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# AWARENESS LEVEL ABOUT USING FEATURES OF LEAN TOOLS TO REDUCE WASTE IN HOUSING PROJECTS

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**Abstract:** The purpose of this paper is to investigate the awareness level of using features of lean tools to reduce/eliminate waste in housing projects in the Gaza Strip. A deductive research approach using a questionnaire survey was adopted in this study. A total of 135 questionnaires were sent out to the target purposive samples in housing projects, 100 usable fully completed questionnaires were returned thus achieving 74% response rate. Exploratory Factor Analysis (EFA) was used in this study. The results of the EFA revealed four components: communication and information sharing, Documentation process, workplace arrangement, and safety and quality. This result will be helpful for enhancing efficiency, production, and quality of housing projects by providing an understanding for the awareness level about implementation of lean tools in the housing projects. This part of the study provides information about the most implemented lean tools, which can be useful for improving lean tools implementation in all housing projects in Gaza Strip.
**Keywords:** lean tools, awareness, waste, housing projects

## 1. INTRODUCTION

The effectiveness of lean tools in controlling and eliminating wastes are becoming more and more acknowledged [1]. However, the application of lean construction is still in its initial stages. In order to improve the implementation of lean construction, Stevens [2] proposed that a harmonization between main contractors and subcontractors as is a prerequisite, while Kamali and Hewage [3] proposed reducing variability to improve performance and improving labour flow reliability, as lean construction principles significantly contributed to maximize value from the customer's perspective [4]. Waste has multiple forms that vary according to the type of industry and working processes [5]. The extent to which waste identified to the parties, involved in the working process, it will help in eliminating and reducing the waste [4]. Lean construction approach is a set of tools that improve project performance by increasing project value and minimizing waste [6].

Over the past years, a significant of effort has been made to raise awareness, provide guidance and share knowledge relating to lean construction by academics, researchers, practitioners and professionals' bodies. Chesworth [7] stated that developing an awareness of knowledge in a theoretical context would assist in challenging cultural behaviours within the practical application. It is often claimed that the lack of data about waste composition and quantities is a major factor, which has inhibited the development of waste management in Palestine [8,9]. With the increase in construction activities and shortage of suitable landfill sites, lack of material resources and limited of fund, construction waste is becoming a serious problem in Palestine. The objective of this paper is to investigate the awareness level of using features of lean tools to reduce/eliminate waste in housing projects in the Gaza Strip.

## 2. LITERATURE REVIEW

The construction industry is often labelled as a huge generator of waste [10]. Not only does waste have an impact on the efficiency of the construction industry but also on the overall state of the economy of any country [11,12]. Reducing the level of waste in the construction industry is a great challenge, because the industry has one of the lowest productivity levels and is not environmentally friendly [10]. The focus therefore should be on both identification and elimination of material and time waste with an aim of improving project performance [11,13,14]. The existences of significant number of wastes in the construction have depleted overall performance and productivity of the industry, and certain serious measures have to be taken to rectify the current situation [15].

Researchers implement different methods to reduce the amount of waste in the construction industry. One of the effective methods for reducing waste is the application of lean approach [16]. Lean construction is simply an attempt to apply lean principals that originate from Toyota Production System (TPS) to construction, aiming at managing and improving construction processes with minimum cost and maximum value by considering customer needs [14,17,18]. Lean construction is a new philosophy to design production system including a set of practices that aims to minimize waste of material, time, effort and maximize quality management [17,19]. The core concept behind lean production is to enable the flow of value creating work steps while eliminating non-value steps [18]. Lean construction is composed of the following techniques: concurrent engineering, last planner, daily huddle meetings, and the kanban system [20]. Salem et al. [21,22] proposed a new lean assessment tool to quantify the results of lean implementations; which include last planner, increased visualization, huddle meetings, first-run studies, five S and fail safe for quality.

Abbasian-Hosseini et al. [23] revealed that lean principles in Iran could enhance the performance of the bricklaying process through more than 40% productivity improvement. Salem et al. [24] indicated that a majority of industries in Qatar have little awareness of lean principles, concepts and techniques. Therefore, industries in Qatar need to give more recognition of lean in their operations in order to advance operating efficiencies towards leading value indicators of operational excellency. Amin [25] reported that LPS technique proved that it could enhance planning aspects of construction management practice and bring numerous advantages. He added that subcontracting firms are one of the main barriers hindering the LPS implementation. Hamzeh et al. [26] presented a reflection on the first implementation of lean principles in general and the LPS in particular on a large scale project in Lebanon. Sweis et al. [27] revealed that the Jordanian construction industry lacks a continuous improvement mentality, suffers from the absence of error proofing devices, and provides minimal training at several levels of the organization. Sarhan et al. [28] reported that lean construction is most commonly used in the construction stage of projects while customer satisfaction is the main benefit derived from lean construction practices. The level of implementation of lean construction in Saudi Arabia construction industry is increasing.

## 3. METHODOLOGY

A deductive research approach using a questionnaire survey was adopted in this study. The population includes engineers (Architects, Civil, Mechanical, Electrical, and Industrial) who work as a supervisor in housing construction projects in the Gaza strip. Purposive sampling was found appropriate since there is no comprehensive, nor any standard, database of Gaza construction companies regarding lean tools applications. The sampling frame included companies in which lean tools were used or were going through the lean transformation process. A total of 135 questionnaires were sent out to the target purposive samples in housing projects, 100 usable fully completed questionnaires were returned thus achieving 74% response rate.

A five-point Likert-type items scale was employed to capture respondents' self-reported attitudes of 1-5 where (1 = never and 5 = very much). Cronbach's Coefficient Alpha (Cα) is used to measure the reliability of the questionnaire. 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 [29]. The Cronbach's coefficient alpha (Cα) was calculated and found 0.94 which is above 0.7, thus, ensures the reliability of the questionnaire.

The modified questionnaire was developed in English language. Based on the belief of the researchers that the questionnaire would be more effective and easier to be understood for all respondents if it is in Arabic (native language) and thus get more realistic results, therefore, the questionnaire (after final revision) was translated in Arabic language. 25 features of lean tools were elicited from a thorough literature review [1,5,20,26,27,28,30,31,32].

Exploratory Factor Analysis (EFA) was used in this study. EFA can be viewed as a data reduction technique which will identify latent factor and reduces large set of variables to a couple of underlying factor [33]. Williams et al. [34] suggested 5-steps exploratory factor analysis, which include the suitability of the data, factors extraction, factors rotation and interpretation, reliability of constructs, and factors Interpretation and labelling.

## 4. RESULTS AND DISCUSSION

This study adopted Principle Component Analysis (PCA) to set up which items could capture the aspects of same dimension for awareness level about using features of lean tools to reduce/eliminate waste in housing projects among 25 features of lean tools. Five steps of exploratory factor analysis need to be considered, these are assessing the suitability of data, factor extraction, factor rotation and retention, reliability of construct, and naming and interpreting the components.

### — First phase: Assessing the suitability of data for factor analysis

Reliability analysis provides a measure of how well a group of observed variables goes together [29]. It was found that Cronbach coefficient alpha equals 0.94 in the first run and 0.93 in the final run for the 25 features of lean tools used in housing projects to reduce/eliminate waste involved in analysis as shown in Table 1. This value of Cronbach coefficient considered acceptable as it is larger than the threshold of 0.70 as recommended by Pallant [35]. The sample size of 100 respondents in this study can be considered adequate as it was larger than 50 as proposed by Sapnas and Zeller [36] and de Winter et al. [37].

Table 1: KMO and Bartlett's test for features of lean tools

| Item | | First run | Last run (sixth run) |
|---|---|---|---|
| KMO Measure of Sampling Adequacy | | 0.83 | 0.86 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 1470.419 | 1053.73 |
| | Df | 300 | 171 |
| | Sig. | 0.00 | 0.00 |
| Cronbach's alpha | | 0.94 | 0.93 |

Udawatta et al. [38] and Tabachnick and Fidell [39] stated that the correlation matrix should be screened, before conducting a factor analysis, to identify variables with low correlation with other variables (correlations less than 0.30) and to eliminate them from the analysis.

As shown in Table (2) all variables are correlated fairly well and none of the correlation coefficients are particularly large; therefore, there is no need to consider eliminating any items at this stage. The value of the Measure of Sampling Adequacy

(MSA) for each item can be found on the diagonal of anti-image correlation matrix produced from SPSS 22 analysis for the involved 25 features of lean tools. Any correlations coefficient above 0.90 should be also eliminated [29,40]. Field [29] and Hair et al. [33] argued that the value of the MSA for each feature should be not less than 0.50. Individual features of lean tools with MSA values less than 0.50 should be considered for elimination from further analysis. It was found that the MSA values for the remained 19 features of lean tools in the last (sixth) run and all of them, larger than 0.50, which is acceptable for factor analysis.

A minimum Kaiser–Meyer–Olkin score of 0.50 is considered necessary to reliably use factor analysis for data analysis [41]. As shown in Table (1), for the first run Bartlett test of sphericity with (chi-square= 1470.419), and the associated significance level is (p-value =0.00 <0.05), which indicated the R-matrix is not an identity matrix; therefore, there are some relationships between the variables, so that, the data were satisfactory for further analysis [42]. In addition, Table (1) presented the values of the overall Kaiser-Meyer-Olkin. The value of the overall KMO for MSA in the first run is found as 0.83 and in the final run 0.86 which indicated that patterns of correlations are relatively compact and so factor analysis should yield distinct and reliable factors.

Table (2): Correlation matrix for features of lean tools

| | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 | A13 | A14 | A15 | A16 | A17 | A18 | A19 | A20 | A21 | A22 | A23 | A24 | A25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | |
| A2 | 0.58 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | |
| A3 | 0.55 | 0.44 | 1.00 | | | | | | | | | | | | | | | | | | | | | | |
| A4 | 0.50 | 0.40 | 0.43 | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| A5 | 0.37 | 0.32 | 0.33 | 0.51 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| A6 | 0.34 | 0.35 | 0.11 | 0.26 | 0.24 | 1.00 | | | | | | | | | | | | | | | | | | | |
| A7 | 0.45 | 0.34 | 0.40 | 0.39 | 0.22 | 0.42 | 1.00 | | | | | | | | | | | | | | | | | | |
| A8 | 0.26 | 0.31 | 0.23 | 0.39 | 0.30 | 0.37 | 0.41 | 1.00 | | | | | | | | | | | | | | | | | |
| A9 | 0.33 | 0.44 | 0.27 | 0.26 | 0.25 | 0.25 | 0.42 | 0.53 | 1.00 | | | | | | | | | | | | | | | | |
| A10 | 0.56 | 0.45 | 0.38 | 0.36 | 0.36 | 0.12 | 0.37 | 0.36 | 0.57 | 1.00 | | | | | | | | | | | | | | | |
| A11 | 0.44 | 0.52 | 0.32 | 0.35 | 0.29 | 0.37 | 0.43 | 0.30 | 0.42 | 0.48 | 1.00 | | | | | | | | | | | | | | |
| A12 | 0.41 | 0.37 | 0.25 | 0.26 | 0.24 | 0.19 | 0.16 | 0.28 | 0.41 | 0.52 | 0.51 | 1.00 | | | | | | | | | | | | | |
| A13 | 0.36 | 0.31 | 0.39 | 0.35 | 0.25 | 0.27 | 0.30 | 0.25 | 0.45 | 0.46 | 0.44 | 0.50 | 1.00 | | | | | | | | | | | | |
| A14 | 0.41 | 0.32 | 0.36 | 0.35 | 0.31 | 0.29 | 0.29 | 0.38 | 0.51 | 0.39 | 0.55 | 0.45 | 0.65 | 1.00 | | | | | | | | | | | |
| A15 | 0.32 | 0.22 | 0.35 | 0.48 | 0.40 | 0.33 | 0.23 | 0.45 | 0.32 | 0.33 | 0.24 | 0.36 | 0.50 | 0.60 | 1.00 | | | | | | | | | | |
| A16 | 0.49 | 0.25 | 0.29 | 0.44 | 0.30 | 0.46 | 0.48 | 0.51 | 0.32 | 0.44 | 0.40 | 0.40 | 0.52 | 0.53 | 0.57 | 1.00 | | | | | | | | | |
| A17 | 0.34 | 0.27 | 0.28 | 0.41 | 0.31 | 0.41 | 0.36 | 0.41 | 0.43 | 0.40 | 0.46 | 0.56 | 0.55 | 0.57 | 0.47 | 0.55 | 1.00 | | | | | | | | |
| A18 | 0.34 | 0.31 | 0.26 | 0.32 | 0.19 | 0.31 | 0.44 | 0.44 | 0.47 | 0.40 | 0.44 | 0.38 | 0.53 | 0.53 | 0.42 | 0.42 | 0.70 | 1.00 | | | | | | | |
| A19 | 0.34 | 0.34 | 0.33 | 0.36 | 0.25 | 0.34 | 0.42 | 0.36 | 0.48 | 0.37 | 0.41 | 0.32 | 0.45 | 0.57 | 0.37 | 0.37 | 0.54 | 0.70 | 1.00 | | | | | | |
| A20 | 0.27 | 0.40 | 0.34 | 0.31 | 0.33 | 0.24 | 0.21 | 0.41 | 0.43 | 0.35 | 0.38 | 0.26 | 0.50 | 0.54 | 0.40 | 0.28 | 0.39 | 0.37 | 0.44 | 1.00 | | | | | |
| A21 | 0.40 | 0.43 | 0.26 | 0.36 | 0.16 | 0.30 | 0.24 | 0.44 | 0.41 | 0.39 | 0.46 | 0.38 | 0.45 | 0.48 | 0.29 | 0.24 | 0.44 | 0.46 | 0.44 | 0.64 | 1.00 | | | | |
| A22 | 0.26 | 0.36 | 0.19 | 0.26 | 0.26 | 0.32 | 0.37 | 0.36 | 0.43 | 0.33 | 0.40 | 0.35 | 0.34 | 0.36 | 0.27 | 0.13 | 0.40 | 0.45 | 0.39 | 0.52 | 0.67 | 1.00 | | | |
| A23 | 0.53 | 0.48 | 0.36 | 0.39 | 0.40 | 0.36 | 0.33 | 0.39 | 0.30 | 0.38 | 0.41 | 0.47 | 0.44 | 0.54 | 0.49 | 0.41 | 0.38 | 0.30 | 0.28 | 0.38 | 0.48 | 0.43 | 1.00 | | |
| A24 | 0.31 | 0.43 | 0.29 | 0.16 | 0.36 | 0.39 | 0.20 | 0.44 | 0.30 | 0.33 | 0.27 | 0.27 | 0.30 | 0.42 | 0.23 | 0.27 | 0.28 | 0.26 | 0.32 | 0.50 | 0.44 | 0.38 | 0.66 | 1.00 | |
| A25 | 0.26 | 0.36 | 0.26 | 0.31 | 0.38 | 0.38 | 0.30 | 0.39 | 0.39 | 0.35 | 0.54 | 0.29 | 0.31 | 0.46 | 0.41 | 0.32 | 0.46 | 0.35 | 0.29 | 0.44 | 0.43 | 0.46 | 0.54 | 0.48 | 1.00 |

— Second phase: Running Exploratory Factor Analysis (EFA)

EFA has been performed for the involved 25 features of lean tools used in housing projects to reduce/eliminate waste using the principal component analysis as the extraction method and the varimax criterion as the rotation method. PCA 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 [39]. After six repetitions of the EFA, six (6) features of lean tools were eliminated and the remaining nineteen (19) features of lean tools were organized under four components. Tables 3 and 4 showed that all the factor loadings met the threshold value of 0.50 or above and all the eigenvalues were greater than 1, which explains 64.68% of the variance. This result is considered high in comparison with several studies in lean construction such as Senaratne and Wijesiri [43]; Agyekum [44]; Ayarkwa et al. [45]. The Cronbach's α was 0.93 for the remained 19 features of lean tools as shown in Table (2). In this line, communalities values were checked in each run, during this process 6 feature were removed as they have community values less than 0.50 [46].

### — Third phase: Factors extraction

PCA is one of the multivariate methods of data analysis used commonly for factor extraction, which reduce a large number of variables into smaller number of uncorrelated variables called principal components [39, 47]. PCA method as a factor extraction technique produces eigenvalues for the number of components (factors). The eigenvalue-greater-than-one rule ("K1" rule) and the visual scree test are the most accurate and commonly used methods to determine the number of retainable components [48,49,50]. Eigenvalue-greater-than-one rule is the most widely known approaches for Guttman [51]; Kaiser [52] and Catell [53] recommended estimating the number of factors for a given item set.

The eigenvalue-greater-than-one rule has been utilized in this study to determine the number of factors to be retained for the appropriate solution. Indeed, after six iterations of factor analysis for the proposed twenty-five features of lean tools, six features of lean tools were eliminated in these iterations and nineteen features of lean tools only remained in the final solution which satisfied all requirements of the factor analysis process. According to Table (3) four components that have eigenvalues greater than 1.0 are chosen.

Table (3): Total variance explained by factor analysis for the last run for features of lean tools

| Component | 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 | 8.28 | 43.60 | 43.60 | 8.28 | 43.60 | 43.60 | 3.69 | 19.41 | 19.41 |
| 2 | 1.53 | 8.07 | 51.67 | 1.53 | 8.07 | 51.67 | 3.29 | 17.32 | 36.73 |
| 3 | 1.41 | 7.41 | 59.08 | 1.41 | 7.41 | 59.08 | 2.66 | 14.03 | 50.76 |
| 4 | 1.06 | 5.60 | 64.68 | 1.06 | 5.60 | 64.68 | 2.65 | 13.92 | 64.68 |
| 5 | 0.94 | 4.95 | 69.62 | | | | | | |
| 6 | 0.80 | 4.19 | 73.81 | | | | | | |
| 7 | 0.71 | 3.76 | 77.57 | | | | | | |
| 8 | 0.64 | 3.38 | 80.95 | | | | | | |
| 9 | 0.63 | 3.33 | 84.28 | | | | | | |
| 10 | 0.50 | 2.64 | 86.92 | | | | | | |
| 11 | 0.45 | 2.37 | 89.29 | | | | | | |
| 12 | 0.38 | 2.00 | 91.29 | | | | | | |
| 13 | 0.36 | 1.89 | 93.18 | | | | | | |
| 14 | 0.31 | 1.66 | 94.84 | | | | | | |
| 15 | 0.24 | 1.26 | 96.10 | | | | | | |
| 16 | 0.24 | 1.24 | 97.33 | | | | | | |
| 17 | 0.21 | 1.08 | 98.41 | | | | | | |
| 18 | 0.17 | 0.87 | 99.29 | | | | | | |
| 19 | 0.14 | 0.71 | 100.00 | | | | | | |
| Extraction Method: Principal component analysis. | | | | | | | | | |

Scree plot is a useful approach for determining how many factors to retain [47,53]. The point of interest is where the curve starts to flatten which can identify the number of the factors to be retained. Figure (1) illustrates the last run of factor analysis for 19 features of lean tools. At the point, 4 on the x-axis the curve starts to flatten and therefore the number of the component that have eigenvalues over one should be retained.

Determining total variance of the items included in data set is one important issue of factor analysis to confirm the number of the retained factors from the two mentioned methods of factors retention [54]. According to Tables 3 and 4 the cumulative percentage of variance explained by the remained four components of 64.68% was considered acceptable. The first component accounts for 19.41% of the variance, the second 17.32%, the third 14.025% and the fourth 13.92%.

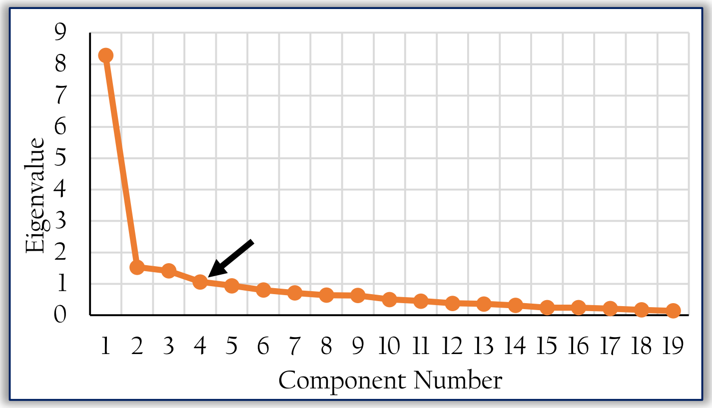


Figure (1): Scree plot for features of lean tools

### — Fourth phase: Factors rotation and retention

In this study, a factor loading of 0.50 was used as the cut-off point based on previous studies on lean construction such as Ogunbiyi [19]; Udawatta et al. [38] and Ayarkwa et al. [45]. Any feature with factor loading less than 0.50 will be removed from the solution. In this regard, the features A2, A8 and A9 have been removed in the second, third and sixth runs, respectively, because their factor loading less than 0.50 on the extracted factor. The final solution for features of lean tools involved 19 loaded on 4 components with loading values more than 0.50 and each item loaded on one factor only.

Gorsuch [55] and Fabrigar et al. [49] recommended that minimum of three items and optimum of four or more items per factor should be included in the factor analysis to ensure an adequate identification of the factors. After six repetitions of the EFA, six (6) features of lean tools were eliminated and the remaining nineteen (19) features of lean tools used in housing projects to reduce/eliminate waste were organized under four components. Hair et al. [33] argued that items with an alpha correlation of 0.70 and higher are viewed as acceptable, but indicate that alpha correlations of 0.60 are also acceptable in exploratory research. The reliability of extracted four components for the remaining 19 features of lean tools was checked by calculating Cronbach's alpha (Cα). As shown in Table (4), the value of Cronbach's (Cα) for the first, second, third and fourth components were 0.87, 0.86, 0.79, and 0.77, respectively. The values of Cronbach's alpha (Cα) for all data and for each component are more than 0.70 which indicating adequate internal consistency according to Pallant [35].

— Fifth phase: Naming and interpreting the principal components

Hart [56] suggested that the component names should be brief (one or two words) and communicate the nature of the underlying construct. In practice, the name for any component can be established by observing the patterns of similarity between items that are loaded on the component. Names of these components have been prepared to summarize the standards that reflecting the awareness level about using features of lean tools to reduce/eliminate waste in housing projects (Table 4). These four components named as follows:

1. Component No.1: Communication and information sharing: involved 5 features and has 8.28 eigenvalue which explained 19.41% of the total variance.
2. Component No.2: Documentation process: comprised of 6 features and has 1.53 eigenvalue which explained 17.32% of the total variance.
3. Component No.3: Workplace arrangement: comprised of 4 features and has 1.41 eigenvalue which explained 14.03% of the total variance.
4. Component No.4: Safety and quality: comprised of 4 features and has 1.06 eigenvalue which explained 13.92% of the total variance.

Table (4): Results of factor analysis for features of lean tools

| Item | Feature of lean tools | Factor loading | Eigenvalue | % variance explained | Cornbach' α |
|---|---|---|---|---|---|
| Component No.1: Communication and information sharing | | | | | |
| A18 | Your organization focused on communication and cooperation to obtain the most product concerning functionality, quality, and productivity | 0.80 | 8.28 | 19.41 | 0.87 |
| A19 | Your organization focused on information sharing for discovering new ideas | 0.73 | | | |
| A17 | Your organization focused on team efforts | 0.71 | | | |
| A13 | Your organization adopted any rules for making sure that procedures are standardized and reproducible | 0.63 | | | |
| A14 | Your organization interested to modify introduced procedures and rules | 0.62 | | | |
| Component No.2: Documentation process | | | | | |
| A22 | Your organization focused on writing a step by step outline of each action in the process as information and materials is passed through each position | 0.73 | 1.53 | 17.32 | 0.86 |
| A24 | Your organization concerned on identifying process times and delay times on actual steps or actions, as well as steps in the process that are non-value activity | 0.72 | | | |
| A21 | Your organization identified the positions (or people) involved in the process of achieving that objective | 0.70 | | | |
| A20 | Your organization defined clear objectives of the process | 0.68 | | | |
| A25 | Your organization drew a "future state" value stream map that has eliminated or reduced areas identified as wasteful or non-value added | 0.61 | | | |
| A23 | Your organization drew a "current state" value stream map, which shows a step by step process flow | 0.56 | | | |
| Component No.3: Workplace arrangement | | | | | |
| A10 | Your organization focused on removing all unnecessary tools and parts and put them in order | 0.72 | 1.41 | 14.03 | 0.79 |
| A12 | Your organization concerned on cleaning workplace and the used devices | 0.70 | | | |
| A1 | Your organization has a realistic plan to evaluate the performance of workers | 0.69 | | | |
| A11 | Your organization depended on any rules for distribution of work, workers, equipment, parts and instructions in such a way that the flow of work is free from inefficient tasks | 0.60 | | | |
| Component No.4: Safety and quality | | | | | |
| A5 | Your organization used project milestones signs of completion dates around the construction site | 0.70 | 1.06 | 13.92 | 0.77 |
| A15 | Your organization has standard practices to check for quality | 0.68 | | | |
| A4 | Your organization used signs and labels related to safety, schedule and quality around the construction site and work performance | 0.63 | | | |
| A16 | Your organization made safety action plans | 0.56 | | | |

Kaiser-Meyer-Olkin measure of sampling adequacy = 0.86. Bartlett's test of sphericity: x2= 1053.73, df=171, p-value =0.00. Total variance explained (%) = 64.68 %. Total reliability Cornbach's α = 0.93. The four components will be discussed in the following sections.

» Component 1: Communication and information sharing

The first component was labelled communication and information sharing and explained 19.41 % of the total variance. This component contained five features of lean tools to reduce/eliminate waste in housing projects with relatively high factor loadings (≥ 0.62). These five features of lean tools are as follows:

1. Your organization focused on communication and cooperation to obtain the most product concerning functionality, quality, and productivity (A18), with factor loading = 0.8.
2. Your organization focused on information sharing for discovering new ideas (A19), with factor loading = 0.73.
3. Your organization focused on team efforts (A17), with factor loading = 0.71.
4. Your organization adopted any rules for making sure that procedures are standardized and reproducible (A13), with factor loading = 0.63.
5. Your organization is interested to modify introduced procedures and rules (A14), with factor loading = 0.62.

The five features of lean tools that loaded on this component are closely related to communication and information sharing features, which reflect the awareness level about using lean tools to reduce/eliminate waste in housing projects. Therefore, this component can be termed communication and information sharing. All of the loaded features on this component had factor loading greater than 0.60, which are considered significant in contributing to the interpretation of this component. This component is considered the most important one in terms of the percentage of the variance among the variables. According to factor analysis theory, the first component accounted for the largest part of total variance of the data. Thus, communication and information sharing component appear to conclude the most important features that reflect the awareness level of using lean tools in the housing project in Gaza Strip. This result reflects the situation in Gaza Strip, which suffers from unstable conditions; thus, any construction company needs to respond to any unpredictable events. To achieve successful respond through lean tools implementation, project parties' needed to improve their ability to provide means of effective communication through using means of communication and utilize technology and facilitate information sharing. Increasing communication channels between all project parties during lean tools implementation will improve performance in Gaza Strip housing projects.

The impact of communication and information sharing on the awareness level about using lean tools has been well documented [14,18,19,28,44]. Diekmann et al. [57] and Zhang and Chen [14] argued that values of cooperation, trust, communication and information sharing are major engines that reflect the awareness level about using lean tools in construction sector. This component reflects the awareness level about using lean tools by ensuring proper and continual communication between all project team members and therefore improves teamwork and increases transparency [26].

The importance of this component in improving the awareness level about using features of lean tools in housing projects has been emphasized. In general, these improvements (communication, information sharing, and team efforts) can lead to improve safety, productivity, quality, and set-up-times improvement, improve morale, teamwork, and continuous improvement that are considered lean benefits [21]. Communication and information sharing among the disciplines is very important because they can discuss problems, difficulties, requirements, and they can solve it together but poor communication leads to making mistakes requiring correction and creates waste [25]. Zhang and Chen [14] and Aziz and Hafez [18] confirmed the same viewpoints that asserted that communication and information sharing at all stages of project is a main indicator for lean production success.

» Component 2: Documentation process

The second component was labelled documentation process and explained 17.32% of the total variance. This component contained six features of lean tools. The majority of these features of lean tools had relatively high factor loadings (≥ 0.56). The six features of lean tools are as follows:

1. Your organization focused on writing a step by step outline of each action in the process as information and materials is passed through each position (A22), with factor loading = 0.73.
2. Your organization concerned on identifying process times and delay times on actual steps or actions, as well as steps in the process that are non-value activity (A24), with factor loading = 0.72.
3. Your organization identified the positions (or people) involved in the process of achieving that objective (A21), with factor loading = 0.70.
4. Your organization defined a clear objectives of the process (A20), with factor loading = 0.68.
5. Your organization drew a "future state" value stream map that has eliminated or reduced areas identified as wasteful or non-value added (A25), with factor loading = 0.61.
6. Your organization drew a "current state" value stream map, which shows a step by step process flow (A23), with factor loading = 0.56.

This component was labelled in accordance with the characteristics of the set of individual features of lean tools loaded on it. Under this component, the correlations between the six features of lean tools can be distinguished by the documentation process, and to which extent the awareness level can be affected with these features of lean tools. Therefore, these features of lean tools were placed into the "Documentation process "component. All of these features of lean tools have acceptable factor loadings (> 0.56) which are considered important in terms of the percentage of the variance among the variables. Thus, this component appears to conclude important features that reflect the awareness level of using lean tools in the housing project in Gaza Strip.

The objectives of the documentation process are to identify gap areas, to facilitate lean implementation in construction projects by the firms that add value to the product or service under consideration [58]. Identifying opportunities for improvement in the coming projects is also seen as another objective for documentation process [59]. The effect of documentation process on the awareness level about using lean tools to reduce/eliminate waste in housing projects has been acknowledged in the literature [1,16,28,32,59]. Documentation process would involve creating current stream map to show the process flow, as well as future stream map to eliminate wasteful processes [16,59,61]. Zhang and Chen [14] and Sarhan et al. [28] concluded that the documentation process used to analyze the current material and information flow to achieve customer satisfaction.

The importance of this component on reflecting the awareness level about using lean tools to reduce/eliminate waste in housing projects can be explained through the fact that documentation process helped to think about flow instead of isolated waste and to implement lean system instead of individual lean tools [19,58]. Vieira and Cachadinha [1] confirmed that this component could be used not only for economic purposes, but also for social and environmental ones, by adding environmental information to the map through the documentation process.

» Component 3: Workplace arrangement

The third component was labelled workplace arrangement, explained 14.03% of the total variance, and contained four features of lean tools. The majority of these features of lean tools had relatively high factor loadings (≥ 0.60). The four features of lean tools are as follows:

1. Your organization focused on removing all unnecessary tools and parts and put them in order (A10), with factor loading = 0.72.
2. Your organization concerned on cleaning workplace and the used devices (A12), with factor loading = 0.7.
3. Your organization has a realistic plan to evaluate the performance of workers (A1), with factor loading = 0.69.
4. Your organization depended on any rules for distribution of work, workers, equipment, parts and instructions in such a way that the flow of work is free from inefficient tasks (A11), with factor loading = 0.60.

The third component contained all features of lean tools, which are related to workplace cleaning and organizing. Therefore, this group of features of lean tools could appropriately be given the heading of "Workplace arrangement". The combination of these workplace arrangement related features of lean tools reflects the awareness level about using lean tools to reduce/eliminate waste in housing projects. Construction companies in Gaza Strip are concerned with implementing lean tools to improve site layout and to prevent accidents in their projects. The influence of workplace arrangement on the awareness level about using lean tools to reduce/eliminate waste in housing projects has been emphasized [10,18,19,21,61]. Vieira and Cachadinha [1] observed that workplace arrangement used to maintain a workplace clean and organized. Ogunbiyi [19] also described the workplace arrangement as dealing with a place for everything and everything in its place.

The benefits of workplace arrangement component as mentioned by Salem et al. [21] and Aziz and Hafez [18] are improved safety, productivity, quality, creation of space, reduced lead times, cycle times, increased machine uptime, improved teamwork, and continuous improvement. In addition to that, workplace arrangement has a direct impact on worker performance where the performance of workers based on their ability to focus on the activities through arranged and organized workplace [19,21].

» Component 4: Safety and quality

The fourth component was labelled safety and quality and it is explained 13.92 % of the total variance. This component contained four features of lean tools. The majority of these features of lean tools had relatively high factor loadings (≥ 0.56). The four features of lean tools are as follows:

1. Your organization used project milestones signs of completion dates around the construction site (A5), with factor loading = 0.7.
2. Your organization has standard practices to check for quality (A15), with factor loading = 0.68.
3. Your organization used signs and labels related to safety, schedule and quality around the construction site and work performance (A4), with factor loading = 0.63.
4. Your organization made safety action plans (A16), with factor loading = 0.56.

The fourth component was labelled "Safety and quality" include four features of lean tools addressing this particular theme. All four features of lean tools loaded on this component refers to the quality and safety activities that increase the awareness about using lean tools to reduce/eliminate waste in housing projects. This group of lean features demonstrates the experienced professional's perception of the importance of safety and quality issues, and how this component contributes to the awareness level about using lean tools to reduce/eliminate waste in housing projects. This component indicated that the construction companies in Gaza Strip seek to keep their records clean about safety and quality problems by enhancing safe practices. In addition, continuous improvement of construction quality and safety not only saves live but also cost, productivity, and time [62].

Safety and quality component is an important part on the awareness level about using lean tools to reduce/eliminate waste in housing projects [16,32,63,64]. It relies on posting various signs and labels around the construction site to provide key information to the workforce, which lead to improve quality of work and reduce accidents [5,19]. In addition to that, safety and quality component is supported by safety plans that alert for potential defects and how to overcome these defects [21]. Awada et al. [65] agreed that the implementation of the lean tools would enhance safety conditions, and would facilitate the achievement of the project in an effective and efficient way. This component deals with all measures taken to prevent an error from occurring [28]. These errors could be quality problems, delays in delivering a mid-process product, and safety issues [6]. Ogunbiyi [19] stated that safety and quality component has economic influence by reducing costs and increasing productivity, environmental influence by reducing or improving materials and social influence by affecting the well-being of workers.

## 5. CONCLUSIONS

The awareness is the main engine for successful implementation of lean tools. This objective established to assess the experienced professionals' awareness level about using lean tools in the housing projects in Gaza Strip. This result will be helpful for enhancing efficiency, production, and quality of housing projects by providing an understanding for the awareness level about implementation of lean tools in the housing projects. This part of the study provides information about the most implemented lean tools, which can be useful for improving lean tools implementation in all housing projects in Gaza Strip.

Factor analysis using the SPSS Version 22 package enabled the features that reflect the awareness level about using lean tools in housing projects, identified to be grouped under four components as:

- communication and information sharing,
- documentation process,
- workplace arrangement, and
- safety and quality.

The results enable construction companies to enhance the features of lean tools, which related to communication, documentation, workplace organizing, quality and safety, towards increasing the awareness level about using lean tools at housing projects in Gaza Strip.

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