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BARRIERS HINDER THE APPLICATION OF LEAN CONSTRUCTION TECHNIQUES TO IMPROVE SAFETY IN CONSTRUCTION PROJECTS

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Abstract: This paper identifies the barriers that hinder the application of lean construction techniques to improve safety in construction projects. To achieve this objective, a deductive approach is adopted using a questionnaire survey of 107 construction professionals. A total of 39 barriers is elicited from a literature review which is categorized into: management, financial, educational, governmental, technical and human attitudinal. Exploratory Factor Analysis (EFA) was used to analyze the collected data and reduced the 39 barriers to 25 barriers. Seven components were extracted from EFA to underline the remained 25 barriers which were labeled as educational related, governmental related, communication, financial related, cultural related, decision making and technical related. Results revealed that the component of "Educational related" are the barriers that have the highest effect on the application of LC techniques to improve safety. On the contrary, "Technical related" has the lowest effect. The findings highlighted the need for overcoming the barriers to apply LC techniques efficiently in safety improvement among Gaza Strip particularly the educational related barriers. Special courses should be organized in the universities and training programs should be conducted to construction participant in order to broaden the benefits of LC and how to adopt LC techniques in safety improvement. This paper will be valuable for construction participants to focus their attention and resources on the significant barriers and to identify strategies to address these barriers and facilitate the application of LC techniques to improve safety in local construction projects.
Keywords: lean construction techniques, safety in construction, questionnaire survey

1. INTRODUCTION

Construction industry is ranked among the most hazardous industries in both developed and developing countries [1, 2]. In Gaza Strip, Palestine, safety is one of the most difficult issue facing the construction industry [13]. Lean construction (LC) considers accidents as potential wastes of time, money and labor that should be eliminated [4, 5]. Thus, accidents on construction projects need to be eliminated using LC techniques which support safety programs [1, 7]. However, the application of LC techniques in construction projects is hindered by several barriers [8]. According to Bashir et al. [6, 9], and Bashir [5], barriers to application 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. Cano et al. [8] summarized these in six groups related to people, organizational structure, supply chain, internal value, external value chain, external management and value chain and externalities. Oladiran [10] categorized these barriers into seven groups: skills and knowledge related, management related, government related, attitude related, resource related, logistics related and others. Currently, there is no study has identified the barriers to the application of LC techniques to improve safety in construction projects in Palestine. To address this gap in knowledge, this study identifies and examines these barriers specifically in the context of the Gaza Strip.

2. BARRIERS CATEGORIES

Barriers to the application of LC techniques to improve safety in construction projects are classified in this paper similarly to the classification Bashir et al. [6, 9] and Bashir [5]. 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.

— Management barriers

Management barriers are referred to various issues related to the support of the top management [11]; since the successful implementation of LC or any new innovative strategy needs to be supported by top management [12, 13]. Management support and committment is a key factor potentially enhancing or hindering the effect of Lean tools on safety improvement [7]. Poor project definition is proved to be a management barrier prevented the successful implementation of LC in construction projects [10, 13, 14, 15]. 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 [16, 17]. 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 [5, 18].

In LC decision making should not 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 [7, 10, 15, 19]. Furthermore, lack of time for innovation is identified as a management barrier faced some construction firms in implementation of LC in construction projects [11, 15, 19, 20, 21, 22, 23]. Sometimes time pressure affects the application of safety itself based on the contractor's belief that safety implementation is time consuming [24]. In addition, Alinaitwe [19], Awada et al. [1], Alarcón et al. [25] identified lack of transparency as a management barrier prevented the successful implementation of LC in construction projects. Lack of communication among participants of the production process is another barrier hindered the implementation of LC in construction projects [12, 13, 26, 27, 28]. Lack of communication can lead to lack of coordination, cooperation and team work which may hamper the LC implementation efforts in construction projects [12]. Poor coordination between the project parties is also identified as a barrier to the implementation of LC in construction projects [4, 29]. Moreover, absence of long term forecast and investment by the top management is one of the major barriers to the implementation of LC [5, 6, 9, 13, 21, 22, 30, 31, 32, 33]. Inadequate planning to implement LC is considered a barrier that hindered the implementation of LC in construction projects [8, 12, 13, 19, 26, 34, 35]. One of the most important LC tools is LPS which mainly aimed to replace the optimistic planning with realistic planning based on workers' abilities [36, 37, 38]. Inadequate planning will impede the application of LPS to replace the optimistic planning with the realistic planning [37]. 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 [13, 19, 39]. Poor management of material resulted in hindering the application of 5S tool which focused on organizing the workplace [5, 36, 40].

— **Financial barriers**

Financial issues are among the most common barriers to LC practice across different organizations in various countries [5, 9, 28, 41]. 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 [8, 9, 13, 36, 42]. Low tender prices is considered by contractors as a main barrier to LC application [13]. Cost of training, consultancy fees and cost to conduct workshops are considered as implementation cost of LC in construction projects [10]. Implementation cost of LC is proved to be a financial barrier impeded the implementation of LC in construction projects [9, 10, 25, 34]. Moreover, poor salaries of professionals do not encourage them to apply any innovative strategies [10, 13, 14, 43].

Lack of incentives and motivation is identified as financial barrier hindered the implementation of LC in construction projects [12, 34]. Incentives and motivation can change the traditional working behavior and enhance their concern about housekeeping, since workers are used to being messy and throwing garbage on the ground [44]. Moreover, Oladiran [10] 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 [10, 14]. 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 [14, 19, 45].

— **Educational barriers**

Educational barriers could pose a great threat to the implementation of LC [41, 46]. Educational barriers included lack of understanding of Lean concept and inadequate knowledge of LC [1, 31]. This can be traced to the fact that LC is a concept evolved from the manufacturing industry [11]. Lack of technical skills is another barrier impedes the implementation of LC in construction projects [5, 6, 13, 32, 42]. Lack of technical skills hindered the conduction of pre task hazards analysis and accidents investigation program which are LC techniques used to promote safety [17]. 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 [9, 12, 26]. Lack of experiences and information sharing is another educational barrier to the implementation of LC in construction projects [9, 25, 35].

— **Governmental barriers**

Bashir et al. [9] stated that the barriers of LC implementation are due to government attitudes and support towards the construction industry in some countries. Governmental barriers are related to the government bureaucracy and instability [10, 13]. Moreover, inconsistency in policies was identified as government barriers to the implementation of LC which has major effects on the plans of construction firms [9, 13, 14]. Additionally, unsteady price of commodities is another barrier prevented the implementation of LC in construction projects [9, 10]. 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 [5,38,47]. Furthermore, some of the financial barriers like inflation, professional wages, and corruption practices could also be related to government issues [5,6].

— **Technical barriers**

Technical barriers have a direct impact on the application of certain LC principle and tools such as reliability, simplicity, flexibility and benchmarking [48]. Lack of agreed implementation methodology to implement LC is identified as technical barrier prevented the successful implementation of LC in construction projects [13, 19]. Moreover, complexity of LC implementation is another barrier to implement LC in construction projects [9, 45]. Similarly, the barrier of long implementation period is considered as one of the major barriers to the implementation of LC in construction projects [13, 34, 49]. 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 [9]. Design related barriers to implement LC successfully in construction projects include incomplete designs [19, 48]. Additionally, poor performance measurement strategies and fragmented nature of the construction industry are technical barriers hindered the implementation of LC in construction projects [9, 13]. 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 [8, 43].

— **Human attitudinal barriers**

According to Bygballe and Swärd [50], human attitude is one of the major factors affecting the implementation of LC in construction industries. Oladiran [10] and Mossman [22] 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 [9, 12, 42]. Lack of leadership may result into introduction of other barriers like employee resistance to change, inability to change the organizational culture and poor communication [34].

In addition, cultural issues are also mentioned as barriers to the successful implementation of LC in construction projects [8, 34]. Moreover, lack of self-criticism limited the capacity to learn from errors which hindered the successful implementation of LC in construction projects [19, 23]. 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 [9, 22, 23, 51]. Additionally, lack of teamwork is proved a barrier impedes the successful implementation of LC in construction projects [9, 42].

3. METHODOLOGY

A deductive approach is adopted in this paper using a questionnaire survey. A questionnaire survey is used as a method to collect the quantitative data. A questionnaire is predominantly used in conducting surveys to find out facts, opinions and views of participants [5]. The main advantages of questionnaires are quick of conducting a survey at a minimum expense in terms of finance, human and other resources [52]. On the other hand, the main limitation of questionnaire is inflexibility since most of questionnaires depend on close ended questions and there is no control over respondents [53].

As the number of the target sample is not known, a purposive sample as a non-probability sampling is adopted in this paper. The target sample includes engineers who work in the field of construction supervision (project manager, site engineers, site supervisors and safety engineers).

In purposive sample, Battaglia [54] stated that the sample size might involve selecting large (1,000+ respondents), medium (100–999 respondents), and small (<100 respondents). In this paper, 120 questionnaires were distributed and 107 were returned completed. Therefore, the response rate is 89.17%, which is considered as very good according to Saldivar [55]. The response rate of 89.17% is very good in comparison with the previous studies of Adegbembo et al. [49] who recorded a response rate of 79.57%. On the other hand, Enshassi and Abu Zaiter [36] recorded a response rate of 77.7% and 74.5% is the response rate which is recorded by Sarhan and Fox [28].

A total of 43 barriers were identified through intensive literature review which hindered the application of LC techniques [9–14, 19–22, 26, 28, 31–34, 42–44, 47]. A pilot study was conducted to test the relevance and comprehensives of the questionnaire before it was sent to potential respondents. The questionnaire was sent to ten engineers with more than 15 years' experience in the construction industry and works in projects funded by external parties where LC techniques are applied. The piloting process involved revising and verifying all barriers collected from literature review. The comments received from each expert were reviewed, and accordingly, several revisions were undertaken to develop the final version of the questionnaire. According to the pilot study, 39 barriers that affect the application of LC techniques to improve safety in construction projects were selected from the 43 identified barriers.

The final questionnaire consisted of two parts. Part one captured the respondents demographic data (education level, specialization, job title, and experience). Part two contained 39 items mesuring the effect of barriers to the application of LC techniques to reduce the causes of accidents on construction projects using a five-point Likert scale ranging from 0 (no effect) to 4 (extreme effect). The 39 barriers were distributed on 6 groups based on previous literature (management, financial, educational, governmental, technical, and human attitudinal). The respondents were asked to express their opinion based on their perception on the effect of the included barriers on the application of LC techniques in safety improvement in the Gazan Construction Projects.

Internal validity of the questionnaire is tested using Pearson correlation. The Pearson correlation is between 1 and -1 and *p*-value is less than 0.05, so the correlation coefficient is considered significant at $\alpha = 0.05$. Thus, it can be said that the barriers to the application of LC techniques are consistent and valid to measure what it was set for. Cronbach's Coefficient Alpha (Cα) was used to assess the reliability of the survey scale by investigating the internal consistency of the responses regarding the 39 barriers. 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 [56], and 0.70 is generally accepted as the minimum accepted value [57]. The calculated value of (Cα) was 0.86 which suggests that the barriers to the application of LC techniques are internally consistent.

In this study, Exploratory Factor Analysis (EFA) is used. 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 [58]. Five steps should be considered for utilizing EFA, which include evaluation of data suitability for EFA, factor extraction, factor retention, factor rotation and interpretation and naming the factors [58–60].

4. RESULTS – FACTOR ANALYSIS RESULTS OF BARRIERS TO THE APPLICATION OF LC TECHNIQUES TO IMPROVE SAFETY IN CONSTRUCTION PROJECTS

The target respondents of the questionnaire were supervisor engineers who work at construction projects funded externally by international donors 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). It was found that, 23.4% of the respondents were highly educated with postgraduate studies, which reflect their experience in construction. 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. Most of respondents were working with contractors with 34.6%, 24.3% were working with 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. The majority of respondents had more than 10 years.

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— Evaluation of Data Suitability for EFA

Several tests should be conducted prior to the factor analysis of collected data 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 coefficient alpha (Cα). The normal range of (Cα) value is between 0.0 and +1 [56]. Table (1) presents the reliability of the first and last run to the barriers to the application of LC techniques to improve safety in construction projects, which was 0.921 and 0.884, respectively. Both of them are significantly high (between 0.0 and +1); and hence the data is reliable.

Table (1): 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

Sample size in this study constituted of 107 respondents which is adequate as it is larger than 50 as proposed by [61]. Correlation matrix is used to determine the relationships between variables which is known as R-matrix [56, 62]. The correlation matrix the 39 listed barriers 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.

Kaiser-Meyer-Olkin (KMO) assesses the sampling adequacy while Bartlett's test of Sphericity checks whether the observed correlation matrix is an identity matrix [63]. As shown in Table (1), 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. The valid results of the test of reliability test, sample size, correlation matrix, the measure of sampling adequacy and the test of Sphericity assisted to ensure that factor analysis was appropriate for the dataset in this paper.

— Factor Extraction

Principal Component Analysis (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 (2), except the Bar11, which has communality value of 0.496, so it was 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. During every run of EFA after eliminating the barriers with low loadings, the communalities should be checked to be more than 0.5.

— Factor Retention

In order to decide the number of factors to be retained for the barriers to the application of LC 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 [59]. 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 (3) 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. From the Table (4) it is shown that only seven components have an eigenvalues greater than 1.0. Therefore, the 25 barriers will be underlined under 7 components.

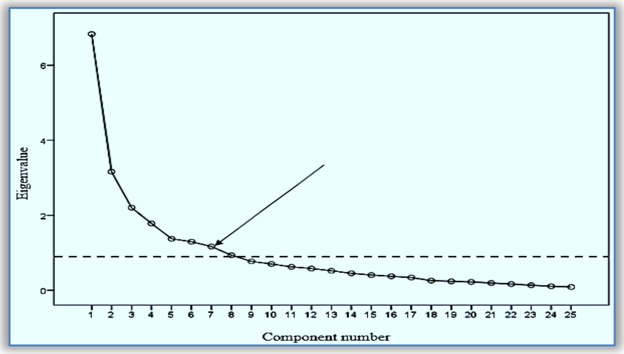

Figure (1): Scree plot of barriers to the application of LC techniques

Scree plot is investigated to determine where there is a noticeable change in its shape which is known as 'the elbow' or point of inflection [62]. As shown in Figure (1) which resulted from the last run of EFA to the barriers, there are 25 components at the horizontal axis. However, only seven 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.

Table (2): Communalities of the barriers to the application of LC techniques

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
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

Table (3): Total variance explained of the barriers to the application of LC techniques

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						

The cumulative percent of variance for the 25 barriers remained in the last run (Sixth run) of EFA is shown in Table (3). This Table shows that 7 components with eigenvalue are larger than one that 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%.

— **Factor rotation**

In order to obtain the optimum solution from EFA, several considerations should be taken including the minimum value of loading value, cross loading and minimum number of variables in each component. As a result of this process, Table (4) shows the 25 remaining barriers. 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 component have at least three barriers with communality values of all more than 0.5. After six repetitions of the EFA, 14 barriers were eliminated and 25 are remained and organized under 7 components.

Table (4): Rotated loading values of the barriers to the application of LC

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			
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		

— **Interpretation of the extracted components**

The components extracted in this research are labeled with names related to the variables included in it. Table (5) 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. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor [62]. The seven components are:

≡ Component 1 (Education): consists of six barriers with eigenvalue of 6.830 and explained 17.895% of the total variance.
≡ Component 2 (Government): consists of four barriers with eigenvalue of 3.163 and explained 10.481% of the total variance
≡ Component 3 (Communication): consists of three barriers with eigenvalue of 2.204 and explained 9.221% of the total variance.
≡ Component 4 (Finance): consists of three barriers with eigenvalue of 1.783 and explained 8.951% of the total variance.
≡ Component 5 (Culture): consists of three barriers with eigenvalue of 1.376 and explained 8.896% of the total variance.
≡ Component 6 (Decision making): consists of three barriers with eigenvalue of 1.299 and explained 8.088% of the total variance.
≡ Component 7 (Technical): consists of three barriers with eigenvalue of 1.170 and explained 7.772% of the total variance.

Table (5): Factor analysis results of the barriers to the application of LC techniques

Barriers		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		
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		

Barriers		Factor loadings	Eigenvalue	Cronbach alpha
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		
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		

5. DISCUSSIONS

The remained barriers (25 barriers) after EFA 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:

— **Component 1: Education related barriers**

The first component of the barriers to the application of LC techniques to improve safety in construction projects is labeled education. 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. Educational related component 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.

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, educational related component has the highest effect degree on the application of LC techniques to improve safety in the Gazan Construction Projects.

In Gaza Strip, LC is considered a new innovative strategy which needs to be understood by the construction participants to apply it successfully. Enshassi and Abu Zaiter [36] 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 does not 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 [64] 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 [5, 49]. Bashir [5] stated 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 [33]. Fernandez-Solis et al. [32] 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.

— **Component 2: Government related barriers**

Government related component constitutes 10.481% of the total variance of 25. Naming of this component based on the variables included in it which are all related to governmental issues. Variables with higher loadings are used to identify the nature of the underlying latent variable represented by each factor. Government related component consists of four barriers which all have a loading value more than 0.70. In Gaza Strip, the local government has not taken any real step to encourage 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.

The success of LC implementation rests in part on the shoulders of the government which is considered as external stakeholder [5, 9, 31]. Oladiran [10] 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 [13]. Similarly, Al-Najem et al. [65] 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 which include: lack of government support towards the construction projects to apply any innovative strategy, unsteady price of commodities 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.

— **Component 3: Communication related barriers**

Communication component constitutes 9.221% of the total variance of 25 barriers. It consists of three barriers related to communication, which all have a loading value more than 0.572. Construction projects in Gaza strip suffer from lack of communication between different professionals and stakeholders. This result has been confirmed by the findings of [64, 66]. 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. 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 previous publications [6, 25, 27]. The project participants have different requirements and priorities with a common objective of successfully completing the project [11, 14]. Therefore, a proper communication between all parties in construction project should be established and improved [11]. In implementing LC techniques, lack of communication among the construction participants highly affected the application of LC techniques [19, 20, 28, 28]. Lack of communication can lead to lack of coordination, cooperation and teamwork highly affected the application of LC techniques in the manufacturing industry in India [12].

Similarly, Small et al. [13] stated that poor communication among stakeholders hindered the LC implementation in construction in Dubai. Awada et al. [1] found that communication barriers especially lack of transparency among project participants act as a major constraint against implementing LC in the Lebanese construction industry. 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.

— **Component 4: Financial related barriers**

Financial related component constitutes 8.951% of the total variance of 25 barriers. Financial related component consists of three barriers related to finance which all have a loading value more than 0.702. Innovative strategies for LC application in the construction industry require some funds for its adequate implementation. However, there is a lack of the financial ability for the firms in Gaza Strip to adopt new innovative techniques. 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.

The effect of financial resources availability on the success LC implementation has been well reported in previous literature [5, 28, 41]. Ayarkwa et al. [14] and Bashir et al. [9] found that finance related issues are among the most common challenges to lean practice across many organizations across UK and Ghana, respectively. Al-Aomar [33] 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 barrier in using LC tools [36]. 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.

— **Component 5: Cultural related barriers**

Cultural related component accounts for 8.896% of the total variance and is loaded with three variables that related to cultural issues with a value more than 0.692. In Gaza Strip, engineers are unwillingness to learn new applications because it is unfamiliar to them and there is no motivation due to bad local political and economic situation. Moreover, companies are resistance for any change and they refuse to adopt a new technology. 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.

Several researchers considered the cultural related issues as the most important barriers that prevented LC implementation in construction projects [14, 20, 32, 34]. Cano et al. [8] concluded that a cultural problem is the most influential barrier impeded the application of LC techniques in Colombian construction projects. Similarly, Sarhan and Fox [28, 51] identified cultural barrier as a significant barrier to the implementation of LC in UK. In Dubai, inadequate organizational culture is also considered as barrier to Lean implementation [13]. Further, AlSehaimi et al. [21] in Saudi Arabia, cultural issues are one of the main potential barriers to the LPS implementation. 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.

— **Component 6: Decision making**

Decision making component accounts for 8.088% of the total variance and is loaded with three variables that related to decision making with a value more than 0.628. 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. [67]. 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 [10]. The traditional hierarchical decision-making is returned to the unclear definition of roles and responsibilities within the team before project start [7]. 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 [32]. Similarly, AlSehaimi et al. [21] 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.

— **Component 7: Technical related**

Component 7 (Technical related) accounts for 7.772% of the total variance and is loaded with three variables which are related to technical issues with a value more than 0.640. In Gaza Strip, LC is a new innovative strategy, which takes 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.

The effect of technical capabilities on the success of LC has been well documented [9, 19, 43]. These issues relate to certain tools; they could hinder a holistic implementation of the concept [6]. LC is a continuous improvement process with an endless journey that may take a long period to be fully implemented [14, 34]. Kim and Park [68] found 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. [13] concluded that lack of agreed implementation methodology and 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 that need to be taken into consideration. Technical barriers can be mitigated by involvement of construction participants in all phases of the projects; and integration between construction participants.

6. CONCLUSION

The aim of this paper is to identify the significant barriers that hinder the application of lean construction techniques to improve safety in the Gazan Construction Projects. Accordingly, 107 questionnaires were sent to construction professionals to identify the effect index of 39 barriers on the application of lean construction techniques in safety improvement. 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, and technical related has the lowest effect. The findings of this section stress the construction participants in Gaza Strip to cope with the barriers affected the implementation of LC techniques in order to identify proper measures to overcome them. Additionally, 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.

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