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Development of Fuzzy Analytical Hierarchy Process (FAHP)-Based Lean Manufacturing Maturity Criteria for The Tanzanian Context

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Abstract

The paper aims to develop Lean Manufacturing (LM) maturity criteria for assessing the level of LM implementation in Tanzania. The criteria will assist to determine LM maturity for manufacturing organizations in the country, which at the moment is not known. The study used survey and purposive sampling techniques to collect responses from 243 responses. Structured questionnaires and interviews were used in collecting responses from various respondents. Descriptive statistics through SPSS and the Fuzzy Analytical Hierarchy Process (FAHP) were used to analyze the data. The study has revealed the elimination of waste, continuous improvement, just-in-time, multifunctional teams, information systems, and zero defects as lean performance criteria for manufacturing industries in Tanzania. FAHP weights indicated that the criteria have different weights based on the level of manufacturing organizations. For micro industries, the FAHP weights of the criteria are the elimination of waste (0.2), continuous improvement (0.11), zero defects (0.26), just in time (0.31), multi-functional teams (0.04), and information systems (0.07). The FAHP weights can be used by the manufacturing organizations in setting strategies for improving the maturity level for each size of the manufacturing organizations. Improvement in maturity level will lead to improvement in organizational performance of manufacturing organizations. Better performance of manufacturing organizations will have positive contributions to the country's Gross Domestic Product (GDP).

Keywords: Lean Manufacturing, Maturity, Criteria, Fuzzy Analytical Hierarchy Process (FAHP).

INTRODUCTION

The application of the Lean Manufacturing (LM) philosophy has demonstrated positive results for organizations that have adopted the philosophy (Maware and Parsley 2022). Reduction of production cost, productivity improvement, lead time reduction, and improved delivery (Sajan and Shalij 2020; Sinkamba et al. 2024) are some of the noticeable benefits of adopting LM. Based on the benefits achieved by organizations, the adoption of the philosophy has been increasing in both developed and developing countries (Sinkamba et al. 2023). Despite the growing importance of the philosophy, the success of LM implementation is low. The literature argues that 30% of LM projects succeed while the rest fail (Mamoojee-Khatib et al. 2023). The low success rate for LM projects might be caused by a lack of suitable evaluation tools.

Moreover, the level of LM maturity for organizations that implement LM for most of the developing countries is not known. With a lack of maturity status, industries fail to make progressive improvements in LM implementation since they do not know if they need to make improvements in the LM implementation or not (Vivares et al. 2018; Sinkamba et al. 2023).

Furthermore, with the increasing trends of implementation, several studies have looked at the maturity level for LM. Maasouman and Demirli (2016) proposed a framework for assessing lean maturity. Moreover, Lupi et al. (2021) developed a lean assessment framework for an engineer to order scenario. Also, Rajagopalan and Solaimani (2020) assessed lean maturity for manufacturing industry in India by using LESAT model. Of all the studies evaluating lean maturity, only a few address the situation in developing countries. According to Hu et al. (2015), the statistics for LM research stands at 1% in Africa, which demonstrates that there is a dearth of research in this area. Moreover, several studies have reported the adoption of LM by large industries in comparison to small, medium, and micro industries (Sahoo 2020). This shows that there is a gap in LM implementation by Small and Medium Enterprises (SMEs) and Maturity Models for LM in developing countries such as Tanzania.

As a result, there is a need to develop lean maturity models that will measure the LM implementation status and provide recommendations for improvement for the areas where implementation is not satisfactory. Based on the aforementioned information, this study intended to develop criteria for the LM maturity level at all levels of manufacturing industries, that is micro, small, medium, and large. The relative weights of the criteria for maturity will be obtained with the use of the Fuzzy Analytical Hierarchy Process (FAHP).

The study will assist in finding the standardized LM criteria weights for the context of the manufacturing industries in Tanzania. The FAHP weights obtained will be used by the manufacturing organizations in setting strategies for improving their maturity level by prioritizing the improvement efforts to the criteria with high weight. A high lean maturity level will enable an improvement in the operational performance of the manufacturing industries in the country, which later might increase the contribution of the sector to the country's GDP, which at the moment stands at 8.4% (Mwinuka and Mwangoka 2023). Furthermore, the study will be vitally imperative for improving the competitive advantage of manufacturing organizations in comparison to their counterparts in Tanzania.

METHODS AND MATERIALS

Data collection approaches

A survey and purposive sampling design were used in this study. Surveys were used because most of the studies on LM implementation use surveys as a design method for data collection. According to Alkhoraif et al. (2019), 30% of the studies on LM use the survey research design. Data were collected from manufacturing organisations located in three regions of Tanzania: Dar es Salaam, Arusha, and Mbeya, with the help of a structured questionnaire and a structured interview. The regions were selected since they have many manufacturing organisations and, likewise, are a good representation of all levels of manufacturing industries (URT, 2016).

The questionnaire consisted of two main sections; the first section comprised a background information of respondents and the second contained LM performance measures, which are elimination of waste, continuous improvement, information systems, just in time, zero defects, and multi-functional teams. LM performance measures were obtained through an extensive literature review from various articles (Åhlström and Karlsson 1996; Belhadi et al. 2018). A 5-point Likert scale was used to evaluate the extent of acceptance for the LM performance measures. The scale was interpreted as follows: 1 – Strongly disagree, 2 – Disagree, 3 – Neutral, 4 – Agree, and 5 – Strongly agree. Before being distributed to the respondents, the validity and reliability of the questionnaires were tested. Content validity was used to determine the validity of the questionnaires from selected practitioners and academics. Cronbach's alpha of above 0.7 signified that the constructs of the questionnaires are reliable. Structured interviews were used in collecting pairwise comparisons of dimensions (criteria) from three experts for each level of manufacturing industries.

Sample

The sample size of 388 was obtained with the help of the Yamane formula. Purposive Sampling techniques were adopted in this study as it is used commonly in many LM studies (Uday et al. 2023). The study targeted respondents with an education level of diploma and above since the ones with low a level of education are not well versed in technical terms related to LM. One sample respondent for each industry was used in this study. 388 questionnaires were sent to the manufacturers through email and WhatsApp. 256 responses were received from the respondents; upon data cleaning, a total of 243 responses, which is equivalent to 66% of all respondents, were found to be useful for analysis. A response rate of 66% is appropriate because other studies related to LM obtained a response rate of 41.38% and it was regarded as a fair response rate (Kale et al. 2022).

Data analysis

The criteria for LM performance were obtained with the help of descriptive statistics from SPSS. Those with a mean score of above 3 were considered as the criteria of LM performance for manufacturing organisations in Tanzania. With the help of FAHP, a Multi Criteria Decision Making (MCDM) tool was used to find the weight of each criterion. Three experts from each level of manufacturing organisations were selected to provide a pairwise comparison of each criterion. Saaty's 9 – point scale as shown in Table 1 was used for pairwise comparison. In Table 1, each fuzzy number is defined by three parameters of the asymmetrical Triangular Fuzzy Number (TFN).

Table 1: Saaty's Nine-Point Scale for Pairwise Comparison

Linguistic Scale	Fuzzy Numbers	Domain	Triangular Fuzzy Number Scale	The converse of Triangular Fuzzy Numbers
Equally significant	$\hat{1}$	$1\leq x \leq 1$	(1,1,1)	$\hat{1}^{-1} = (\frac{1}{1},\frac{1}{1},\frac{1}{1})$
Weakly significant	$\hat{3}$	$2\leq x \leq 4$	(2,3,4)	$\hat{3}^{-1} = (\frac{1}{4},\frac{1}{3},\frac{1}{2})$
Fairly significant	$\hat{5}$	$4\leq x \leq 6$	(4,5,6)	$\hat{5}^{-1} = (\frac{1}{6},\frac{1}{5},\frac{1}{4})$
Strongly significant	$\hat{7}$	$6\leq x \leq 8$	(6,7,8)	$\hat{7}^{-1} = (\frac{1}{8},\frac{1}{7},\frac{1}{6})$
Absolutely significant	$\hat{9}$	$9\leq x \leq 9$	(9,9,9)	$\hat{9}^{-1} = (\frac{1}{9},\frac{1}{9},\frac{1}{9})$
The intermittent values between two adjacent scales	$\hat{2}$	$1\leq x \leq 3$	(1,2,3)	$\hat{2}^{-1} = (\frac{1}{3},\frac{1}{2},\frac{1}{1})$
	$\hat{4}$	$3 \leq x \leq 5$	(3,4,5)	$\hat{4}^{-1} = (\frac{1}{5},\frac{1}{4},\frac{1}{3})$
	$\hat{6}$	$5\leq x \leq 7$	(5,6,7)	$\hat{6}^{-1} = (\frac{1}{7},\frac{1}{6},\frac{1}{5})$
	$\hat{8}$	$7\leq x \leq 9$	(7,8,9)	$\hat{8}^{-1} = (\frac{1}{9},\frac{1}{8},\frac{1}{7})$

Source: Arora et al. (2022)

The process used in finding the fuzzy AHP weight for the LM performance criteria is shown in the following steps:

Step 1: Selection of the criteria to be included in FAHP

The criteria used were obtained based on mean obtained from the SPSS software. Criteria of LM performance such as elimination of waste, continuous improvement, zero defects, multifunctional teams, information systems, and just in time were found to have a mean of above 3, which indicates they are acceptable by the respondents.

Step 2: Structuring and preparation of a fuzzy pairwise comparison matrix

After obtaining the criteria of each level of manufacturing industries, three experts for each level were selected based on their experiences to establish pairwise comparisons for all criteria. With the help of the structured interview, the pairwise comparison was obtained. Saaty's 9 - point scales of relative importance were used in collecting the preference between each criterion for the pairwise comparison as shown in Table 1. The normal pairwise comparison was formulated based on Saaty's 9 point of scale as shown in Equation (1), and thereafter it was converted to a fuzzy pairwise comparison matrix by using the triangular fuzzy scale as indicated in Equation (2).

A normal pairwise comparison matrix

$$\begin{bmatrix} 1 & a12 & \dots & a1n \\ : & 1 & : & : \\ a31 & a32 & 1 & a3n \\ a41 & a42 & \dots & 1 \end{bmatrix} \qquad (1)$$

A fuzzy pairwise comparison matrix

$$\begin{bmatrix} 1 & \hat{a}_{12} & \dots & \hat{a}_{1n} \\ : & 1 & : & : \\ \frac{1}{\hat{a}_{12}} & \frac{1}{\hat{a}_{23}} & 1 & \hat{a}_{3n} \\ \frac{1}{\hat{a}_{1n}} & \frac{1}{\hat{a}_{24}} & \dots & 1 \end{bmatrix} \qquad (2)$$

Step 3: Combining the preferences of the decision makers

The preferences of the three decision makers for each level of manufacturing industries were combined to get the aggregate preference of decision makers by using Equation (3).

$$a_{ij} = Min_k a_{ij}^k,\ b_{ij} = \frac{1}{k}\sum_{k=1}^{k} b_{ij}^k,\ C_{ij} = Max_K C_{ij}^k \qquad (3)$$

Step 4: Take the geometric mean of every criterion

For combined preferences, a geometric mean was calculated as shown in Equation (4)

$$\hat{r}_i = (\hat{a}_{i1} * \hat{a}_{i2} * \hat{a}_{i3} * \dots\dots\dots * \hat{a}_{in})^{\frac{1}{n}} \qquad (4)$$

Where: $l_{ij} = \left(\prod_{m=1}^{M} l_{ij}^m\right)^{\frac{1}{m}}$, $m_{ij} = \left(\prod_{m=1}^{M} m_{ij}^m\right)^{\frac{1}{m}}$, $u_{ij} = \left(\prod_{m=1}^{M} u_{ij}^m\right)^{\frac{1}{m}}$

Step 5: Calculation of fuzzy weight

Equation (5) was used in calculating a fuzzy weight for each criterion.

$$\widehat{w}_i = \hat{r}_i * (\hat{r}_1 + \hat{r}_2 + \hat{r}_3 + \dots + \hat{r}_n)^{-1} \qquad (5)$$

Where: $\hat{r}_k = (l_k, m_k, u_k)$ and $(\hat{r}_k)^{-1} = (\frac{1}{u_k}, \frac{1}{m_k}, \frac{1}{l_k})$

Step 6: Defuzzification of the fuzzy weight for each criterion

Equation (6) was used for the defuzzification of the fuzzy weight.

Df_{ij} =fuzzified weight (w_i)

$$w_i = \frac{l+m+u}{3} \qquad (6)$$

Step 7: Normalising the defuzzified fuzzy weight for each criterion

Equation (7) was used in normalising the defuzzified fuzzy weight.

$$NW_i = \frac{Df_{ij}}{\sum(Df)_{ij}} \qquad (7)$$

RESULTS AND DISCUSSION

Demographic information of respondents

Education levels of the respondents were as follows: those with a diploma were 35.4%, with a degree were 58.8%, and those with the postgraduate education were 5.8% as shown in Figure 1. This demonstrates that most of the respondents had attained a high level of education and were in a position to understand the concepts and terms of LM.

The working experiences of respondents were as follows: 0 – 5 years of experience were 19.8%, 5 – 10 years were 34.2%, 10 – 15 years were 16.5%, and above 15 years were 29.6% as indicated in Figure 2. This demonstrates that most respondents had a working experience of above 5 years. The long experience of workers reveals that the responses represent the reality that obtained from the long serving in the organisations.

The departments which led with a high number of respondents were Production (74.9%), followed by Marketing (9.5%), Quality (6.2%), Finance (5.8%), Maintenance (1.6%), Logistics (1.2%), and Research and Development (0.8%) as shown in Figure 3.

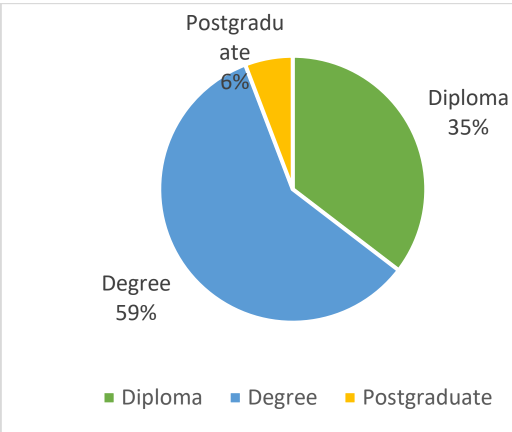

Figure 1: Educational Levels of Respondents

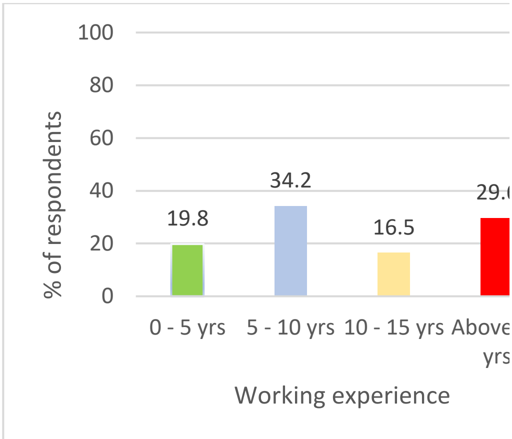

Figure 2: Working Experiences of Respondents

This indicates that LM is more highly implemented in the production department than in the remaining departments of the manufacturing organisations in Tanzania. Moreover, the results show that 78.6% of respondents were from small and medium enterprises (SMEs) while only 21.4% were from large manufacturing organisations as revealed in Figure 4. The large number of respondents from SMEs might be based on the fact that the majority of the manufacturing organisations in various areas of the world are from SMEs. For instance in India, more than 80% of manufacturing organisations are SMEs (Thanki and Thakkar 2020), while in Africa, more than 90% of formal sectors are from SMEs (Mutalemwa 2015).

The demographic information of experts who were used to make pairwise comparisons of dimensions for LM is detailed in Table 2. Most of the selected experts were in managerial positions and had an experience of more than nine years in their working organisations. The vast experience of experts demonstrates that the pairwise comparison which they made are reliable since they have been in practice for many years.

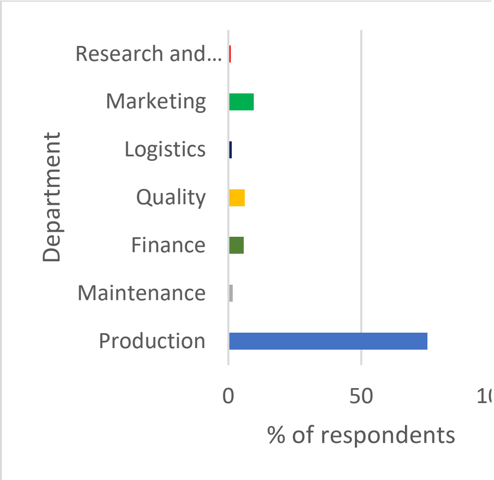

Figure 3: Departments of Respondents

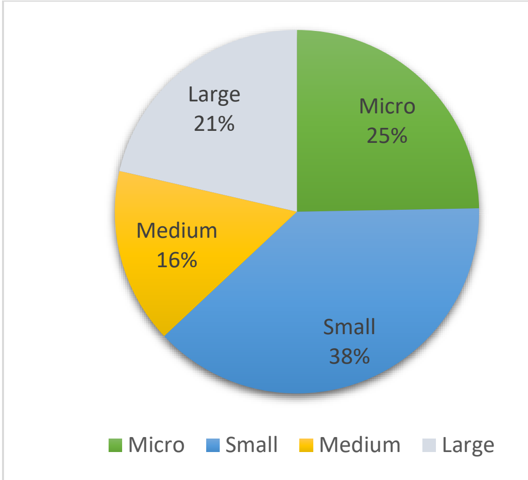

Figure 4: Levels of Manufacturing Industries

Table 2: Details of Experts for the Pairwise Comparison

Level of Industry	Experts No.	Position in the Industry	Years of Experience
Micro	1	Owner	12
	2	Owner	10
	3	Owner	13
Small	1	Production Manager	11
	2	Production Manager	9
	3	Quality Engineer	10
Medium	1	Production Manager	11
	2	Production Engineer	12
	3	Maintenance Engineer	14
Large	1	Production Manager	13
	2	Production Manager	11
	3	Production Manager	15

Criteria for LM performance

Based on the results as shown in Table 3, the criteria for LM performance in Tanzania include elimination of waste, continuous improvement, zero defects, multifunctional teams, just in time, and information systems since they have a mean score of above 3, which is the medium value for the acceptance of LM performance.

Table 3: The Extent of Acceptance for the Criteria of LM Performance

Dimension	Mean	Std. Deviation
Elimination of Waste (W)	3.85	0.830
Continuous Improvement (C)	4.16	0.798
Multifunctional Teams (M)	3.99	0.888
Zero Defects (Z)	4.25	0.792
Just in Time (J)	4.07	0.818
Information Systems (IS)	4.01	0.916

FAHP weights for criteria of Micro industries

After obtaining the criteria for each level of manufacturing organisations, the normal pairwise comparison matrix and the triangular fuzzy pairwise comparison of the six criteria were conducted as shown from Tables 4 to 9.

Table 4: The Normalised Pairwise Comparison Matrix for Expert 1

	W	C	Z	J	M	IS
W	1	5	0.3	0.14	4	6
C	0.2	1	0.25	0.2	6	2
Z	3	4	1	4	6	5
J	7	5	0.25	1	7	3
M	0.25	0.17	0.17	0.14	1	0.17
IS	0.17	0.5	0.2	0.33	6	1

Table 5: The Triangular Fuzzy Pairwise Comparison Matrix for Expert 1

	W	C	Z	J	M	IS
W	(1,1,1)	(4,5,6)	(0.25,0.3,0.5)	(0.13,0.14,0.17)	(3,4,5)	(5,6,7)
C	(0.17,0.2,0.25	(1,1,1)	(6,7,8)	(0.17,0.2,0.25)	(5,6,7)	(1,2,3)
Z	(2,3,4)	(0.13,0.14,0.17)	(1,1,1)	(3,4,5)	(5,6,7)	(4,5,6)
J	(6,7,8)	(4,5,6)	(0.2,0.25,0.3)	(1,1,1)	(6,7,8)	(2,3,4)
M	(0.2,0.25,0.3	(0.14,0.17,0.2)	(0.14,0.17,0.2)	(0.13,0.14,0.17)	(1,1,1)	(0.14,0.17,0.2)
IS	(0.14,0.17,0.2	(0.3,0.5,1)	(0.17,0.2,0.25)	(0.25,0.3,0.5)	(5,6,7)	(1,1,1)

Table 6: The Normalised Pairwise Comparison Matrix for Expert 2

	W	C	Z	J	M	IS
W	1	7	3	0.14	4	6
C	0.14	1	0.25	0.2	6	3
Z	0.3	4	1	4	0.17	5
J	7	5	0.25	1	7	3
M	0.25	0.17	6	0.14	1	0.17
IS	0.17	0.3	0.2	0.3	6	1

Table 7: The Triangular Fuzzy Comparison Matrix for Expert 2

	W	C	Z	J	M	IS
W	(1,1,1)	(6,7,8)	(2,3,4)	(0.13,0.14,0.17)	(3,4,5)	(5,6,7)
C	(0.13,0.14,0.17)	(1,1,1)	(0.2,0.25,0.3)	(0.17,0.2,0.25)	(5,6,7)	(2,3,4)
Z	(0.25,0.3,0.5)	(3,4,5)	(1,1,1)	(3,4,5)	(0.14,0.17,0.2)	(4,5,6)
J	(6,7,8)	(4,5,6)	(0.2,0.25,0.3)	(1,1,1)	(6,7,8)	(2,3,4)
M	(0.2,0.25,0.3)	(0.14,0.17,0.2)	(5,6,7)	(0.13,0.14,0.17)	(1,1,1)	(0.14,0.17,0.2)
IS	(0.14,0.17,0.2)	(0.25,0.3,0.5)	(0.17,0.2,0.25)	(0.25,0.3,0.5)	(5,6,7)	(1,1,1)

Table 8: The Normalised Pairwise Comparison Matrix for Expert 3

	W	C	Z	J	M	IS
W	1	6	0.3	0.14	5	6
C	0.17	1	0.25	0.2	6	4
Z	3	4	1	5	6	5
J	7	5	0.2	1	7	6
M	0.2	0.17	0.17	0.14	1	0.17
IS	0.17	0.25	0.2	0.17	6	1

Table 9: The Triangular Fuzzy Comparison Matrix for Expert 3

	W	**C**	**Z**	**J**	**M**	**IS**
W	(1,1,1)	(5,6,7)	(0.25,0.3,0.5)	(0.13,0.14,0.17)	(4,5,6)	(5,6,7)
C	(0.14,0.17,0.2)	(1,1,1)	(0.2,0.25,0.3)	(0.17,0.2,0.25)	(5,6,7)	(3,4,5)
Z	(2,3,4)	(3,4,5)	(1,1,1)	(4,5,6)	(5,6,7)	(4,5,6)
J	(6,7,8)	(4,5,6)	(0.17,0.2,0.25)	(1,1,1)	(6,7,8)	(5,6,7)
M	(0.17,0.2,0.25)	(0.14,0.17,0.2)	(0.14,0.17,0.2)	(0.13,0.14,0.17)	(1,1,1)	(0.14,0.17,0.2
IS	(0.14,0.17,0.2)	(0.2,0.25,0.3)	(0.17,0.2,0.25)	(0.14,0.17,0.2)	(5,6,7)	(1,1,1)

After the normal and fuzzy pairwise comparisons, the preferences of the three experts were combined to get the aggregate preference as shown in Table 10. The next step was to take the geometric mean of each criterion. The geometric mean is shown in Table 11. After the fuzzy geometric mean, the fuzzy weight for each criterion was computed as indicated in Table 12. Thereafter, defuzzification of the fuzzy weight was computed as portrayed in Table 13. Normalisation of the defuzzified weight followed as revealed in Table 14.

Table 10: The Aggregate Preference of the Three Experts

	W	**C**	**Z**	**J**	**M**	**IS**
W	(1,1,1)	(4.93,5.94,6.95)	(0.5,0.65,1)	(0.13,0.14,0.17)	(3.3,4.3,5.3)	(5,6,7)
C	(0.15,0.17,0.2)	(1,1,1)	(0.62,0.76,0.9)	(0.17,0.2,0.25)	(5,6,7)	(1.82,2.9,3.9)
Z	(1,1.4,2)	(1.1,1.3,1.6)	(1,1,1)	(3.3,4.3,5.3)	(1.5,1.8,2.1)	(4,5,6)
J	(6,7,8)	(4,5,6)	(0.19,0.2,0.28)	(1,1,1)	(6,7,8)	(2.7,3.8,4.8)
M	(0.19,0.23,0.28)	(0.14,0.17,0.2)	(0.46,0.56,0.65)	(0.13,0.14,0.17)	(1,1,1)	(0.14,0.17,0.2)
IS	(0.14,0.17,0.2)	(0.25,0.34,0.53)	(0.17,0.2,0.25)	(0.21,0.25,0.37)	(5,6,7)	(1,1,1)

Table 11: The Fuzzy Geometric Mean Value ($\hat{r}_i$)

Dimension	**Fuzzy Geometric Mean Value ($\hat{\boldsymbol{r}}_{\boldsymbol{i}}$)**
W	(1.32,1.55,1.88)
C	(0.72,0.87,1.04)
Z	(1.66,2.04,2.46)
J	(2.05,2.45,2.84)
M	(0.25,0.28,0.33)
IS	(0.43,0.51,0.64)

Table 12: The Fuzzy Weight for Each Criterion

Dimension	**Fuzzy Weight ($\tilde{\boldsymbol{w}}_{\boldsymbol{i}}$) = $\hat{\boldsymbol{r}}_{\boldsymbol{i}} * (\hat{\boldsymbol{r}}_{\boldsymbol{1}} + \hat{\boldsymbol{r}}_{\boldsymbol{2}} + \hat{\boldsymbol{r}}_{\boldsymbol{3}} + \cdots + \hat{\boldsymbol{r}}_{\boldsymbol{n}})^{-\boldsymbol{1}}$**
W	(0.14,0.2,0.29)
C	(0.08,0.11,0.16)
Z	(0.18,0.27,0.38)
J	(0.22,0.32,0.43)
M	(0.03,0.04,0.05)
IS	(0.05,0.07,0.1)

Table 13: Defuzzification of Fuzzy Weight

Dimension	**Defuzzified Weight ($\boldsymbol{w}_{\boldsymbol{i}}$)**
W	0.21
C	0.12
Z	0.28
J	0.33
M	0.04
IS	0.07
Total	**1.04**

Table 14: Normalisation of the Defuzzified Weight

Dimension	**Normalized Weight**
W	0.20
C	0.11
Z	0.26
J	0.31
M	0.04
IS	0.07
Total	**1**

Therefore, for micro industries, the weights of criteria are as follows: elimination of waste (W) (0.20), continuous improvement (C) (0.11), zero defects (Z) (0.26), Just in Time (J) (0.31), multifunctional teams (M) (0.04), and information systems (IS) (0.07). For the remaining levels of manufacturing organisations, that is small, medium and large, FAHP weights were calculated as done for micro industries. The summary of FAHP weights for criteria of all levels of manufacturing organisations is shown in Table 15.

Table 15: FAHP Weights for criteria of LM

Lean Dimension	**Weights based on Levels of Manufacturing Organisations**			
	Micro	**Small**	**Medium**	**Large**
Elimination of Waste (W)	0.20	0.26	0.25	0.24
Continuous Improvement (C)	0.11	0.18	0.21	0.23
Zero Defects (Z)	0.26	0.25	0.22	0.18
Just in Time (J)	0.31	0.19	0.20	0.19
Multifunctional Teams (M)	0.04	0.05	0.05	0.06
Information Systems (IS)	0.07	0.07	0.07	0.10

Based on the calculations for FAHP-based weight for each level of manufacturing organisations as indicated in Table 15, it was revealed that the weights of criteria vary for each level of manufacturing organisations. This reflects that, to reach a high maturity level, each size of the industry will have to concentrate much on the criteria that have high weights for LM performance measures.

The dimensions (criteria) for LM performance measures observed in this study were also used in other studies for assessing the LM implementation (Belhadi et al. 2018; Sânchez and Pérez 2001; Åhlström and Karlsson 1996). The difference between those studies and this one is the fact that the criteria in this study have been prioritised with the help of FAHP for the context of manufacturing organisations in Tanzania. The study has ranked the criteria based on their importance for each level of manufacturing organisations in the country. Furthermore, with the use of fuzzy, the subjectivity and uncertainty of weights from experts were eliminated.

The criteria will be used in measuring the level of lean maturity. The fuzzy-based weight will assist organisations in determining which criteria have a greater impact on influencing the maturity of LM and which should be given higher attention in the implementation of LM for the organisation's performance. Furthermore, the FAHP-based weights for the obtained criteria will enable manufacturing organisations to improve the LM performance and later on will assist organisations in achieving a competitive market advantage against their rivals. A better performance of manufacturing organisations in Tanzania will have a greater impact on the contribution of the sector to the country's GDP.

CONCLUSION

The study established FAHP-based weights of LM performance measures for manufacturing organisations in the context of Tanzania based on the size of the manufacturing organisations, that is micro, small, medium and large. Furthermore, the study revealed that the FAHP-based weights for each criterion differ according to the size of the manufacturing organisations. The FAHP-based weights obtained in this study will be useful in determining the maturity level of various manufacturing organisations. Likewise, the weights can be used by the manufacturing organizations of different levels in setting strategies for improving their maturity levels. Improvement in the maturity level will improve the operational performance of the manufacturing organisations, which in the long run will improve the contribution of the sector to the country's GDP, and increase their competitive advantage in the market.

Moreover, the study has added to the field of LM the specific FAHP-based weights for LM performance in manufacturing organisations of various levels in developing countries such as Tanzania.

Declaration of Interest

The authors declare that there is no conflict of interest regarding this work.

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