Priority Analysis of Lean Manufacturing Practices: A Fuzzy-AHP Approach in Automotive Industry

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Abstract. The major aim of this research is to apply a Fuzzy Analytic Hierarchy Process (FAHP) approach to rank the importance of Lean Manufacturing (LM) practices in the automotive industry. Although lean concept is widely investigated in previous literature, highlighting the most important practices of LM in automotive industry is not considered. To fill the gap of previous literature, this study applies a FAHP to prioritize the LM practices in automotive industry. Mainly, the hierarchy structure of the addressed Multiple-Criteria Decision Making (MCDM) approach is as follows. The first level of decision making hierarchy aims to rank the best LM practices using three decision making criteria of the second level. These decision making criteria include application in industry, measurability and managerial acceptance. The third level of decision includes four major practices of LM namely, manufacturing management leanness, management responsibility leanness, workforce leanness and technology leanness. According to the obtained results, technology leanness is the best LM practice to be adopted by automotive manufacturers.

1. Introduction
Numerous concepts have been developed to deal with the growing competition of today’s competitive markets [1-2]. Managers, practitioners and researchers have acknowledged the necessity of improving their adopted practices with regard to functional and operative concepts such as Lean Manufacturing (LM) [3-4]. With the beginning and progress of LM, numerous studies have applied or developed its associated practices. However, although LM concept is widely investigated in previous studies, less attention has been paid to determine the most important practices of LM in automotive industry. Therefore, recognizing the LM practices, introducing the selection criteria, and ranking the LM practices is a challenge which is less investigated in the previous literature.

Therefore, applying a FAHP approach to rank the importance of LM practices in the automotive industry is the main goal of this research. The research scope is related to the automotive industry of a developing country. Nonetheless, the conceptual framework of the research, procedure, methodology,
and obtained results is beneficial to scholars, practitioners and managers to find and prioritize the best practices of LM. This research provides contributions by recognizing the LM practices, suggesting prioritization criteria, and ranking the LM practices using a FAHP.

2. Literature Review

Lean manufacturing (LM) target is to produce the products according to customers’ request and minimum waste [5]. The LM concept has been investigated in numerous areas including Supply Chain Management (SCM), manufacturing, construction management and service industry [6-14]. According to [14], LM practices includes manufacturing management leanness, management responsibility leanness, workforce leanness and technology leanness. This research investigated LM practices to recognize the critical factors for its success execution. In addition, this study applied a methodical tactic to the investigation of LM system, allowing for the leanness practices in an integrated approach.

Therefore, the conducted literature review showed that numerous studies have been conducted on LM. Though, none of the previous studies developed criteria and ranked the importance of LM practices in automotive industry. In addition, application of MCDM techniques to prioritize the importance of LM practices provides better results in terms of visibility and logic comparing to qualitative approaches such as survey or questionnaire.

3. Research Methodology

This research has been conducted in four phases as follows:

Phase 1: Identification of Lean Manufacturing (LM) practices

As mentioned, this study applies a Fuzzy-AHP approach to prioritize LM practices in Automotive Industry. The adopted LM practices of [14] are applied to be investigated and ranked in a developing country. According to this study, manufacturing management leanness, management responsibility leanness, workforce leanness and technology leanness are four major practices of LM.

Phase 2: Developing the Multiple-Criteria Decision Making (MCDM) Hierarchy

There are numerous decisions with concurrent consideration of different criteria. In this regard, MCDM methods are helpful to see all these criteria simultaneously [15-16]. In this study, the first level of decision making hierarchy aims to prioritize the different practices of LM. The second level determines the selection criteria which includes application in industry, measurability and managerial acceptance. In other words, these three criteria are used to rank manufacturing management leanness, management responsibility leanness, workforce leanness and technology leanness in the third level of decision making hierarchy. Figure 1 shows the decision hierarchy of this research.

Phase 3: Fuzzy Analytic Hierarchy Process

As mentioned, this study applied a FAHP model to rank the different practices of LM in automotive industry. The Chang’ extended analysis [17] is implemented in this research. The developed equations of Chang’s [17] FAHP are as follows.

\[ M_q = (l_q, m_q, u_q) \]  
\[ l_q = \min \left( B_{q} \right) \]
\[ m_j = \sqrt[n]{\prod_{k=1}^{n} B_{jk}} \]  
\[ u_j = \max(B_{jk}) \]  

Where, Triangular Fuzzy Numbers (TFNs) are shown by L, M and K. \( K \) decision makers’ scores to compare the significance of \( C_i - C_j \) is shown by \( B_{ij} \). Therefore, \( C_i - C_j \) displays model’s considered criteria. The numerical calculations for each two TFN \( M_1 \) and \( M_2 \) can be defined as follows:

\[ M_1 + M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \]  
\[ M_1 * M_2 = (l_1 * l_2, m_1 * m_2, u_1 * u_2) \]  

\[ M_1^{-1} = \left[ \frac{1}{l_1}, \frac{1}{m_1}, \frac{1}{u_1} \right], \quad M_2^{-1} = \left[ \frac{1}{l_2}, \frac{1}{m_2}, \frac{1}{u_2} \right] \]  

In which, the inverse values of \( M_1 \) and \( M_2 \) are displayed by \( M_1^{-1} \) and \( M_2^{-1} \). Equation 8 is applied to identify \( S_k \) as follows:

\[ S_k = \sum_{j=1}^{n} M_{kj} \left[ \sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij} \right]^{-1} \]  

After computing the \( S_k \), it is essential to calculate the possibility degrees of \( S_k \). Subsequently, computing the possibility degree of \( M_1 \) and \( M_2 \) can be done as follows:

\[ \text{V} (M_1 \geq M_2) = 1 \quad \text{if} \quad M_1 \geq M_2 \]
\[ \text{V} (M_1 \geq M_2) = 0 \quad \text{if} \quad L_1 \geq U_2 \]
\[ \text{V} (M_1 \geq M_2) = \text{hgt} (M_1 \cap M_2) \quad \text{otherwise} \]  

\[ \text{hgt}(M_1 \cap M_2) = \frac{u_1 l_2}{(u_1 - l_1) + (m_2 - m_1)} \]  

Calculation of the possibility degree of a convex fuzzy number which is required to be greater than \( k \) convex fuzzy numbers is as follows:

\[ V(M_1 \geq M_1, ..., M_k) = V(M_1 \geq M_1) \ldots V(M_1 \geq M_k) \]
Next Equation is applied to calculate the weights of indices in pairwise matrices. Consequently $W(x_i)$ is computed using Equation 12.

$$W(x_i) = \text{Min} \{ V(S_i \geq S_j) \} \quad k = 1, 2, 3, \ldots, n \quad k \neq i$$ 

(12)

Thus, the $w(X_i)$ which is a weight vector can be calculated using Equation 13.

$$w(X_i) = [W(C_i), W(C_j), W(C_k)]^T$$

(13)

Next equation calculates the normal quantities $w_i$ as follows:

$$w_i = \frac{w'_i}{\sum w'_i}$$

(14)

**Phase 4: Calculation and Interpretation**

Pairwise comparison matrices are required to develop the FAHP. Therefore, a questionnaire is developed to gather the required data. As mentioned, the first level of decision making hierarchy aims to rank the best LM practices using three decision making criteria of the second level. These decision criteria include application in industry, measurability and managerial acceptance.

The third level of decision includes four major practices of manufacturing management leanness, management responsibility leanness, workforce leanness and technology leanness. Therefore, these four practices should be compared based on three selection criteria of application in industry, measurability and managerial acceptance. Subsequently, three sections are assigned to gather the required information in the form of pairwise comparison matrices. The applied questionnaire and data collection approach are verified using pilot tests prior to the data collection stage.
4. Results and Discussion

Twelve experts were asked to fill the FAHP questionnaire. As discussed, pairwise comparison matrices are required to develop the FAHP. Therefore, the developed questionnaires were filled in the form of pairwise comparison matrices to ease the data collection procedure. Microsoft Excel 2013 software was applied to do the related calculation of FAHP. According to the obtained result, technology leanness is the most important LM practice to be adopted by automotive lean manufacturers. Manufacturing management leanness, management responsibility leanness and workforce leanness are next choices to be adopted by lean manufacturers.

| LM Practice                  | Weight |
|------------------------------|--------|
| Management responsibility leanness | 0.24   |
| Manufacturing management leanness | 0.25   |
| Technology leanness         | 0.31   |
| Workforce leanness          | 0.20   |

5. Conclusion

This research applied a FAHP to prioritize the importance of LM practices in the automotive industry. The hierarchy structure of the addressed MCDM approach included three linked levels. The first level aimed to rank the best LM practices using three decision making criteria of the application in industry, measurability and managerial acceptance. These criteria were used in the second level of decision making hierarchy. The third level included four major practices of LM namely, manufacturing management leanness, management responsibility leanness, workforce leanness and technology leanness. According to the results, technology leanness is the best LM practice to be applied in the automotive industry. As a direction for future research, this study can be repeated in other industries. In addition, the suggested research methodology can be applied for other manufacturing strategies.

6. References

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