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INVESTIGATION AND ASSESSMENT THE LEVEL OF ADOPTION LEAN PHILOSOPHY IN SMES UNDER UNCERTAINTY BY EFA/FAHP/FTOPSIS INTEGRATED MODEL

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Abstract:
Small and Medium Enterprises (SMEs), thus it is pursues to improve their performance to stay in the global competitive markets through adopting an efficient manufacturing systems, one of them is lean production (LP). LP is a continuous improvement philosophy that based on using various lean activities to improve enterprise performance by eliminating various type of waste. In this paper, a Lean Level Assessment Methodology is proposed which integrated Exploratory Factor Analysis (EFA), Fuzzy Analytic Hierarchy Process (FAHP) and Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS) to identify level of importance of lean activities and assess the level of SMEs leanness concerning five dimensions of lean activities. SMEs lean activities have surveyed through a comprehensive literature review, where twenty six lean activities have identified as the most common SMEs activities that classifying into five lean dimensions. A questionnaire was developed to collect data related to the levels of adoption of these lean activities by SMEs using a triple Likert scale. EFA was used to extract the most influencing lean activities on SMEs leanness based on questionnaire data. FAHP was used to determine the weights and the level of importance of these lean activities, while FTOPSIS was employed to investigate and assess the level of SMEs' leanness related to the five lean dimensions activities. The proposed methodology has applied in four Iraqi SMEs (A1, A2, A3, and A4) for producing healthy water and soft drink in Baghdad. The results have explained that only 19 lean activities are the most influencing on SMEs leanness. Efficient manager is an important lean activity that has 58.90% level of importance. Although the four Iraqi SMEs have approximately acceptable level of leanness related the five lean dimensions, there is variation in adoption these lean dimensions activities by SMEs. SMEs management should develop a continuous improvement strategy based on utilizing SMEs' efforts and resources to improve activities of the weaker dimension for improving their competitiveness and ensuring sustainability in the rapidly changing business environment. One limitation of this paper is the difficulty in obtaining data related to lean activities and their performance through SMEs' processes and activities.

Key words: *Exploratory Factor analysis, FAHP, FTOPSIS, Lean Activities, SMEs*

INTRODUCTION

SMEs are independent, non-subsidiary enterprises which employ limited number of employees [1], it has a simple organizational structure with very few levels that and lead to a high communication and involvement with top management for immediate decision-making and rapid, implementation of management strategies [1]. SMEs play an important part in modern economy where represent the backbone of economies worldwide. It represents about 90% of total companies in most world economies and provides between 50-60% of the total employment opportunities and contributes about 46% of the global GDP. Nowdays, the interest about SMEs has increase for many reasons the most large and famous companies have been divided its work into spread SMEs in world due to many reasons like; the global competition, to be near from its clients, near to raw material, get cheap workers in addition large and famous companies increasingly subcontract their operations to SMEs [3]. SMEs has important role in manufacturing and supply the subassemblies of the large companies manufactured products, where SMEs also help big enterprises such as supplying raw materials and parts and distributing products made by them. Nowadays, SMEs are pursued to improve their performance through adopting efficient manufacturing systems like Lean Production Philosophy (LP).to ensure stay in the competitive markets. LP is continuous improvement philosophy that lead to improve efficiency, productivity, quality and reduces costs in any organization through eliminate eight types of waste [5, 6]. It pursues to make enterprise more

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competitive and enhance their market position to stay competitive with the global rivals in the global markets by focusing on involvement all levels of enterprise in improvement practices and activities for reducing or eliminating wastes throughout it by working as a team in improvement suggestions, problems solving, decisions making and other improvement practices and activities to improve productivity, quality, work environment and reduce cost. Additionally, lean policies and activities related to suppliers and customers play a crucial role in achieving these improvements [7, 8, 9]. Although there are more than 100 lean activities, SMEs are not able to implement all these due to skill, financial and expertise constraints [10].

In this paper, lean level assessment model that integrates EFA, FAHP and FTOPSIS has been proposed to identify the level of importance of lean activities and assess the level of SMEs' leanness. EFA was used to extract the most influential SMEs lean activities that have a significant impact on SMEs leanness using software SSPS 23. FAHP was used to identify the importance level of lean activities while, FTOPSIS was employed to investigate and assess the level of SMEs leanness across five lean dimensions. Lean activities were surveyed through comprehensive literature review. Questionnaire was developed to collected data from homogenous sample of SMEs.

LITERATURE REVIEW

Literature review has conducted that involve three sections related methods used in developing methodology of the research, these are.

Exploratory Factor Analysis

EFA is a suitable method to extract few influencing, valuable and manageable factors from a large number of related variables that investigated by questionnaire before using them in other analysis thus, helping the decision makers to focus on few factors in solving their problem and make decision [11]. The reliability of a questionnaire is examined by Cronbach's Alpha (α), it can be computed by Eq. 1 [13].

$$\boldsymbol{\alpha} = \frac{k}{k-1}[1 - \frac{\sum S^2 y}{S^2 x}], \quad (1)$$

where:

α is Alpha Cronbech,

$\sum S^2_y$ is sum of items variance,

k is number of tested items,

S^2_x is variance of total score.

Alpha Cronbech (α) measures the extent the correlation answers of questionnaire questions with each other by estimate the variance in a set of questionnaire responses [13]. It provides a simple way to measure the reliability and internal consistency of the questionnaire in addition to measure of scale reliability and it ranges between 0 and 1 as shown in Table 1 and more than 0.7 is considered acceptable value and a high alpha value shows that factors in test are highly correlated [14, 15, 16].

Table 1

Cronbach's value (α) interpretation

Cronbach's value (α)	Internal consistency
α ≥ 0.9	Excellent
0.9 > α ≥ 0.8	Good
0.8 > α ≥ 0.7	Acceptable
0.7 > α ≥ 0.6	Questionable
0.6 > α ≥ 0.5	Poor
0.5 > α	Unacceptable

Source: [17].

Exploratory factor analysis involves three main steps [11]:

A. Assessment of the Data Suitability for EFA

Firstly, identify strength of the relationship among the items through correlation matrix |R| where must the coefficient of correlation (r) > 0.3 in the correlation matrix. Kaiser-Meyer-Olkin (KMO) test and Bartlett's test both are used with Factor analysis to assess suitability of data for conduct factor analysis. KMO test is a measure that used to identify the suitability of data for factor analysis by test the adequacy of the sample size [11] where its value varies from 0 to 1 where KMO value interpretation show in Table 2 and it can be measured by Eq. 2.

$$\boldsymbol{\alpha}\mathrm{KMOj} = \frac{\sum_{i \neq j} \boldsymbol{R^2 ij}}{\sum_{i \neq j} \boldsymbol{R^2 ij} + \sum_{i \neq j} \boldsymbol{U^2 ij}}, \quad (2)$$

where:

R_{ij} is the correlation matrix,

U_{ij} is the partial covariance matrix.

Table 2

KMO Value Interpretation

KOM Value	Interpretation of Sampling Adequacy
1-0.9	Very Good
0.8-0.9	Good
0.7-0.8	Medium
0.6-0.7	Reasonable
0.5-0.6	Acceptable

Source: [18].

Bartlett's test has used as a measure to evaluate the general essentialness of the correlation matrix where, it tests whether the correlation coefficients are 0 or less 0.05 for conducting the factor analysis. The test computes the probability that the correlation matrix has significant correlations among at least some of the variables in a dataset [19]. The significant value < 0.05 indicates that a factor analysis may be useful for the questionnaire data. The Bartlett's test value can be calculated by Eq. 3.

$$\boldsymbol{\alpha}\text{Bartlett's test of Sphericity} = -(\mathrm{n} - 1 - \frac{\boldsymbol{2p+5}}{\boldsymbol{6}}) \cdot \ln |\mathrm{R}|, \quad (3)$$

where:

p is number of variables,

n is total sample size,

R is correlation matrix.

B. Factor Extraction by Principal Component Analysis Method

Principal component analysis (PCA) is a common method of FA for extracting the significant and influencing minimum factors required to represent the available data set. Eigenvalue is used to determine the number of extracted

factors where eigenvalue represents the amount of the total variance explained by that factor. In factor analysis, the remarkable factors having eigenvalue greater than one are retained and are considered to be significant where it indicates that more common variance than unique variance is explained by this factor.

C. Factor rotation and interpretation.

Varimax method has used to minimize the variables numbers that have high influence on each factor.

Many researchers have used EFA in various application in industry field, Olugu et al. [20] Used EFA to investigate and test the criterion validity of the measures and their metrics for Green Supply Chain Performance Measures in the Automotive Industry. Jain et al. [21] used Exploratory and Confirmatory Factor Analysis to evaluate and extract the influencing variables affecting flexibility in FMS. Phogat et al. [19] used Exploratory and confirmatory factor analysis to evaluate and extract the influencing elements of just in time (JIT) for implementation in maintenance. Mor et al. [22] explore the factors affecting supply chain performance in dairy industry. Ahmadi et al. [23] proposed model integrated EFA and Data Envelopment Analysis to evaluate balanced ambidexterity fostering innovation in manufacturing SMEs. Iskamto et al. [24] used EFA to extract dimensions of assessment of the SME. Performance in Indonesia where four dimensions are extracted that identify by 31 items that also extracted by FA. Sun et al. [25] used EFA to extract the influencing dimensions and criteria on selection suppliers. Nawaz Wassan et al. [26] used EFA to identify the critical success factors of Total Quality Management implementation in the Pakistan manufacturing industry.

Fuzzy Analytic Hierarchy Process (FAHP)

Analytic Hierarchy Process (AHP) is a multi-criteria decision-making method that widely used to identify criteria weights and priorities of alternatives in a structured way based on experts subjective judgment by pairwise comparison among criteria [27]. Although the experts judgments are considered the main input of AHP matrix ,this method is difficult for making decisions in some problems that involve incomplete data and uncertain thus this led to shortage in using AHP [28, 29]. The fuzzy sets proposed by Zadeh (1965) are combined with AHP to form FAHP for handling uncertainty and imprecision to use for decision-making problems in industry and other fields due to its ability to deal with vagueness and fuzziness of linguistic judgments compared with inability of AHP, especially the various selection problems [27]. It has used for; solving both quantitative and qualitative problems, it can be used alone or with another MCDM method for handling vagueness and uncertainty in the given weights for evaluating alternatives; identifying an effective prioritization using pair-wise comparison process [28, 30, 31].

FAHP has become a popular FMCDM method where, it is used in various fields such as; airline retail, agriculture, automobile, maritime, pharmacy, manufacturing, logistics and service, in addition to use it to solve different problems like; sustainability, supplier selection, machine selection, management business, location selection, impacts assessment, technique selection, risk analysis teaching performance evaluation and assets management. FAHP has applied in Lean Production in various fields; Kumar et al. [36] proposed an integrated framework for lean implementation process in the steel processing industry using fuzzy complex proportional assessment of alternatives (FCOPRAS), FAHP and value stream mapping (VSM). VSM was applied to identify the wastes at each stage in production process and lean tools were determined from literature based on the wastes that identified from the current state. FAHP was used to prioritize the lean tools based on the positive correlation on one another then developed future state value stream map to show the improvements that achieved due to the implementation of selected lean tools. Comparison of current and future VSM illustrates a high reduction in wastes using the lean tools. Bueno et al. [37] developed a hierarchical approach using FAHP for simplifying the application of Lean principles. Six criteria; stocking, process, inspection, cost, management and capacity and 33 sub-criteria have been used to evaluate processes and operations in three companies from different branches for assessing the lean level of these companies. Cost has the highest degree of importance 20%, then management construct 23% and capacity 22%. Narayana1 et al. [38] developed a fuzzy model based on FAHP to evaluate performance of ten medium-scale Indian automobile manufacturing industries regarding green and lean implementation and assess lean level of these industries. AHP has used to identify criteria importance and identifying the important, essential and critical criteria for implementing the lean and green concept then AHP has used to assess lean level of these medium scale enterprises. Alhuraish et al. [39] Analyzed companies performance using AHP to rank the performance based on operational performance and financial performance and Innovation performance as a criteria with 12 sub- criteria. AHP has applied using Super Decisions software package to compute the rating score. Results illustrate those companies that implementing lean manufacturing and Six Sigma are more effective in improving their operational and financial performance and implementing lean manufacturing alone is sufficient for improvement innovation performance. Susilawati et al. [40] proposed a Fuzzy Analytical Hierarchy Process (FAHP) algorithm based Performance Measurement System (PMS) application software for lean companies by C++ language for assessing the lean level of an automotive company in the Indonesian manufacturing industry to measure and improve the company's performance using six criteria; financial perspectives, customer issues, supplier issues, people, and process. Results illustrate that the lean performance level of each criteria assess by FAHP is 0.297 for financial perspective, 0.262 for customer issues, 0.171 for process, 0.071 for supplier issues, 0.083 for people and 0.166 for process. The lean level of company according these criteria is 0.574. Ravikumar et al. [41] developed a model that combined AHP, FAHP and interpretive structural modeling (ISM) for investigating and evaluating the lean

implementation performance of 6 MSMEs based on eleven lean criteria; Organizational culture, Strong management and Leadership, Determination of Objective and Goals, Skills and expertise, getting employee trust, Financial capabilities, Communication of the transformation process and goals-Effective Communication, Education and training, Performance measures, Plan and strategy, Customer focus and Thinking development. ISM is used to identify criteria weights then AHP model has used to identify the best in lean implementation by comparing one criterion over another and FAHP has used to ranking these 6 MSMEs industries.

Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS)

Chen's Fuzzy TOPSIS or FTOPSIS plays an important role in the situation of ambiguity and uncertainty due to its ability to overcome the probable shortcomings while dealing with vagueness and unclear in decision making. It can deal with both quantitative and qualitative information. Fuzzy TOPSIS simultaneously consider both the negative ideal solution (NIS) and the positive ideal solution (PIS), and preference order ranking based on their relative proximity [42]. Yanfeng Li et al. [43] proposed an assessment model that integrates Entropy, Fuzzy CRITIC and TOPSIS to evaluate the lean level of three production lines ABC of H company. Devnath et al. [44] developed integrated model using Quality Function Deployment (QFD) and TOPSIS, to evaluate, and prioritize the lean practices and policies to find and rank the major wastes on a production floor. House of Quality (HOQ) was used to identify major waste by identify a significant waste signs through interviews and on-field investigation then converted those signs into seven major wastes while TOPSIS was utilized to prioritize the suitable lean practices and policies. The results found that inventory waste is the crucial one on the shop floor then followed by over production and motion waste and Kanban or pull system is the best tool to eliminate waste. Mirnoori [45] proposed model for evaluating and ranking twenty lean practices using three MCDM methods; TOPSIS, SAW and VIKOR. Results show that these methods showed approximately the same ranking in evaluation lean practices. Rajpurohit et al. [46] proposed an assessment model for assessing the lean level of three SMEs A, B, C by FTOPSIS and experts identified directly weights for criteria and rating the firms' performance against lean criteria. The lean performance levels of these SMEs are firm C (0.48) is leaner as compared to firm B and firm B (0.46) is leaner than firm A (0.45). Kumar et al. [47] proposed a framework for a comparative evaluation of lean performance of three firms. Three experts assessed and identified weights of criteria and firms' performance rating against lean criteria. Sensitivity analysis is conducted to verify the robustness of the proposed methodology. The results show the overall performance of firm 3 > firm 1 > firm 2. Akram et al. [48] developed an innovative approach using fuzzy TOPSIS to assess the lean level of one enterprise the Partizan Sanat company using eleven criteria, criteria weights have identified by experts. The company lean level is at the mediocre level of leanness (0.52). Hojjati et al. [49] Integrating two methods SAW and TOPSIS to evaluate the lean practices and policies and ranking aspect of efficacy under four criteria: lead time, cost, defects and value. The results show obtained scores level of tools was different aspect to four criteria where, the highest score for decreasing lead time, cost, belong to: Continuous flow; Pull system meanwhile highest score for reducing defects belong to Poka Yoke) also the results have been shown that the hybrid model can take advantage of various methodologies. The hybrid model will be more helpful in assisting integrated decision making for the purpose of tools evaluation and selection.

RESEARCH METHODOLOGY

Lean level assessment methodology has been proposed to identify the most influencing lean activities on SMEs leanness, determine the level of importance of these activities and assess the level of leanness of SMEs. Steps of methodology can be illustrated in Figure 1.

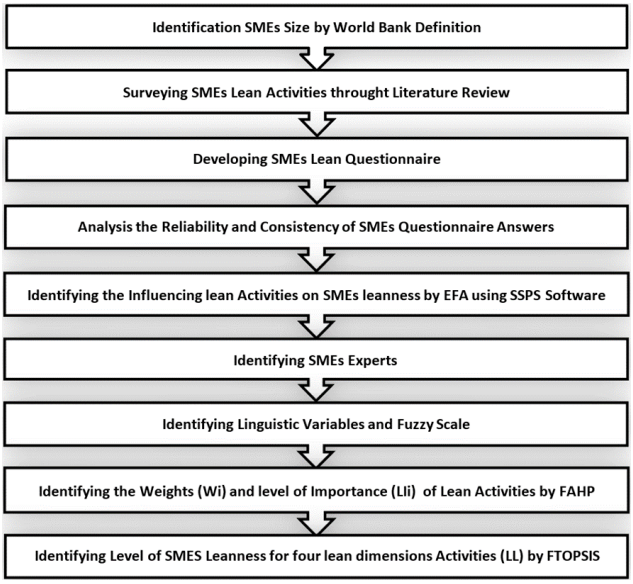


Fig. 1 The general structure of Lean Level Assessment Model

Step 1. Identifying SMEs Size by World Bank Definition: Definition of World Bank (WB) for SMEs has been adopted where, number of employees (E) is used as a measure to identify the enterprise size. The enterprise is categorized as small if $10 < E \leq 50$ while considered medium if $50 \leq E \leq 300$ [50], Thus SMEs have rang of employees number $10 \leq E \leq 300$.

Step 2. Identifying SMEs Lean Activities: SMEs Lean activities has been identified through literature review from 2015-2021 using research gate, Google engine and key words lean philosophy, SMEs, Lean activities Twenty six lean activities have been identified as shown in Table 3 that categorized based on its related to five lean dimensions.

Table 3

Survey of SMEs lean Activities

Lean Dimensions	Lean Activities	Symbol	D.D. Harjanto (2021) [51]	W.P. Bueno (2020) [37]	S.N. Sathiya Narayana (2020) [38]	V. Yadav, G. Khandelwal (2019) [52]	N.K. Vishal A Wankhede (2019) [53]	H.T.S. Caldera (2018) [16]	A. Belhadi (2018) [54]	S. Sahoo (2018) [55]	L. Rajpurohit (2017) [56]	A. Abreu(2017) [57]	M. Cengiz Toklu (2017) [58]	R. Vidyadhar R (2016) [59]	S. Thanki (2016) [60]	Zanjbeel Tabassum (2016) [61]	P.K. Balasubramanian (2016) [62]	B. Zhou (2016) [63]	M. Godinho Filho (2016) [64]	C. Laoha (2015) [65]	C. Laoha (2015) [66]
Process	Pull Approach (Kanban)	P1						●	●		●	●	●	●	●		●	•	●		
	Lot Size Reduction	P2													●		●				
	Set Up Reduction (SMED)	P3			●			●	●			●	●	●	●	●	●	•		●	
	Workplace Organization	P4			●			●	●		●	●		●	●	●	●	•		●	●
	Preventive Maintenance	P5		●		●	●		●		●	●	●	●	●	●	●	•	●	●	●
	Visual Management System	P6	●			●		●			●			●	●	●		•	●	●	●
	Poka Yoke	P7			●				●			●		●	●	●	●		●	●	●
	Adoption of VSM	P8							●						●		●	•	●		
	Standardization and Simplification Work	P9	●						●		●	●			●	●	●				
	Kazien Team	P10				•	•		•		•	•				●		•			
	Quality Circle	P11	●			•	•	●	•		•	•						•	●		
Management	Efficient Manager	T1			•	•				•					•				•		
	Motivating, and Supporting Employees	T2	●		●					●		●			●				●		
	Employee Involvement and Empowerment	T3			●					●					●				●		
	Smooth Information Flow and Sharing	T4			●	●	●	●		●					●				●		
Suppliers	Supplier Relationship	S1			●						●	●	●						●		
	Suppliers Development	S2	●		●						●	●							●		
	Evaluation Suppliers' Performance	S3			●							●									
	JIT purchasing deliveries by supplier	S4	●		●		●					●	●								
Customers	Execution Customer Suggestions and Requirements	C1	●									●							●		
	Handling and Solving Customer Complaints	C2	●		●							●			●				●		
	Customer Satisfaction	C3										●							●		
Employees	Team Work	E1			●	●	●		●		●	●	●		●		●				●
	Flexible/Multiskill Workforce	E2			●	●	●				●	●			●				●		●
	Employee Training	E3		●		●			●			●					●		●		
	Job Rotation between Employees	E4		●	●	●						●			●				●		

Step 3. Developing SMEs Lean Questionnaire: A Questionnaire was developed using triple Likert scale 1, 2, 3 using 88 questions related 26 lean activities. Scale 3 refer to highly implementation this activities in SMEs processes and activities, scale 2 refer to partial implementation this activities in SMEs processes and activities and 1 refer to less implementation this activities in SMEs processes and activities.

Step 4. Analysis the Reliability and Consistency of SMEs Questionnaire Answers: The data collected by questionnaire has been independently tested for questions of each lean activity by Cronbach's alpha test for measuring the internal consistency and reliability the answers for further statistical analysis where the value of Cronbach's α over 0.7 is considered satisfactory value that prove reliability and consistency of experts answers.

Step 5. Identifying the Most Influencing Lean Activities on SMEs Leanness using EFA: Principle components method (PC) as one of the most common method of EFA has been used to identify the influencing lean activities on SMEs leanness. The sequential steps of PC begin by identify the correlation between each two lean activities through correlation matrix then identify suitability of data to conduct EFA through KMO test and Bartlett's test, after that classify it according its level of correlation into components (groups) based on the calculated Eigen value where component with high Eigen value is the most influence due to its involve the most influence lean activities.

Step 6. Identifying the SMEs Experts: The optimum numbers of experts typically used in decision-making for accurate results are between 5-7 [67] so, five experts with experience in SMEs processes and activities were consulted to get their opinions regarding importance of lean activities on SMEs lean performance throught questionnaire by pairwise comparison.

Step 7. Identifying Linguistic Variables and Fuzzy Numbers: Linguistic variables and fuzzy scale for TFN were identified as shown in **Błąd! Nie można odnaleźć źródła odwołania.**.

Table 4
Linguistic variables and fuzzy scale for TFN

Scale	Linguistic Variables	Fuzzy Triangular Scale (4)
1	Absolutely less Important	0.22, 0.25, 0.28
2	Very Strongly Less Important	0.28, 0.33, 0.40
3	Fairly Strongly Less Important	0.40, 0.50, 0.66
4	Weakly Less Important	0.66, 1, 1.5
5	Equal Important	1, 1, 1
6	Weakly More Important	0.66, 1, 1.5
7	Fairly Strongly More Important	1.5, 2, 2.5
8	Very Strongly More Important	2.5, 3, 3.5
9	Absolutely More Important	3.5, 4, 4.5

Source: [68, 69].

Step 8. Identifying the Weights of Importance (Wi) of Lean Activities by FAHP: FAHP was used to identify the weights of importance of lean activities throught the following sequential steps:

1. Constructing the fuzzy pairwise comparison matrix for each Expert to obtain their opinion about importance of lean activities on SMEs lean performance.
Let: $k_1, k_2, \ldots\ldots, k_p$ are the experts no, k = 1,2,….p.
Let $A^{\sim k}\ [a_{ij}^{\sim k}]_{m\times n}$ is the fuzzy pairwise comparison matrix for expert k.
Let's l_{ij}, m_{ij}, u_{ij} are the lower, peak and upper limits of TFN, $a_{ij}^{\sim} = (l_{ij},\ m_{ij}\ , u_{ij})$ be a Triangular Fuzzy Number (TFN), i = 1,2,…,m and j = 1,2,…,n.
2. Aggregating the experts judgments matrices to construct the aggregated matrix using Eq. 4 [70].

$$\boldsymbol{a_{ij}^{\sim}} = \frac{\sum_{k=1}^{p} \boldsymbol{aij^k}}{\boldsymbol{k}} \quad (4)$$

3. eighting lean activities by Buckley's Column Geometric Mean Method by the following steps [70, 71]:
3.1. Calculating the fuzzy geometric mean $z^{\sim}_i$ for each lean activity using Eq. 5 [70].

$$z_i^{\sim} = [\prod_{j=1}^{n} a_{ij}^{\sim}]^{1/n}, \quad (5)$$

where:
$z^{\sim}_i$ refer to geometric mean of the triangular fuzzy number $\prod_{j=1}^{n} a_{ij}^{\sim} = a_{i1}\ \cdot a_{i2} \cdot \ldots\ldots, a_{mn}$
Π is a capital Pi that refers to multiply all value within a sequential range.
$a_{ij}^{\sim}$ refer to triangular fuzzy number that represent importance of lean activity in row ith over lean activity in column j^{th}.
3.2. Computing the fuzzy weights ($w_i^{\sim}$) of each lean activity by Eqs. 6-9:

$$w_i^{\sim} = z_i^{\sim} \cdot (z_1^{\sim} + z_2^{\sim} + \cdots z_m^{\sim})^{-1}, \quad (6)$$

where:
$w_i^{\sim} = (l_i, m_i, u_i)$,
$z^{\sim}_i$ is the geometric mean of the triangular fuzzy number
3.3. Utilizing Center of Area (COA) defuzzification method to transform the fuzzy weight into crisp weights by Eq. 7 [72, 73].

$$\text{Weights of Importance } W_i = \frac{li \oplus mi \oplus ui}{3}. \quad (7)$$

3.4. Normalizing weights by Eq. 8 to obtain weights of importance of lean activities (W_i) [72]:

$$\boldsymbol{W_i} = \frac{\boldsymbol{W_i}}{\sum_{m}^{i-1} \boldsymbol{W_i}}. \quad (8)$$

4. Identifying the Level of Importance (LI_i) of SMEs Lean Activities by Eq. 9.

$$\boldsymbol{ll_i = w_i \cdot 100} \quad (9)$$

Assessing the Level of Lean Activities (LL) by FTOPSIS
Level of SMEs adoption of the lean activities can be computed through the sequential steps:
1. Identifying the linguistic variables and fuzzy scale of TFN for Rating the Performance of lean activities as shown in Table 5.

Table 5

Linguistic Variables of TFN for Performance Rating

Linguistic Variables	Symbol	Lower Limit	Medium Limit	Upper Limit
Very Low	VL	0.00	0.00	0.10
Low	L	0.00	0.10	0.25
Medium Low	ML	0.15	0.30	0.45
Medium	M	0.35	0.50	0.65
Medium High	MH	0.55	0.75	0.85
High	H	0.80	0.90	1.00
Very High	VH	0.90	1.00	1.00

Source: [48].

2. Five experts have asked in each company to rate the performance of lean activities to get their judgments about lean performance of each lean activity using linguistic variables Table 5.

F-TOPSIS calculations for identifying the lean performance level for lean activities can be summarized in the following sequential steps [74, 75].

Step 1. Developing the Assessment Performance Matrix: The assessment performance matrix has been constructed as shown in Table 6 2 that involve weights of importance of lean activities W_j that computed previously by FAHP and rate of performance of lean activities of enterprise by Linguistic Variables of Performance Rating in Table 5 as shown in Table 6.

where:

k = Expert No., k = 1, 2, ... p.

W_j = weights of importance of lean activities obtain by FAHP, j = 1,2,...,m

$\tilde{x}_{Ci\,Aa}$ is the fuzzy performance rating of lean activities of lean dimension dn for each SMES using Table 5 using Triangular Fuzzy Number(TFN).

A_a is the SMEs no. j = 1, 2....,m

dn is the lean dimensions where n = 1,2,3,4,5.

C_i is lean dimension activities, i = 1,2,.....n

Table 6

Lean Performance Rating Matrix

Weights of Lean Activities w_j	Lean activities of dn lean dimension \ SMEs	A1	A2	... ...	A_j
	C1	$\tilde{x}_{C\,1\,A1}$	$\tilde{x}_{C\,1A2}$	....	$\tilde{x}_{C1j}$
	C2	$\tilde{x}_{C\,2A3}$	$\tilde{x}_{C\,2A2}$	.... .	$\tilde{x}_{C2j}$
	....	...	...	....	...
	C_i	$\tilde{x}_{iA1}$	$\tilde{x}_{i\,A2}$	....	$\tilde{x}_{n\,m}$

Aggregating experts judgments form the aggregated judgment matrix using Eq. 10:

$$\tilde{x}_{ij} = \frac{\sum_{k=1}^{p} \tilde{x}_{ij}^{\,k}}{k}, \tag{10}$$

$\tilde{x}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ be a, l_{ij}, m_{ij}, u_{ij} are the lower, peak and upper limits of is the lower limit of TFN.

Step 2. Normalizing the Performance Matrix: Linear scale transformation has been used to normalize the aggregated performance matrix to obtain the normalized fuzzy decision matrix $\tilde{R}$. The normalized decision matrix is computed by Eq. 11 and Eq. 12.

$$\tilde{R} = [\tilde{r}_{ij}]_{m\times n}, \tag{11}$$

$\tilde{r}_{ij}$ for beneficial subjective lean dimensions.

$$\tilde{r}_{ij} = \frac{\tilde{x}_{ij}}{u_j^*} = \left(\frac{l_{ij}}{u_j^*}, \frac{m_{ij}}{u_j^*}, \frac{u}{u_j^*}\right), \tag{12}$$

$\tilde{r}_{ij}$ for cost lean activities

$$\tilde{r}_{ij} = \left(\frac{\tilde{l_j}}{u_{ij}}, \frac{\tilde{l_j}}{m_{ij}}, \frac{\tilde{l_j}}{l_{ij}}\right), \tag{13}$$

u_j^* should identify for beneficial subjective lean activities, where $u_j^* = \max_i u_{ij}$.

Step 3. **Computing the Weighted Normalized Decision Matrix ($\tilde{V}$):** Linear scale transformation has been used to maintain the property to which the ranges of normalised triangular fuzzy numbers belong [0, 1]. The weighted normalized decision matrix $\tilde{V}$ has been formed as follow using Eq. 14 and Eq. 15 as follow:

$$\tilde{V} = [\tilde{V}_{ij}]_{m\times n}, \tag{14}$$

$$\tilde{V}_{ij} = \tilde{r}_{ij} \times W_j, \tag{15}$$

where:

$\tilde{r}_{ij}$ = normalize fuzzy value obtained by step 2.

W_j = weight of importance of lean activities obtained by FAHP.

Step 4. Identifying (FPIS, A^*) and (FNIS, A^-)

Identifying the fuzzy positive ideal solution (FPIS) that denoted by aspiration H* by Eq. 16 and the fuzzy negative ideal solution (FNIS) that denoted by the worst levels H^- by Eq. 17.

$$H^* = (\tilde{V}_1^*, \tilde{V}_2^*, \tilde{V}_3^*, \dots \dots \tilde{V}_n^*), \tag{16}$$

$$\boldsymbol{H^-} = (\tilde{\boldsymbol{V}}_{\boldsymbol{1}}^-, \tilde{\boldsymbol{V}}_{\boldsymbol{2}}^-, \tilde{\boldsymbol{V}}_{\boldsymbol{3}}^-, \dots \dots \tilde{\boldsymbol{V}}_{\boldsymbol{n}}^-), \tag{17}$$

$\tilde{V}_J^* = (u_j, u_j, u_j)$ and u_j = max. $\tilde{u}_{ij}$

$\tilde{V}_i^- = (l_j^-, l_j^-, l_j^-$ and $l_j^- = min.\, l_j^-$

Step 5. Calculating Distance to (H^*) (H^-)

The distance of each sub-criteria i from the ideal implementation (H^*) and from the negative ideal implementation (H^-) can be computed by Eq. 18 and Eq. 19

$$\boldsymbol{d_i^*} = \sum_{j=1}^{n} (\tilde{\boldsymbol{v}}_{\boldsymbol{ij}}, \boldsymbol{v_j^*})\ \forall_{\boldsymbol{i}} = \boldsymbol{1, 2, 3, \dots \dots, m}, \tag{18}$$

$$d_i^- = \sum_{j=1}^{n} (\tilde{v}_{ij}, v_j^-)\ \forall_i = 1,2,3, \dots \dots, m \tag{19}$$

Step 6. Calculating the level of SMEs leanness (LL_i): LL_i has been computed by Eq. 20 where, Level of SMEs leanness is belonging to the closed interval [0, 1].

$$LL_i = {d_i^-}\Big/{\left(d_i^- + d_i^*\right)}, \tag{20}$$

where:

$0 \le LL{\cdot}i \le 1$

Step 7. Ranking level of lean activities: Ranking SMEs according to its LL_i from highest level to lowest one for each lean dimension activities.

RESULTS AND DISCUSSION

The proposed methodology has been applied in four Iraqi SMEs for producing healthy water, juice and soft drinking. Information about the 60 SMEs located in Baghdad city has obtained from Iraqi industries union and industrial development office. The developed questionnaire has sent to SMEs in Baghdad by two ways; by hand and got the answers through interview the mangers of these enterprises; by e-mail using questionnaire in form of Microsoft word that fill by SMEs manger and return it later in same way. Unfortunately 25 of SMEs refused to cooperating and 5 SMEs not return the answers of questionnaire after wait 3 months with continuously remind them to answer questionnaire finally, 30 questionnaires have returned with answers that represent 50% of the SMEs population and this percentage of the answers is acceptable for studying in case of homogenous sample.

Number of employees (E) has been used as a measure to recognize the size of enterprise. Twenty six lean activities related SMEs that included into five lean dimensions have been considered based on literature review Table 3. The Statistical calculations that involve Cronbach's test, Factor Analysis have been conducted using the statistical software SPSS V23.

The collected information from the 30 SMEs by questionnaire was analyzed statistically by Cronbach's alpha test for analysis the reliability and consistency of SMEs questionnaire for each lean activity and dimension as shown in Table 7 where, Cronbach's alpha values for all are above 70 which is acceptable range and indicates that questionnaire answers are highly correlated and consistent and it is valid for later research work.

After checking Cronbach's alpha value, Exploratory Factor Analysis using principle component method was employed to identify the influencing lean activities on SMEs leanness for each dimension. Exploratory Factor Analysis involved testing the questionnaire data related to each lean dimension by Kaiser-Meyer-Olkin (KMO) test and Bartlett's test to ensure this data is suitable for Exploratory Factor Analysis. KMO test was used to assess the adequacy of the sample size as shown in Table 8. KMO values for all lean dimensions exceeded 0.50, indicating that the size of sample was adequate and suitable for exploratory factor analysis. Additionally, Bartlett's Sphericity Test yielded values below 0.005, which are statistically significant for each variable and are considered acceptable by providing realistic bases for factor analysis where, both tests decides whether the sample is sufficient to perform the exploratory factor analysis.

Table 7

Cronbech Alpha Values

Lean Dimensions	Cronbech Alpha	Lean Activities	Cronbech Alpha
Processes	0.84	Pull approach (Kanban) **P1**	0.75
		Lot size reduction **P2**	0.92
		Set up reduction(SMED) **P3**	0.91
		Workplace Organization(5S) **P4**	0.72
		Preventive Maintenance(PM) **P5**	0.73
		visual management system (flow charts, safety instruction **P6**	0.76
		Poka Yoke **P7**	0.78
		Adoption of Value Stream Mapping **P8**	0.70
		Standardization and Simplification work **P9**	0.73
		Kazien Team **P10**	0.71
		Quality Circle **P11**	0.73
Management	0.76	Efficient Manager **T1**	0.76
		Motivating, and Supporting Employees **T2**	0.77
		Employee Involvement and empowerment **T3**	0.71
		Smooth information flow and transparency in information sharing **T4**	0.73
Suppliers	0.78	Supplier relationship **S1**	0.72
		Suppliers development **S2**	0.74
		Evaluation Suppliers' performance **S3**	0.74
		JIT deliveries by supplier **S4**	0.75
Customers	0.79	Execution Customer Suggestions and Requirements **C1**	0.72
		Handling and Solving Customer Complaints **C2**	0.72
		Customer Satisfaction **C3**	0.78
Employees	0.72	Team work **E1**	0.76
		Flexible/Multiskill Workforce **E2**	0.79
		Employee Training **E3**	0.74
		Job Rotation Between Employees **E4**	0.91

KMO values for all five lean dimensions as shown in Table 8, exceeded 0.50, indicating that the sample size is adequate. Additionally, Bartlett's values were identified to be less than the significant value of 0.005. The influencing and important lean activities were identified by exploratory factor analysis and lean activities with importance degree higher than the standard limit equal 0.50 thus it is considered influence on SMEs leanness.

Table 8
Exploratory Factor Analysis Results

Lean Dimensions	Lean Activities	KMO Values	Bartlett's Values	Degree of Influence and importance	Ranking	Remained Criteria
Process	P1	0.551	0.002	0.595	4	
	P2			0.576	7	
	P3			0.323	10	Eliminate
	P4			0.592	5	7
	P5			0.635	1	
	P6			0.587	6	
	P7			0.635	2	
	P8			0.331	9	Eliminate
	P9			0.176	11	Eliminate
	P10			0.602	3	
	P11			0.340	8	Eliminate
Management	T1	0.512	0.005	0.551	3	3
	T2			0.583	2	
	T3			0.601	1	
	T4			0.328	4	Eliminate
Supplier	S1	0.512	0.004	0.744	1	
	S2			0.189	4	Eliminate
	S3			0.682	2	3
	S4			0.669	3	
Customer	C1	0.727	0.008	0.552	3	3
	C2			0.548	2	
	C3			0.588	1	
Employee	E1	0.668	0.006	0.335	4	Eliminate
	E2			0.545	3	3
	E3			0.589	1	
	E4			0.576	2	

Conversely, lean activity with less than 0.5 importance has eliminated due to it is has less influence on SMEs leanness as shown in Table 8. As a result, the final influencing lean activities are reduced to nineteen only. Smooth information flow and transparency in information sharing has excluded from due to its weak influence on management leanness. Set up reduction (SMED), Adoption of value stream mapping, Standardization and Simplification work and Quality Circle have been excluded due to its weak influence on process leanness. Supplier's development has excluded due to its weak influence on supplier leanness whereas all lean activities of customer have considered due to its influence on customer leanness. Finally, team work has excluded due to its weak influence on employee leanness.

FAHP was used to determine the weights and level of Importance of lean activities of each lean dimension using Equations 6-9. Kazien team (P7) has the highest weight 0.213 and importance level 21.29%. Therefore, it is considered the most crucial lean activity that has highest influence on improve SMEs performance and make it more leanness. In contrast, lot size reduction rank as the least importance lean activity as shown in Table 9.

Table 9
Weights and Level of Importance of Lean Activities of Process Dimension

Lean Activities	Weights of Importance	Level of Importance	Ranking
P1	0.117	11.71%	6
P2	0.084	8.43%	7
P3	0.174	17.37%	2
P4	0.171	17.12%	3
P5	0.122	12.24%	4
P6	0.118	11.84%	5
P7	0.213	21.29%	1
∑ W	1.00	100.00%	

Efficient manger (T1) is the highest importance lean activities that has weight of importance 0.589 and level of importance 58.90% as illustrate in Table 10.

Table 10
Weights and Level of Importance of Lean Activities of Management Dimension

Lean Activities	Weights of Importance	Level of Importance	Ranking
T1	0.589	58.90%	1
T2	0.243	24.27%	2
T3	0.168	16.82%	3
∑ W	1.00	100%	

This highlights that SMEs managers plays a pivotal role in driving SMEs to be successful and leanness. Supplier relationship activity has highest weight 0.498 and importance level 49.78% as shown in Table 11 thus long and good relation with few suppliers has high influence and importance on SMEs lean performance that ensure supply the needed purchasing items in time with the required quality.

Table 11
Weights and Level of Importance of Lean Activities of Supplier Dimension

Lean Activities	Weights of Importance	Level of Importance	Ranking
S1	0.498	49.78%	1
S2	0.190	19.00%	3
S3	0.312	31.21%	2
∑ W	1.00	100%	

Customer's satisfaction and execution their requirement and suggestion emerge as crucial lean activities with weights 0.385 and level of importance 38.54% as shown in Table 12 due to the customer is the king and successful SMEs depend on meet the customer requirements so these activities have high influence on leanness of SMEs. Job rotation activity is identified as the most significant lean activity with weight 0.4118 and importance level 41.18% as illustrate in Table 13 thus effort should take to training employee on various tasks to replace the absent employees to ovoid working stoppages.

Table 12
Weights and Level of Importance of Lean Activities of Customer Dimension

Lean Activities	Weights of Importance	Level of Importance	Ranking
C1	0.385	38.55%	1
C2	0.229	22.92%	3
C3	0.385	38.54%	2
∑ W	1.00	100.00%	

Table 13
Weights and Level of Importance of Lean Activities of Employee Dimension

Lean Activities	Weights of Importance	Level of Importance	Ranking
E1	0.411	41.10%	2
E2	0.177	17.72%	3
E3	0.412	41.18%	1
∑ W	1.00	100%	

The level of leanness for the four SMEs (A1, A2, A3, and A4) has been calculated by FTOPSIS, using Eqs 10-20 to identify their leanness level in implementation of lean activities across the five lean dimensions. Distance to the positive ideal solution (PIS) and from the negative ideal solution (NIS) were computed for lean activities within each lean dimension for the four SMES as illustrate in Tables 14, 16, 18, 20 and 22. The level of Leanness of the four SMEs related each lean dimension has calculated. Enterprise A3 achieved the highest level of leanness for the process dimension and ranks as the highest one as shown in Table 15 and also it has the highest leanness for the rest dimension and ranking as the highest leanness as shown in Table 17 for management dimension, Table 19 for supplier dimension, Table 21 for customer dimension and Table 23 for Employee dimension.

Table 14
Identifying FPIS and FNIS for SMEs related Lean Activities of Process Dimension

SMEs	A1		A2		A3		A4	
Lean Activities	FPIS	FNIS	FPIS	FNIS	FPIS	FNIS	FPIS	FNIS
P1	0.10	0.12	0.10	0.12	0.10	0.12	0.10	0.12
P2	0.09	0.04	0.10	0.04	0.03	0.11	0.04	0.10
P3	0.03	0.13	0.08	0.11	0.03	0.13	0.04	0.13
P4	0.08	0.12	0.07	0.12	0.10	0.10	0.08	0.12
P5	0.09	0.07	0.03	0.10	0.06	0.10	0.07	0.09
P6	0.04	0.13	0.10	0.11	0.02	0.15	0.03	0.14
P7	0.21	0.12	0.05	0.21	0.17	0.16	0.19	0.14

Table 15
Level of SMEs leanness for Lean activities of Process Dimension

SMEs Ranking	d+	d-	LL	Ranking
A1	0.64	0.74	0.53	4
A2	0.54	0.82	0.60	2
A3	0.52	0.87	0.63	1
A4	0.55	0.83	0.60	3

Table 16
Identifying FPIS and FNIS for SMEs related Lean Activities of Management Dimension

SMEs	A1		A2		A3		A4	
Lean Activities	FPIS	FNIS	FPIS	FNIS	FPIS	FNIS	FPIS	FNIS
T1	0.15	0.37	0.23	0.30	0.15	0.37	0.11	0.40
T2	0.15	0.24	0.12	0.27	0.15	0.24	0.20	0.18
T3	0.13	0.11	0.13	0.11	0.10	0.15	0.10	0.15

Table 17
Level of SMEs leanness for Lean activities of Management Dimension

SMEs	d+	d-	LL	Ranking
A1	0.43	0.71	0.63	3
A2	0.48	0.67	0.58	4
A3	0.40	0.76	0.66	1
A4	0.42	0.73	0.64	2

Table 18
Identifying FPIS and FNIS for SMEs related Lean Activities of Supplier Dimension

SMEs	A1		A2		A3		A4	
Lean Activities	FPIS	FNIS	FPIS	FNIS	FPIS	FNIS	FPIS	FNIS
S1	0.01	0.04	0.03	0.02	0.02	0.04	0.02	0.04
S2	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
S3	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.02

Table 19
Level of SMEs leanness for Lean activities of Supplier Dimension

SMEs Ranking	d+	d-	LL	Ranking
A1	0.04	0.07	0.62	2
A2	0.05	0.06	0.52	4
A3	0.04	0.07	0.64	1
A4	0.04	0.07	0.61	3

Table 20
Identifying FPIS and FNIS for SMEs related Lean Activities of Customer Dimension

SMEs	A1		A2		A3		A4	
Lean Activities	FPIs	FNIS	FPIs	FNIS	FPIs	FNIS	FPIs	FNIS
C1	0.02	0.04	0.03	0.03	0.02	0.04	0.03	0.03
C2	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.02
C3	0.02	0.03	0.01	0.03	0.01	0.03	0.01	0.03

Table 21
Level of SMEs leanness for Lean activities of Customer Dimension

SMEs Ranking	d+	d-	LL	Ranking
A1	0.05	0.09	0.62	3
A2	0.05	0.08	0.59	4
A3	0.05	0.09	0.67	1
A4	0.04	0.09	0.66	2

Table 22
Identifying FPIS and FNIS for SMEs related Lean Activities of Employee Dimension

SMEs	A1		A2		A3		A4	
Lean Activities	FPIS	FNIS	FPIS	FNIS	FPIS	FNIS	FPIS	FNIS
E1	0.03	0.05	0.04	0.04	0.02	0.07	0.01	0.07
E2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
E3	0.02	0.04	0.02	0.04	0.01	0.04	0.01	0.04

Table 23
Level of SMEs leanness for Lean activities of Employee Dimension

SMEs Ranking	d+	d-	LL	Ranking
A1	0.09	0.12	0.57	3
A2	0.09	0.11	0.55	4
A3	0.06	0.14	0.70	1
A4	0.06	0.14	0.70	2

Enterprise A2 has the least level of leanness in four dimensions except for the process dimension as illustrates in Table 24, where it holds the second ranking followed A3. A1 and A4 both have varied leanness level related the four lean dimensions as shown in Table 24. Management of enterprises A1, A2 and A4 must focus their efforts and resources to improve lean activities of the weak lean dimensions to improve their lean performance.

Table 24
Level of SMEs Leanness Ranking

Lean Dimension	A1	A2	A3	A4	Highest Level	Lowest Level
Process	4	2	1	3	A3	A1
Management	3	4	1	2	A3	A2
Supplier	2	4	1	3	A3	A2
Customer	3	4	1	2	A3	A2
Employee	3	4	1	2	A3	A2

Figure 2 illustrate visually the variation in lean performance of the four SMES for each Lean dimension. Although the leanness level of the four SMEs related the five dimensions have been varied, the level of leanness is in mid-level in most dimensions.

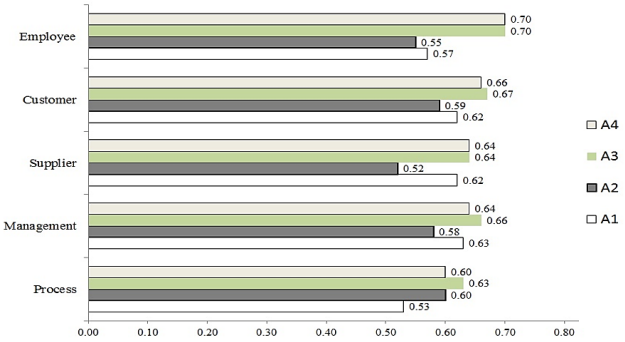


Fig. 2 SMEs Leanness Level for each Lean Dimension Activities

Identifying level of lean dimension activities is important issue that can significantly help SMES management and decision-makers in analyzing the effectiveness of their manufacturing strategies and identify potential opportunities for improvement due to its helps pinpoint the most crucial and important lean dimension activities that have a high impact on reducing or eliminating associated waste. Furthermore, it helps them to focus more on the weaker lean dimension activities for continuous improvement. Continuous assessment of lean activities helps organizations identify the potential opportunities for improvement.

CONCLUSIONS

Today, SMEs play an essential role in the development the economy of any country where, it is represented 90% of total companies in most world economies and contribute to about 46% of the global Gross domestic product GDP by creation 50-60% of the total employment opportunities. SMEs like large companies have pursued to adopted lean Production philosophy for continuously improve its performance through eliminate waste to ensure stay competitive in the changing global markets. Although various lean activities are available for continuous improving the enterprises performance, SMEs is incapable to implement all of these lean activities for many reasons related to its structure and financial resources. SMEs lean activities have been surveyed through literature review from 2015-2021 where twenty six SMEs lean activities have identified. Lean questionnaire using triple Likert scale has developed using 88 questions related the twenty six lean activities to investigate implementation of these lean activities in SMEs. Thirty Iraqi SMEs involved in the production of healthy water, juice, and soft drinks were evaluated to assess their leanness concerning the five lean dimensions' activities. Collecting data from these Iraqi SMEs and convincing them to participate in questionnaire surveys to evaluate their activities and performance presented significant challenges. These difficulties primarily stemmed from the large number of SMEs stoppage working due to absent the government supports and SMEs concerns about sharing data related to their business operations, driven by their competitive concerns in the market. This can be considered a noteworthy limitation of this paper. Exploratory factor analysis has used as an important statistical approach using SPSS software V23 for identifying the influencing lean activities. Nineteen influence lean activities on Iraqi SMEs leanness are recognized. Cronbech Alpha test has been conducted to analysis the reliability and consistency of SMEs questionnaire answers and the results show all values of Cronbech Alpha are above the acceptable values 70. KMO test has used to measure sample size adequacy and the results values are > 0.50 which refer the size of sample is adequate and suitable for exploratory factor analysis. FAHP has used to identify weight and level of importance of lean activities, where the most important lean activity is efficient manager with level of importance equal 58.90%. FTOPSIS has used to assess the level of leanness of the four SMEs (A1, A2, A3, A4) in implementation and adoption lean activities related five lean dimensions namely process, management, supplier, customer and employee where levels of leanness the four SMEs are approximately in adoption lean dimensions activities in midlevel but A3 has highest level of leanness related the five lean dimension so it is considered the most leanness one. Continuously assessment the level of leanness of SMEs in adoption lean activities related five lean dimensions will help SMEs management to identify the weak lean dimension activities and focuses their efforts and resources for improve it due to

its high influence on SMEs lean performance by elimination various waste. For future work, this methodology can be applied in service or education fields using FANP or other weighting methods or using fuzzy VIKOR as assessment method with considering limitations of this paper related considering few number of structures as a case study.

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