process	Awada et al., 2016, Pestana and Gambatese, 2016, Cudney et al., 2015, Gambetese and Pestana, 2014, Enshassi and Abu Zaiter, 2014, Bashir, 2013, Bashir et al., 2011, Nahmens and Ikuma, 2009 , Salem et al., 2005	From literature review
AL4	Fail safe for quality and safety (Poka yoke)	Enshassi and Abu Zaiter, 2014, Bashir, 2013, Bashir et al., 2011, Mitropoulos et al., 2007, Salem et al., 2005	From literature review
AL5	Daily Huddle Meetings (DHM)	Enshassi and Abu Zaiter, 2014, Bashir, 2013, Salem et al., 2005	From literature review
AL6	First Run Studies (FRS)	Bashir, 2013, Saurin et al., 2006, Howell et al., 2002	From literature review
AL7	Continuous improvement (Kaizen)	Enshassi and Abu Zaiter, 2014, Bashir, 2013, Salem et al., 2005	From literature review
AL8	Accident investigation (5 Why’s)	Cudney et al., 2015, Forman, 2013, Gnoni et al. 2013, Nahmens and Ikuma, 2009.	From literature review

Table (D7): Items of application of LC techniques to reduce the causes of accidents on the construction sites

#	Item	Source	The way that was done to get the item
App1	Providing employees with safety equipment	Bashir, 2013, Bashir et al., 2011	Modified
App2	Developing a plan for supervision	Bashir, 2013, Bashir et al., 2011	Modified
App3	Developing a schedule based on worker's abilities	Bashir, 2013, Bashir et al., 2011	Modified
App4	Worker's empowerment and involvement in task planning and scheduling	Camuffo et al., 2017, Gambetese et al., 2016, Gambetese and Pestana, 2014, Gao and Low, 2014, Bashir, 2013, Gnoni et al., 2013, Bashir et al., 2011, Hasle, 2011, Forman, 2010, Saurin et al., 2006	Modified and merged
App5	Correlating work methods with worker's skills and abilities	Camuffo et al., 2017, Bashir, 2013, Bashir et al., 2011, Mitropoulos et al., 2007	Modified and merged
App6	Involvement of all employees in safety planning	Nahmens and Ikuma, 2009	Modified
App7	Conducting pre task hazard analysis to identify risks predicted at activity and reducing it	Gambetese et al., 2016, Pestana and Gambatese, 2016, Gambetese and Pestana, 2014, Bashir, 2013, Bashir et al., 2011, Sacks et al., 2009, Howell et al., 2002	Literature review
App8	Conducting weekly work planning	Gambetese and Pestana, 2014, Bashir, 2013, Bashir et al., 2011	Modified
App9	Using camera connected with computer algorithm to warn safety officer when workers violate safety conditions	Shrestha et al., 2011	Literature review
App10	Using visual demarcations and boards on site	Bashir, 2013	Modified

Table (D7): Items of application of LC techniques to reduce the causes of accidents on the construction sites

#	Item	Source	The way that was done to get the item
App11	Using safety signs and labels on site	Sarhan et al., 2017, Enshassi and Abu Zaiter, 2014, Aziz and Hafez, 2013, Bashir, 2013, Arleroth and Kristensson, 2011, Sacks et al. 2009, Saurin et al., 2006, Kilpatrick, 2003	Modified and merged
App12	Cleaning the workplace and removing materials and machines that are not required	Bashir, 2013, Bashir et al., 2011, Nahmens and Ikuma, 2009	Modified and merged
App13	Organizing material and plant	Bashir, 2013, Bashir et al., 2011	Modified
App14	Separating needed tools from unneeded materials and clearing the unwanted materials	Bashir et al., 2011, Nahmens and Ikuma, 2009	Modified and merged
App15	Defining standard procedures to maintain the working environment clean and organized and improve safety culture	Bashir, 2013, Bashir et al., 2011	Modified
App16	Creating continuous improvement in safety culture to increase safety culture among the workforce	Bashir, 2013, Bashir et al., 2011	Modified
App17	Conducting visual inspection	Bashir, 2013	Modified
App18	Using Alarms and warning gadgets to warn workers from crossing the unsafe boundaries	Bashir et al., 2011, Saurin et al., 2006	Modified and merged
App19	Using safe guards and Personal Protective Equipment (PPE)	Bashir et al., 2011, Saurin et al., 2006	Modified and merged

Table (D7): Items of application of LC techniques to reduce the causes of accidents on the construction sites

#	Item	Source	The way that was done to get the item
App20	Conducting daily meeting to increase communication between teamwork, increase workers awareness of safety to make them identify risks and reduce it	Bashir, 2013	Modified and merged
App21	Make a plan for the critical tasks	Bashir, 2013, Mitropoulos et al., 2007	Modified
App22	Illustration of work methods using videos, photos, etc.	Bashir, 2013	Modified
App23	Involvement of all employees in improvement process	Bayfield and Roberts, 2005	Modified
App24	Conducting pre task hazard analysis to identify risks predicted at activity and reducing it	Nahmens and Ikuma, 2009	Literature review
App25	Conducting accident investigation and root-cause analysis program	Wong et al., 2016, Bashir, 2013, Chi and Han, 2013, Enshassi, 2010, Razuri et al., 2007	Modified

Table (D8): Items of benefits of LC techniques related to safety improvement in construction projects

#	Item	Source	The way that was done to get the item
Ben1	Better work plan	Bashir, 2013, Fernandez-solis et al., 2013, AlSehaimi et al., 2009	Literature review
Ben2	Better safety management plan	Bashir, 2013	Literature review
Ben3	Improving the rate of workflow on-site	Oladiran, 2017, Pestana and Gambatese, 2016	Literature review

Table (D8): Items of benefits of LC techniques related to safety improvement in construction projects

#	Item	Source	The way that was done to get the item
Ben4	Delivering the projects on time or in some cases ahead of schedule	Dave et al., 2015, Bashir, 2013, Al-Aomar, 2012, Ayarkwa et al., 2012a, Ogunbiyi et al., 2012, Mossman 2009	Literature review
Ben5	Submit work with high quality and less defects to minimize the rework	Oladiran, 2017, Chikhalikar and Sharma, 2015, Mehra et al., 2015, Modi and Thakkar, 2014, Bashir, 2013, Fernandez-solis et al., 2013, Ogunbiyi et al., 2013, Pasale and Bagi, 2013, Ayarkwa et al., 2012a, Ogunbiyi et al., 2012, Zhou, 2012, Bashir et al., 2011. Mossman, 2009, Salem et al., 2005, Kilpatrick, 2003	Modified and merged
Ben6	Maximizing the workers productivity and work efficiency	Couto et al., 2017, Sarhan et al., 2017, Adegbembo et al., 2016, Mehra et al., 2015, Khosravi et al., 2014, Modi and Thakkar, 2014, Ogunbiyi et al., 2014, Ahuja, 2013, Bashir, 2013, Fernandez-solis et al., 2013, Issa, 2013, Marhani et al., 2013, Ogunbiyi et al., 2013, Pasale and Bagi, 2013, Marhani et al., 2012, Ogunbiyi et al., 2012, Zhou, 2012, AlSehaimi et al., 2009, Mossman 2009, Gapp et al., 2008, Salem et al., 2005, Kilpatrick, 2003	Modified and merged
Ben7	Reducing the additional costs resulting from accidents	Couto et al., 2017, Oladiran, 2017, Khosravi et al., 2014, Modi and Thakkar, 2014, Salem et al. 2014, Ahuja, 2013, Bashir, 2013, Ogunbiyi et al., 2013, Ayarkwa et al., 2012a, Zhou, 2012, Anvari	Modified

Table (D8): Items of benefits of LC techniques related to safety improvement in construction projects

#	Item	Source	The way that was done to get the item
		et al., 2011a, Suresh et al., 2011, Mossman, 2009	
Ben8	Increasing profit	Oladiran, 2017, Chikhalikar and Sharma, 2015, Modi and Thakkar, 2014, Mossman, 2013m Al-Aomar, 2012, Nesensohn et al., 2012, Zhou, 2012, Ogunbiyi et al., 2011, Mossman, 2009	Literature review
Ben9	Reducing wastes on site	Oladiran, 2017, Chikhalikar and Sharma, 2015, Modi and Thakkar, 2014, Ahuja, 2013, Bashir, 2013, Ogunbiyi et al., 2013, Al-Aomar, 2012, Ayarkwa et al., 2012a, Suresh et al., 2011, Mossman 2009, Green and May, 2006	Literature review
Ben10	Site organization to reduce clutter and congestion on workplace to create space and convenience for employees	Oladiran, 2017, Pestana and Gambatese, 2016, Mehra et al., 2015, Modi and Thakkar, 2014, Ogunbiyi et al., 2014, Bashir, 2013, Vieira and Cachadinha, 2011, Salem et al., 2005, Kilpatrick, 2003	Modified and merged
Ben11	Facilitating coordination in tools' handling	Oladiran, 2017	Modified
Ben12	Distinguishing dangerous places from safe ones	Tezel and Aziz, 2016	Literature review
Ben13	Reducing site hazards such as noise and dust	Oladiran, 2017, Ahuja, 2013	Literature review

Table (D8): Items of benefits of LC techniques related to safety improvement in construction projects

#	Item	Source	The way that was done to get the item
Ben14	Control the construction site environmentally (less weather effects)	Oladiran, 2017, Ahuja, 2013	Literature review
Ben15	Creating a trust bond and enhancing transparency between the project parties	Sarhan et al., 2017, Adegbembo et al., 2016, Dave et al., 2015, Ogunbiyi et al., 2013, Ayarkwa et al., 2012a, Gapp et al., 2008	Literature review
Ben16	Increasing communication and collaboration among project practitioners	Oladiran, 2017, Dave et al., 2015, Ogunbiyi et al., 2014, Bashir, 2013, Fernandez-solis et al., 2013, Mossman, 2013, Al-Aomar, 2012, Ogunbiyi et al., 2012, AlSehaimi et al., 2009, Green and May, 2006, Gapp et al., 2008, Salem et al., 2005	Modified and merged
Ben17	Enhancing employees' sense of belonging and their problem-solving ability	Oladiran, 2017, Adegbembo et al., 2016, Mossman, 2013, Ayarkwa et al., 2012a	Literature review
Ben18	Employees can clearly know the critical work areas and durations of these	Pestana and Gambatese, 2016, Cerveró-Romero et al., 2013	Literature review
Ben19	Improving employees' self- disciplined	Adegbembo et al., 2016, Pasale and Bagi, 2013, Ayarkwa et al., 2012a	Literature review
Ben20	Stakeholders satisfaction	Oladiran, 2017, Sarhan et al., 2017, Adegbembo et al., 2016, Singh et al., 2014, Bashir, 2013, Ogunbiyi et al., 2013, Al-Aomar, 2012, Zhou, 2012, Anvari et al., 2011a, Mossman 2009, Gapp et al., 2008, Salem et al. 2005	Literature review

Table (D8): Items of benefits of LC techniques related to safety improvement in construction projects

#	Item	Source	The way that was done to get the item
Ben21	Reducing stress level on management and conflicts in projects	Fernandez-solis et al., 2013, Mossman, 2013, Gapp et al., 2008	Literature review
Ben22	Promoting free flow of information on-site between project practitioners	Oladiran, 2017, Bashir, 2013, Ayarkwa et al., 2012a	Literature review

Table (D9): Items of barriers to the application of LC techniques regarding safety improvement

#	Item	Source	The way that was done to get the item
Bar1	Lack of management support and commitment to the application of LC techniques in safety improvement	Attri et al., 2017, Small et al., 2017, Sandeep and Panwar, 2016, Bashir et al., 2015, Mehra et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Ayarkwa et al., 2012a, Ayarkwa et al., 2012b, Zhou, 2012, Bashir et al., 2010, Porwal et al., 2010, Abdullah et al., 2009, Alinaitwe, 2009, Mossman, 2009, Oladiran, 2008, Kim and Park, 2006, Salem et al., 2005, Kilpatrick, 2003	Modified
Bar2	Poor project definition which explain the vision, mission and main objectives of the project and its stakeholders	Small et al., 2017, Ayarkwa et al., 2012b, Brady et al., 2011, Oladiran, 2008	Modified
Bar3	Centralization of decision making	Camuffo et al., 2017, Brady et al., 2011, Alinaitwe, 2009, Oladiran, 2008	Literature review

Table (D9): Items of barriers to the application of LC techniques regarding safety improvement

#	Item	Source	The way that was done to get the item
Bar4	Lengthy approval procedure from top management to take any step	Small et al., 2017, Fernandez-Solis et al., 2013, Porwal et al., 2010, Alinaitwe, 2009, AlSehaimi et al., 2009	Modified
Bar5	Lack of time in construction firms for innovation and application of any innovative strategy	Zhou, 2012, Brady et al., 2011, Abdullah et al., 2009, Alinaitwe, 2009, AlSehaimi et al., 2009, Mossman, 2009, Alarcon et al., 2002	Modified
Bar6	Lack of transparency	Awada et al., 2016, Alarcón et al., 2011, Alinaitwe, 2009	Literature review
Bar7	Poor communication among project parties (managers, administrators, foremen, etc.)	Attri et al., 2017, Small et al., 2017, Mehra et al., 2015, Singh et al., 2014, Sarhan and Fox, 2013, Zhou, 2012, Alarcón et al., 2011, Abdullah et al., 2009, Alinaitwe, 2009, Kilpatrick, 2003	Literature review
Bar8	Poor coordination among project parties (managers, administrators, foremen, etc.)	Attri et al., 2017, Mehra et al., 2015, Gambetese and Pestana, 2014, Kilpatrick, 2003	Literature review
Bar9	Absence of long term forecast of safety improvement	Small et al., 2017, Bashir et al., 2015, Ogunbiyi, 2014, Shang and Pheng, 2014, Bashir, 2013, Fernandez-Solis et al., 2013, Al-Aomar, 2012, Bashir et al., 2010, AlSehaimi et al., 2009 Mossman, 2009	Modified
Bar10	Inadequate planning to apply of LC techniques in safety improvement	Attri et al., 2017, Small et al., 2017, Sandeep and Panwar, 2016, Cano et al., 2015, Dave et al., 2015, Mehra et al., 2015,	Modified

Table (D9): Items of barriers to the application of LC techniques regarding safety improvement

#	Item	Source	The way that was done to get the item
		Alinaitwe, 2009, Salem et al., 2005, Alarcon et al., 2002	
Bar11	Logistics' problems (Ex. poor management of materials, equipment and tools and short supply of material)	Attri et al., 2017, Small et al., 2017, Sandeep and Panwar, 2016, Cano et al., 2015, Dave et al., 2015, Mehra et al., 2015, Alinaitwe, 2009, Salem et al., 2005, Alarcon et al., 2002	Modified
Bar12	Inadequate funding of the project to provide the required resources and training	Small et al., 2017, Bashir et al., 2015, Cano et al., 2015, Enshassi and Abu Zaiter, 2014, Bashir, 2013, Ayarkwa et al., 2012b, Zhou, 2012, Bashir et al., 2010, Porwal et al., 2010, Alinaitwe, 2009, Mossman, 2009, Oladiran, 2008, Salem et al., 2005	Literature review
Bar13	Low tender prices	Small et al., 2017	Literature review
Bar14	High cost of LC implementation including cost of training, consultancy fees and cost to conduct workshops	Sandeep and Panwar, 2016, Bashir et al., 2015, Bashir, 2013, Al-Aomar, 2012, Alarcón et al., 2011, Oladiran, 2008	Modified
Bar15	Poor salaries do not encourage employees to apply any innovative strategies	Small et al., 2017, Ayarkwa et al., 2012b, Oladiran, 2008	Modified
Bar16	Lack of incentives and motivation	Attri et al., 2017, Sandeep and Panwar, 2016, Mehra et al., 2015, Bashir, 2013, Alinaitwe, 2009, Oladiran, 2008	Literature review
Bar17	Lack of LC concept understanding	Small et al., 2017, Awada et al., 2016, Shang and Pheng, 2014, Bashir, 2013,	Literature review

Table (D9): Items of barriers to the application of LC techniques regarding safety improvement

#	Item	Source	The way that was done to get the item
		Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Sarhan and Fox, 2012, Alarcón et al., 2011, Bashir et al., 2010, Porwal et al., 2010, Abdullah et al., 2009, Mossman, 2009, Oladiran, 2008, Salem et al., 2005, Alarcon et al., 2002	
Bar18	Lack of knowledge to apply LC techniques in safety improvement	Awada et al., 2016, Sandeep and Panwar, 2016, Shang and Pheng, 2014, Bashir, 2013, Sarhan and Fox, 2013, Ayarkwa et al., 2012a, Zhou, 2012, Bashir et al., 2010, Alinaitwe, 2009, Oladiran, 2008, Salem et al., 2005, Alarcon et al., 2002	Modified
Bar19	Lack of technical skills to apply LC techniques in safety improvement	Small et al., 2017, Bashir, 2013, Fernandez-Solis et al., 2013, Bashir et al., 2010, Porwal et al., 2010, Abdullah et al., 2009, Alinaitwe, 2009, and Mossman, 2009, Oladiran, 2008, Kim and Park, 2006, Alarcon et al., 2002	Modified
Bar20	Lack of education and training needed to apply LC techniques in safety improvement	Attri et al., 2017, Small et al., 2017, Sandeep and Panwar, 2016, Bashir et al., 2015, Cano et al., 2015, Mehra et al., 2015, Shang and Pheng, 2014, Singh et al., 2014, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Al-Aomar, 2012, Ayarkwa et al., 2012b, Sarhan and Fox, 2012, Brady et al., 2011, Porwal et al. 2010, Abdullah et al., 2009, Alinaitwe, 2009, Mossman, 2009, Oladiran, 2008, Kim and Park, 2006,	Modified

Table (D9): Items of barriers to the application of LC techniques regarding safety improvement

#	Item	Source	The way that was done to get the item
		Salem et al., 2005, Kilpatrick, 2003, Alarcon et al., 2002	
Bar21	Lack of awareness program to increase knowledge about LC	Attri et al., 2017, Bashir et al., 2015, Mehra et al., 2015, Singh et al., 2014, Sarhan and Fox, 2013, Al-Aomar, 2012, Sarhan and Fox, 2012, Abdullah et al., 2009, Alinaitwe, 2009, Mossman, 2009, Oladiran, 2008, Kim and Park, 2006, Mastroianni and Abdelhamid, 2003, Alarcon et al., 2002	Literature review
Bar22	Lack of information and experiences sharing among construction firms	Bashir et al., 2015, Dave et al., 2015, Bashir, 2013, Fernandez-Solis et al., 2013, Alarcon et al., 2011, Brady et al., 2011, Bashir et al., 2010, Alarcon et al., 2002	Literature review
Bar23	Lack of government support towards the construction projects to apply any innovative strategy	Bashir et al., 2015, Cano et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Bashir et al., 2010	Literature review
Bar24	Inconsistency in the government policies	Small et al., 2017, Bashir et al., 2015, Bashir, 2013, Ayarkwa et al., 2012b, Alinaitwe, 2009, Oladiran, 2008	Literature review
Bar25	Government bureaucracy and instability	Small et al., 2017, Oladiran, 2008	Literature review
Bar26	Unsteady price of commodities (Ex. PPE, safety signs, etc.)	Bashir et al., 2015, Bashir, 2013, Bashir et al., 2010, Alinaitwe, 2009, Oladiran, 2008	Literature review
Bar27	Lack of agreed implementation methodology to implement LC techniques	Small et al., 2017, Alinaitwe, 2009	Modified

Table (D9): Items of barriers to the application of LC techniques regarding safety improvement

#	Item	Source	The way that was done to get the item
Bar28	Complexity of LC implementation since LC does not just involve applying LC techniques on site, but also involves developing a culture among the staff for a continuous improvement	Gade, 2016, Bashir et al., 2015, Singh et al., 2014, Bashir, 2013, Alarcon et al., 2002	Modified
Bar29	Long implementation period needed for LC techniques application in safety improvement	Small et al., 2017, Adegbembo et al., 2016, Sandeep and Panwar, 2016, Bashir et al., 2015, Bashir, 2013, Marhani et al., 2013, Ayarkwa et al., 2012b, Bashir et al., 2010, Abdullah et al., 2009, Mossman, 2009, Kim and Park, 2006, Kilpatrick, 2003, Alarcon et al., 2002	Modified
Bar30	Incomplete designs which leads to increases the probability of re-work	Bashir et al., 2015, Bashir, 2013, Ayarkwa et al., 2012, Alinaitwe 2009, Koskela 1999	Modified
Bar31	Poor performance measurement strategies	Small et al., 2017, Bashir et al., 2015, Bashir, 2013	Literature review
Bar32	Fragmented nature of the construction industry	Small et al., 2017, Adegbembo et al., 2016, Ogunbiyi, 2014, Ayarkwa et al., 2012b, Pheng and Shang, 2011, Porwal et al., 2010, Alinaitwe, 2009	Literature review
Bar33	Selfishness among professionals to provide their experience in using LC techniques to improve safety	Mossman, 2009, Oladiran, 2008	Modified
Bar34	Lack of teamwork	Bashir et al., 2015, Cano et al., 2015, Fernandez-Solis et al., 2013, Al-Aomar,	Literature review

Table (D9): Items of barriers to the application of LC techniques regarding safety improvement

#	Item	Source	The way that was done to get the item
		2012, Ayarkwa et al., 2012b, Bashir et al., 2010, Porwal et al., 2010, Abdullah et al., 2009, Alinaitwe, 2009, Mossman, 2009, Oladiran, 2008, Kim and Park, 2006, Salem et al., 2005	
Bar35	Poor leadership	Attri et al., 2017, Bashir et al., 2015, Mehra et al., 2015, Bashir et al., 2010, Porwal et al., 2010, Alinaitwe, 2009, Mossman, 2009, Alarcon et al., 2002	Literature review
Bar36	Cultural issues	Sandeep and Panwar, 2016, Cano et al., 2015, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Ayarkwa et al., 2012a, Ayarkwa et al., 2012b, Sarhan and Fox, 2012, Zhou, 2012, AlSehaimi et al. 2009, Alinaitwe, 2009, Nesensohn et al. 2012, Mossman, 2009, Oladiran, 2008, Kim and Park, 2006, Salem et al., 2005	Literature review
Bar37	Resistance to change by employees	Attri et al., 2017, Awada et al., 2016, Sandeep and Panwar, 2016, Mehra et al., 2015, Shang and Pheng, 2014, Fernandez-Solis et al., 2013, Sarhan and Fox, 2013, Al-Aomar, 2012, Ayarkwa et al., 2012b, Zhou, 2012, Porwal et al., 2010, Oladiran, 2008, Kilpatrick, 2003, Mastroianni and Abdelhamid, 2003	Literature review

Table (D9): Items of barriers to the application of LC techniques regarding safety improvement

#	Item	Source	The way that was done to get the item
Bar38	Lack of self-criticism which limited the capacity to learn from errors	Alinaitwe, 2009, Alarcon et al., 2002	Modified
Bar39	Fear of unfamiliar practices due to the misconceptions and misunderstandings of LC	Bashir et al., 2015, Bashir, 2013, Al-Aomar, 2012, Sarhan and Fox, 2012, Bashir et al., 2010, Mossman, 2009, Alarcon et al., 2002	Modified

Table (D10): Items of success factors to apply LC techniques in safety improvement successfully

#	Item	Source	The way that was done to get the item
SF1	Management support and commitment to the application of LC techniques in safety improvement	Azyan et al., 2017, Oladiran, 2017, Netland, 2016, Sandeep and Panwar, 2016, Sarhan et al., 2016, Bashir et al., 2015, Cano et al., 2015, Bashir, 2013, Antony et al., 2012, Bashir et al., 2010, Porwal et al., 2010, AlSehaimi et al., 2009, Oladiran, 2008, Salem et al., 2005	Modified
SF2	Developing and implementing an effective plan to apply LC techniques in safety improvement	Cano et al., 2015, Bashir, 2013, Bashir et al., 2010	Modified
SF3	Ensuring the culture of continuous improvement in construction projects to obtain the reduction of costs, increase quality and productivity	Nasrollahzadeh et al., 2016, Sarhan et al., 2016, Ayarkwa et al., 2012 b	Literature review
SF4	A clear definition of roles, responsibilities, functions and levels of authority before the application of LC techniques	Sarhan et al., 2016, Cano et al., 2015, Oladiran, 2008, Achanga et al., 2006	Modified

Table (D10): Items of success factors to apply LC techniques in safety improvement successfully

#	Item	Source	The way that was done to get the item
SF5	Decentralization of construction management	Cano et al., 2015, Oladiran, 2008, Achanga et al., 2006	Modified
SF6	Construction managers should be proactive in decision-making	Cano et al., 2015, Brady, 2014, Shang and Pheng, 2014, Ayarkwa et al., 2012 b	Literature review
SF7	Good leadership	Azyan et al., 2017, Cano et al., 2015, Shang and Pheng, 2014, Antony et al., 2012, Brady et al., 2011, Porwal et al., 2010, Ballard et al., 2007, Achanga et al., 2006	Literature review
SF8	Constructing transparency between project participants	Cano et al., 2015, Brady, 2014, Shang and Pheng, 2014, Ayarkwa et al., 2012 b	Literature review
SF9	Effective communication, cooperation, coordination and promoting integration between stakeholders	Oladiran, 2017, Small et al., 2017, Cano et al., 2015, Antony et al., 2012, Ayarkwa et al., 2012 b, AlSehaimi et al., 2009, Oladiran, 2008, Achanga et al., 2006	Modified and merged
SF10	Establish a recognition and reward system to encourage employees to participate in the application of LC techniques to improve safety	Netland, 2016, Cano et al., 2015, Antony et al., 2012, Salem et al., 2005	Modified
SF11	Adequate funding of projects to cover the provisions of consultancy and training	Azyan et al., 2017, Netland, 2016, Antony et al., 2012, Oladiran, 2008, Achanga et al., 2006	Modified
SF12	Invest time as much as money to successfully apply LC techniques	Antony et al., 2012	Literature review

Table (D10): Items of success factors to apply LC techniques in safety improvement successfully

#	Item	Source	The way that was done to get the item
SF13	Providing adequate education and training for employees at all levels on the LC concept and techniques	Azyan et al., 2017, Oladiran, 2017, Small et al., 2017, Netland, 2016, Sandeep and Panwar, 2016, Sarhan et al., 2016, Bashir et al., 2015, Cano et al., 2015, Shang and Pheng, 2014, Singh et al., 2014, Antony et al., 2012, Ayarkwa et al., 2012 a, b, Zhou, 2012, Brady et al., 2011, Bashir et al., 2010, Porwal et al., 2010, Abdullah et al., 2009, Alinaitwe, 2009 and Mossman, 2009, Oladiran, 2008, Ballard et al., 2007, Salem et al., 2005,	Modified
SF14	Simplifying the language of Lean to enlighten the employees on the benefits of LC techniques application to achieve their compliance to the LC application	Bashir et al., 2015, Bashir, 2013, Ogunbiyi et al., 2011	Modified and merged
SF15	Establishing awareness programs to increase the understanding of the LC using workshops and research conferences to guide the application of LC techniques in safety improvement	Oladiran, 2017, Bashir et al., 2015, Cano et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Ayarkwa et al., 2012a	Modified
SF16	Promotion of the LC concept to the stakeholders of construction projects	Bashir et al., 2015, Bashir, 2013, Oladiran, 2008	Literature review
SF17	Engagement of skillful site operatives and skillful professionals to guide the application of LC techniques in safety improvement	Netland, 2016, Bashir et al., 2015, Bashir et al., 2015, Cano et al., 2015, Bashir, 2013, Oladiran, 2008, Achanga et al., 2006	Modified and merged

Table (D10): Items of success factors to apply LC techniques in safety improvement successfully

#	Item	Source	The way that was done to get the item
SF18	Government should provide a clear direction for the construction firms to apply LC techniques in safety improvement through introducing policies to encourage construction firms to engage in the application of LC techniques to improve construction safety	Oladiran, 2017, Small et al., 2017, Bashir et al., 2015, Shang and Pheng, 2014, Bashir, 2013, Ayarkwa et al., 2012 b, Suresh et al., 2012, Oladiran, 2008	Modified and merged
SF19	Legislation bodies should introduce laws to facilitate the full application of LC techniques among construction firms	Oladiran, 2017, Bashir et al., 2015, Bashir, 2013	Modified
SF20	Government should provide the basic infrastructure and standards to apply LC techniques	Oladiran, 2008	Modified and merged
SF21	Government should work closely with professional bodies to introduce LC to improve construction safety	Oladiran, 2008	Modified
SF22	Standardize and ensure complete designs	Cano et al., 2015, Oladiran, 2008	Literature review
SF23	Workers empowerment and involvement in the application of LC techniques in safety improvement	Azyan et al., 2017, Small et al., 2017, Netland, 2016, Bashir et al., 2015, Cano et al., 2015, Bashir, 2013, Ayarkwa et al., 2012 b, Brady et al., 2011, AlSehaimi et al., 2009	Modified
SF24	Application of LC techniques gradually step-by-step in improving safety to decrease the complexity of LC implementation	Bashir et al., 2015, Bashir, 2013	Modified

Table (D10): Items of success factors to apply LC techniques in safety improvement successfully

#	Item	Source	The way that was done to get the item
SF25	Constitution of an improvement committee to be responsible for the application of LC techniques in safety improvement	Cano et al., 2015	Modified
SF26	Establishing appropriate performance measurement approaches to measure the effectiveness of implemented LC techniques in safety improvement and identifying the mistakes to improve their weak links	Netland, 2016, Sandeep and Panwar, 2016, Cano et al., 2015, Ogunbiyi, 2014, Brady et al., 2011, Ballard et al., 2007	Modified