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Application of Fuzzy AHP for Ranking Critical Success Factors for the Successful Implementation of Lean Production Technique

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ABSTRACT

The implementation of lean production techniques in a product assembly environment depends on a numbers of factors and these factors constitute the backbone for the successful implementation of the lean technique. Although, many research efforts, both theoretical and practical studies have been made over the year on the identification and evaluation of the critical success factors (CSFs) for lean implementation, but very little or less effort has been devoted to evaluating the actual contribution of each of these factors to the overall success of the lean implementation program. This study therefore presents a framework for ranking and evaluating the contribution of these critical success factors in the order in which they accounts for the successful implementation of lean production techniques using Fuzzy Analytic Hierarchy Process (FAHP) approach.

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INTRODUCTION

Lean production technique is basically aimed at cutting out the “Fat” in the production process, most especially those areas that are inefficient and add no value to products and services. The idea is to allow for manufacturers and manufacturing companies work more economically by using their manufacturing skills, time, space, money, and other manufacturing influencing factors more efficiently and effectively (Bronislav & Robert, 2014).

The implementation of lean production techniques depends on a number of factors and these factors constitute the key to its success. Although, many research efforts both theoretical and practical studies have been made over the year on the identification and evaluation of the critical success factors (CSFs) for lean implementation, But very little or less effort has been devoted to evaluating the actual contribution or the extents to which each of the factors contributes to the overall success of the lean implementation program.

This study therefore seeks to identify and prioritize the CSFs in the order in which they accounts for the successful implementation of lean production techniques within a product assembly environment using Fuzzy Analytic Hierarchy Process (FAHP) approach. The Analytic Hierarchy Process (AHP) method allows for the definition of the factors in a hierarchical structure, to evaluate the factors and for the relative importance of each of the factor to be quantified based on a certain objective and preference of the lean experts. However, to overcome the effects of uncertainty and variations in the lean expert’s preferences, a fuzzy set theory is integrated with the traditional AHP. The study gain its data through post and face to face interview of 30 lean experts in Original Equipment Manufacturers (OEMs) companies, and the survey questionnaire questions were based on the Saaty Scale (Saaty 1980).

Literature Review:

a. Critical success factors for lean implementation:

Lean production technique on a basic level can simply be referred to as the synchronization of the process output for the satisfaction of customer’s demands. A number of research efforts have been made over the years on the critical success factors for lean production implementation. Manoj *et al*, (2013), analyzes the operational performance impact and the critical success factors of lean implementation in a food processing SMEs. Using

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questionnaire survey, he concluded that the skill of the workforce, in-house expertise and the organizational culture are the main critical factors for successful implementation of lean manufacturing practices.

Using a case study in the aeronautics industry, Jose *et al*. (2014), presence five main factors that will aid the adoption and implementation of lean process, and the factors includes training, communication, rewards, job design, and work organization. Also, a variety of explanatory elements were also identified in each of the main factors found in each phase of the transition process to Lean Production. Achanga *et al*. (2006), identified four critical success factors that can provide useful insight for the enhancement of critical decision-making, needed for the delivery of corporate strategic ambitions towards the implementation of lean manufacturing technique. The factors identified include; Leadership, management, finance, organizational culture and skills and expertise.

Kumar *et al*. (2009), identifies and describes 14 critical success factors, and their importance to the implementation lean and six sigma methods within SMEs. The factors includes Management involvement and commitment; Organization infrastructure; Communication; Link quality improvement to employee; Culture change; Education and training; Link quality improvement to customer; Link quality improvement to business; Link quality improvement to supplier; Project selection; IT and innovation, Project management skill; Vision and plan. Grove *et al*. (2010) identifies some of the challenges faced by health practitioners in the implementation of lean techniques in a health service environment and profile a solution the overcome the problems. Among these challenges are; high process variability; poor communication and leadership, a lack of understanding of lean method; problems with defining and identifying waste; and the difficulty in determining the customers and the value from customer's perspective. The challenges to the implementation of the lean method could be overcome by adopting the following; upfront planning, excellent communication, identification and sharing of best practice, transformational leadership, and having a shared vision.

Mefford (2009) identified four essential factors for successful implementation of lean techniques and the factors includes; Belief in the new program that it will work; management commitment; Involving all the staffs (employees) in the organization, having adequate resources to undertaken the program; Patience and long term view for the results, while Sim and Rogers (2009), concluded that, the critical success factor for lean implementation lies in the commitment of leader in charge and that the implementation process problem lies primarily on the aging and high seniority hourly workforce and a lack of committed leadership at this research site.

Bhasin (2011), identifies the following as a obstacles to the successful implementation of lean techniques; inadequate external funding; inadequate internal funding; lack of understanding of the potential benefits; need to convince shareholders/owners, cost of investment, cultural issues; Insufficient skills to implement lean; Employee attitude/resistance to change; Insufficient management time; Insufficient supervisory skills to implement lean. Scherrer-Rathje *et al*. (2009), concluded that the success to lean implementation lies on factors like management commitment to the strategy, involvement of management to ensure its implementation, autonomy of the employee to make decisions regarding business process changes; transparency of target goals and performance improvements and long-term sustainability of lean program.

On comparing and reviewing the CSFs for the implementation of lean production techniques proposed by the various researchers in the reviewed literature, we found that some of the success factors identified, were consistent and can be relevant to the implementation of lean production techniques in a product assembly environment. Hence, we have proposed a set of key success factors that we believe will be more relevant to the implementation of lean techniques in this area and was confirmed by a questionnaire survey send to seven lean experts in OEMs companies. The proposed key success factors include;

1. Management commitment,
2. Management Leadership,
3. Finance,
4. Organizational culture,
5. Skills and expertise,
6. Patience and long term view for the results,
7. Monitoring and evaluation of performance (performance measurements).

b. Fuzzy AHP:

The fuzzy analytical Hierarchy process (fuzzy AHP) can be described as an extension of the Analytic Hierarchy process, which stands as an excellent tool for solving both quantitative and qualitative problems, the method is unique for its ability to deal with fuzziness and vagueness of linguistic judgments by establishing an effective prioritization. The fuzzy AHP method was borne out of the inability of the AHP to deal with imprecision and subjective-ness in the pair-wise comparison process [Cengiz Kahraman *et al* 2008]

The fuzzy AHP allows complex multi-criteria decisions problems to be structured into hierarchy descending from an overall objective to various criteria, sub-criteria and so on until the lowest level. Where the objective of the decision is represented at the top level of the hierarchy and the criteria and sub-criteria contributing to the decision are represented at the intermediate levels. Finally, the decision alternatives or selection choices are laid down at the last level of the hierarchy [Armando Calabrese *et al*, 2013].

There have been lots of application and proposal for the use of fuzzy AHP methods in literature by various author, however for the purpose of this paper we will restrict ourselves to the most recent proposals and applications. Kim I. *et al* (2014) utilized the Fuzzy AHP in quantifying failure risk of excavation work of high-rise building, the Authors uses the fuzzy analytic hierarchy process to weights the environmental influences that can derive a failure during excavation work. Finally he subjected through a case study that the fuzzy model can used as an input for fuzzy comprehensive operations to compute the quantitative failure risk. Amiri (2010) utilizes the AHP and Fuzzy (TOPSIS) approach for the selection of oil-field development projects, where the AHP was used in constructing hierarchical structure of the project selection problem and in the determination of the criteria weight while the fuzzy TOPSIS method is used in ranking the alternative. Finally, he concluded that the alternatives' ranks could be changed by fuzzy preference evaluation.

Ayhan (2013) applies the Fuzzy AHP model in determining the best supplier in a gear motor company with respect to selected criteria. Chou & Yu (2013) proposes a new hybrid fuzzy Analytic Hierarchy Process (AHP) algorithm to deal with the decision-making problems in an uncertain and multiple-criteria environment. The model is applied in selecting the location choices of international distribution centers in international ports from the view of multiple-nation corporations. The result from the study shows that the proposed new hybrid fuzzy AHP model is an appropriate tool to solve the decision-making problems in an uncertain and multiple-criteria environment. Srichetta & Thurachon (2012) utilizes the fuzzy analytic hierarchy process (fuzzy AHP) to determine the relative importance of the decision criterion in order to select the best product of notebook computers. The result from the numerical calculations shows that fuzzy AHP is capable of handling fuzziness of data in a multi-criteria decision making problem.

Torfi *et al*, (2010) propose a Fuzzy multi-criteria decision-making approach (FMCDM) which they used evaluating alternative options in respect to user's preference orders. Using Two FMCDM methods for solving the MCDM problem that is the Fuzzy Analytic Hierarchy Process (FAHP) and an extension of the Fuzzy Technique for Order Preference by Similarity to Ideal Solution (FTOPSIS) where the FAHP was applied to determine the relative weights of the evaluation criteria while the extended (FTOPSIS) is used in ranking the alternatives.

Vahidnia *et al*. (2009) used the Fuzzy AHP technique to determine the optimal site for the construction of a new hospital; the Geographical Information System (GIS) were utilized to analysis and classify the main criteria used in the selection of the site. The Fuzzy AHP was used to evaluate alternatives and determine the best site location. Lee, Chen, and Chang (2008) utilized Fuzzy AHP and balance scored card (BSC) to evaluate information technology departments in the manufacturing industry. The BSC was used to identify the hierarchy of the problem based on four major perspectives of performance measures, which was then prioritized using Fuzzy AHP to suggest the best improvement strategies.

The FAHP Model:

The methodology is developed using the Chen and Hwang (1992) model for the identification and prioritization of the critical success factors in the order in which they accounts for the successful implementation of lean production techniques within a low volume product assembly environment. The method involves a four steps approach:

Step 1: Converting linguistic terms to fuzzy numbers and then to crisp scores: This involves the conversion of linguistic terms like, Equally, Moderately, Strongly, Very strongly, Extremely etc. into fuzzy numbers like M1, M2, M3, M4, M5 etc. respectively using a five point linguistic conversion scales as shown in figure 1, also the conversion of fuzzy numbers to crisp scores, this involves the use of a fuzzy scoring approach that is a modification of the fuzzy ranking approaches proposed by Jain (1976) and Chen (1985). The crisp score of fuzzy number "M" is obtained as follows:

$$\mu_{max}(X) = \begin{cases} x, 0 \leq x \leq 1 \\ 0, \text{otherwise} \end{cases}$$

$$\mu_{min}(X) = \begin{cases} 1 - x, 0 \leq x \leq 1 \\ 0, \text{otherwise} \end{cases}$$

The fuzzy max and min of the fuzzy numbers are defined in a manner such that the absolute location of fuzzy numbers can be automatically incorporated in the comparison cases. The score of each the fuzzy number M_i is given as:

$\mu_R(M_1) = \text{Sup}\,[\mu_{max}(x)^{\wedge}\,\mu_{M1}(x)]$ for the right and

$\mu_L(M_1) = \text{Sup}\,[\mu_{min}(x)^{\wedge}\,\mu_{M1}(x)]$ for the left and

The total score of a fuzzy number M_i is given as:

$\mu_T(M_1) = [\mu_R(M_1) + 1 - \mu_L(M_1)]/2$

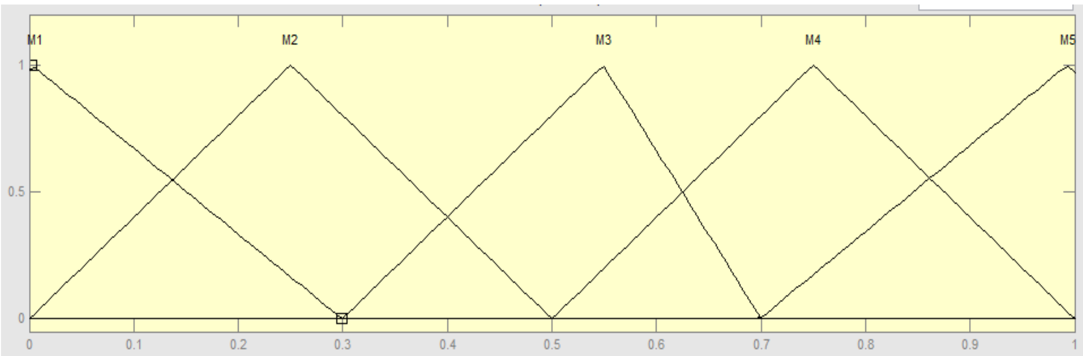

Fig. 1: Linguistic terms for the fuzzy numbers conversion

Equally (M1) importance

$$\mu_{M1}(X) = \begin{cases} 1, x = 0 \\ (0.3 - x)/(0.3), 0 \leq x \leq 0.3 \end{cases}$$

Moderately (M_2) importance

$$\mu_{M2}(X) = \begin{cases} (x - 0)/(0.25), 0 \leq x \leq 0.3 \\ (0.5 - x)/(0.25), 0 \leq x \leq 0.5 \end{cases}$$

Strongly (M_3) importance

$$\mu_{M3}(X) = \begin{cases} (0 - 0.3)/(0.2), 0.3 \leq x \leq 0.5 \\ (0.5 - x)/(0.2), 0.5 \leq x \leq 0.7 \end{cases}$$

Very strongly (M_4) importance

$$\mu_{M4}(X) = \begin{cases} (x - 0.5)/(0.25), 0.5 \leq x \leq 0.75 \\ (1.0 - x)/(0.25), 0.75 \leq x \leq 1.0 \end{cases}$$

Extremely (M_5) importance

$$\mu_{M5}(X) = \{(X - 0.7)/(0.3),\ 0.7 \leq X \leq 1.0$$

The score of each the fuzzy number for the right and left is calculated as follows:

$\mu_R(M_1) = Sup_x\, [\mu_{max}(x)^{\wedge}\, \mu_{M1}(x)] = 0.23$

$\mu_L(M_1) = Sup_x\, [\mu_{min}(x)^{\wedge}\, \mu_{M1}(x)] = 1.0$

The total score of a fuzzy number M_i is given as:

$\mu_T(M_1) = [\mu_R(M_1) + 1 - \mu_L(M_1)]/2 = 0.115$

Similarly the Right and Left scores for each of the fuzzy numbers are shown in Table 1 and Table 2 shows the linguistic variables and converted fuzzy number to crisp score.

Table 1: The right, left and total score for the fuzzy numbers

Fuzzy Numbers	μ_R	μ_L	μ_T
M1	0.25	1	0.115
M2	0.39	0.8	0.295
M3	0.58	0.59	0.495
M4	0.79	0.4	0.695
M5	1	0.23	0.895

Table 2: Linguistic variables, fuzzy number and the crisp scores

Linguistic Variables	Fuzzy Numbers	Crisp score
Equally	MI	0.115
Moderately	M2	0.295
Strongly	M3	0.495
Very strongly	M4	0.695
Extremely	M5	0.895

Step 2: Construct Relative importance matrix

The relative importance matrix is developed based on expert reasoning and it involves the assigning of weight to the matrix by comparing criteria with criteria as shown in Table 3 below. In the matrix, diagonal elements are always 1 this is because a criterion is compare with itself.

Table 3: Scale of relative preference Satty, (1980)

Intensity of preference	Reciprocal	Linguistic variable
1	1	Just equal
3	1/3.	slightly important
5	1/5.	Strongly important
7	1/7.	Very strongly important
9	1/9.	Extremely Important
2,4,6,8	1/2, 1/4, 1/6, 1/8	Intermediate values (when compromise is needed)

Step 3: Consistency checking

This is required to check, if the weights assigned to the criteria based on expert reasoning is correct or not. When the value is less than 0.1 then the weights is said to be consistent. The consistency check involves the following steps:

a. Geometric Mean: The geometric mean is calculated by multiplying the elements of each of the row and then raise to the power of the reciprocal of the size of the matrix. The Total geometric mean is then calculated by adding the geometric mean for each row.

b. Normalized Weight: This is calculated for each row by dividing the geometric mean of each row by the total geometric mean and then weights obtained are arranged in a matrix.

c. The consistency is checked using following formulae:

$A_1 = A_R * N$ where A_R is the relative importance matrix and N is the normalized matrix.

$A_2 = A_1 / N$

d. The average of A_2 is calculated by: $\lambda_{max} = \sum$ of A_2 elements / No. of A_2 elements

e. Consistence index is given as: CI= λ_{max} -n / n-1 where n is the size of matrix.

f. Finally the consistency ratio is calculated as: CR = CI / RI where RI is random index, which is already given for specific number of criteria. If the final value of CR is less than 0.1, then the weights are consistent.

Step 4:- Ranking: The ranking is obtained by multiplying the decision making matrix (DMM) by normalized matrix (N).

Case Study:

The implementation of lean production techniques depends on a number of factors and these factors constitute the key to its success. However it is important to know the extents to which each of these factors contributes to the overall success of the lean implementation program. In doing this a questionnaire was sent out and the study was carried out based on the reasoning of seven lean experts in OEMs companies where the critical success factors proposed in the previous section were ranked using the FAHP. The hierarchy used in ranking the CSFs are based on various conflicting criteria is shown in figure 2 below also Table 4, shows the number, name of CSFs, the linguistic variables along with their corresponding fuzzy numbers (see figure 3).

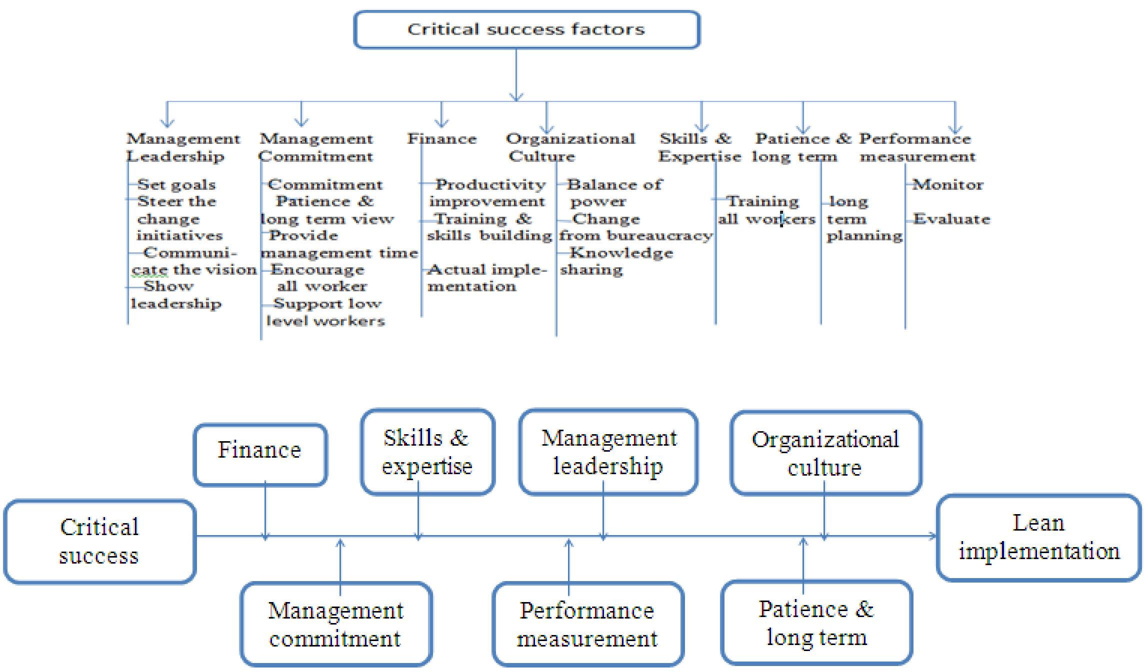

Fig. 2: Hierarchy of evaluation CSFs ranking

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Step 1:- Converting linguistic terms to fuzzy numbers and then to crisp scores: A seven point fuzzy scale (fig 3) was used for the conversion of linguistic terms into fuzzy numbers and then the fuzzy numbers into crisp score. The procedure is given below.

Table 4: CSFs and their linguistic variables

Intensity of preference	CSFs	Linguistic Variables	Fuzzy number
1	Management Commitment (CSF 1)	None	M1
2	Management Leadership (CSF2)	Very poor	M2
3	Finance (CSF3)	Poor	M3
4	Organizational culture (CSF4)	Medium	M4
5	Skills and Expertise (CSF5)	Good	M5
6	Patience and long term view (CSF6)	Very good	M6
7	Performance measurement (CSF7)	Excellent	M7

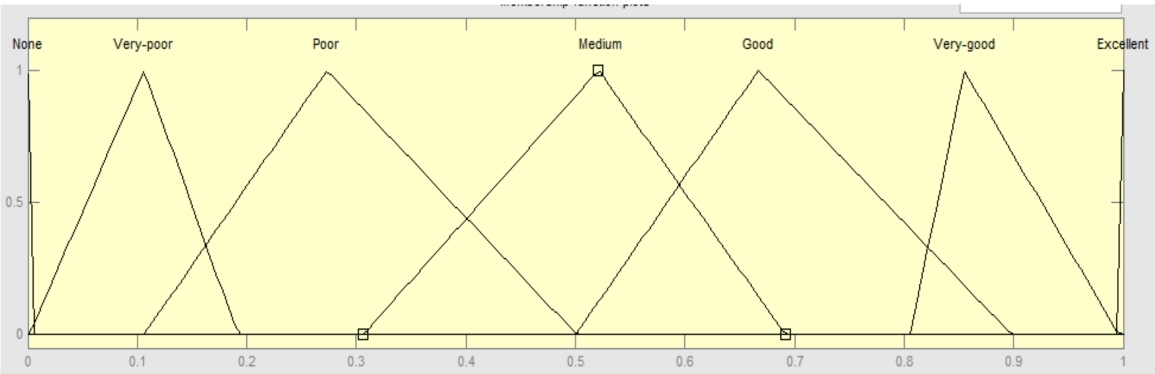

Fig. 3: Seven point fuzzy scale linguistic terms to fuzzy numbers conversion

$\mu_{M1}(X) = 1, X = 0$

$$\mu_{M2}(X) = \begin{cases} (x-0)/(0.1), 0 \le x \le 0.1 \\ (0.2-x)/(0.1), 0.1 \le x \le 0.2 \end{cases}$$

$$\mu_{M3}(X) = \begin{cases} (x-0.1)/(0.2), 0.1 \le x \le 0.3 \\ (0.5-x)/(0.2), 0.3 \le x \le 0.5 \end{cases}$$

$$\mu_{M4}(X) = \begin{cases} (x-0.3)/(0.2), 0.3 \le x \le 0.5 \\ (0.7-x)/(0.2), 0.5 \le x \le 0.7 \end{cases}$$

$$\mu_{M5}(X) = \begin{cases} (x-0.5)/(0.2), 0.5 \le x \le 0.7 \\ (0.9-x)/(0.2), 0.7 \le x \le 0.9 \end{cases}$$

$$\mu_{M6}(X) = \begin{cases} (x-0.8)/(0.1), 0.8 \le x \le 0.9 \\ (1-x)/(0.1), \quad 0.9 \le x \le 1 \end{cases}$$

$\mu_{M1}(X) = 1, X = 1$

The left scores, right scores, the total scores and crisp scores for the different fuzzy numbers are given in the Table 5 below.

Table 5: Left scores, right scores, the total scores and crisp scores for the different fuzzy numbers

Linguistic variables	Fuzzy numbers	μ_L (Mi)	μ_R (Mi)	μ_T (Mi)	Crisp scores
None	M1	1	0	0	0
Very poor	M2	0.9091	0.1818	0.1364	0.1364
Poor	M3	0.75	0.4167	0.3333	0.3333
Medium	M4	0.5833	0.5833	0.5	0.5
Good	M5	0.4167	0.75	0.6667	0.6667
Very good	M6	0.1818	0.9091	0.8636	0.8636
Excellent	M7	0	1	1	1

Considering the linguistic variables in the above table the decision making matrix (DMM) for the CSFs is formed based on the seven experts (E) reasoning on how the CSFs contributes to the successful implementation of lean technique in a product assembly environment using the crisp values.

DMM =

	E1	E2	E3	E4	E5	E6	E7
CFS1	1	1	0.8636	1	1	1	0.8636
CSF2	0.6667	0.8636	1	0.6667	0.8636	0.6667	0.8636
CSF3	0.1364	1	0.5	0.3333	0.3333	0.5	0.8636
CSF4	0.5	0.3333	0.1364	0.1364	0.5	0.1364	0.5
CSF5	0.5	0.5	0	0.5	1	0.8636	0.6667
CSF6	0.8636	0.8636	1	0.6667	0.5	1	0.3333
CSF7	0.8636	0.6667	0.6667	0.8636	0.5	0	0.5

Step 2:-Construct Relative importance matrix (A_R): The relative importance matrix is developed based on the reasoning of seven lean experts in OEMs companies. The experts were ask to rank the identified CSFs for the implementation of lean technique in a product assembly environment using Satty (1980) relative preference scale (Table 3).

A_R =

	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7
CFS1	1	2	5	9	9	5	5
CSF2	0.5	1	5	7	5	3	2
CSF3	0.2	0.2	1	3	3	1	2
CSF4	0.1	0.1	0.3	1	0.3	0.5	1
CSF5	0.1	0.2	0.3	3	1	2	3
CSF6	0.2	0.3	1	2	0.5	1	2
CSF7	0.2	0.5	0.5	1	0.3	0.5	1

Step 3: Consistency check: To ensure the correctness of weights assigned by seven lean experts a consistency check is performed.

- Geometric mean (GM)

GM1 = [1*2*5*9*9*5*5] = 20250 ^ (1/7) = 4.1229
GM2 = [0.5*1*5*7*5*3*2] = 525 ^ (1/7) = 2.4467
GM3 = [0.2*0.2*1*3*3*1*2] ^ (1/7) = 0.9542
GM4 = [0.1*0.1*0.3*1*0.3*0.5*1] ^ (1/7) = 0.3326
GM5 = [0.1*0.2*0.3*3*1*2*3] ^ (1/7) = 0.7276
GM6 = [0.2*0.3*1*2*0.5*1*2] ^ (1/7) = 0.7387
GM7 = [0.2*0.5*0.5*1*0.3*0.5*1] ^ (1/7) = 0.4971
GM_{Total} = GM1+GM2+GM3+GM4+GM5+GM6+GM7 = 9.8198

- Normalized weight (N)

N1 = GM1 / GM_{Total} = 4.1229 / 9.8198 = 0.4199
N2 = GM2 / GM_{Total} = 2.4467 / 9.8198 = 0.2492
N3 = GM3 / GM_{Total} = 0.9542 / 9.8198 = 0.0972
N4 = GM4 / GM_{Total} = 0.3326 / 9.8198 = 0.0339
N5 = GM5 / GM_{Total} = 0.7276 / 9.8198 = 0.0741
N6 = GM6 / GM_{Total} = 0.7387 / 9.8198 = 0.0752
N7 = GM7 / GM_{Total} = 0.4971 / 9.8198 = 0.0506

- A1 = A_R * N

$$A1 = \begin{bmatrix} 1 & 2 & 5 & 9 & 9 & 5 & 5 \\ 0.5 & 1 & 5 & 7 & 5 & 3 & 2 \\ 0.2 & 0.2 & 1 & 3 & 3 & 1 & 2 \\ 0.1 & 0.1 & 0.3 & 1 & 0.3 & 0.5 & 1 \\ 0.1 & 0.2 & 0.3 & 3 & 1 & 2 & 3 \\ 0.2 & 0.3 & 1 & 2 & 0.5 & 1 & 2 \\ 0.2 & 0.5 & 0.5 & 1 & 0.3 & 0.5 & 1 \end{bmatrix} * \begin{bmatrix} 0.4199 \\ 0.2492 \\ 0.0972 \\ 0.0339 \\ 0.0741 \\ 0.0752 \\ 0.0506 \end{bmatrix} = \begin{bmatrix} 3.0053 \\ 1.8798 \\ 0.7314 \\ 0.2404 \\ 0.5990 \\ 0.5372 \\ 0.4015 \end{bmatrix}$$

- A2 = A1 / N

$$A2 = \begin{bmatrix} 3.0053 \\ 1.8798 \\ 0.7314 \\ 0.2404 \\ 0.5990 \\ 0.5372 \\ 0.4015 \end{bmatrix} / \begin{bmatrix} 0.4199 \\ 0.2492 \\ 0.0972 \\ 0.0339 \\ 0.0741 \\ 0.0752 \\ 0.0506 \end{bmatrix} = \begin{bmatrix} 7.1572 \\ 7.5433 \\ 7.5247 \\ 7.0915 \\ 8.0837 \\ 7.1436 \\ 7.9348 \end{bmatrix}$$

- $\lambda_{max} = \sum$ of A_2 elements / No. of A_2 elements
  = 52.4788 / 7 = 7.497
- CI= λ_{max} -n / n-1
  = [7.497 – 7] / [7-1]
  = 0.08283
- CR = CI / RI
  = 0.08283 / 1.32 = 0.06275

The assigned weights are consistent since the CR value is less than 0.1.

Step 4:- Ranking (R): The ranking is obtained by multiplying the decision making matrix (DMM) by normalized matrix (N).

$$R = \begin{bmatrix} 1 & 1 & 0.8636 & 1 & 1 & 1 & 0.8636 \\ 0.6667 & 0.8636 & 1 & 0.6667 & 0.8636 & 0.6667 & 0.8636 \\ 0.1364 & 1 & 0.5 & 0.3333 & 0.3333 & 0.5 & 0.8636 \\ 0.5 & 0.3333 & 0.1364 & 0.1364 & 0.5 & 0.1364 & 0.5 \\ 0.5 & 0.5 & 0 & 0.5 & 1 & 0.8636 & 0.6667 \\ 0.8636 & 0.8636 & 1 & 0.6667 & 0.5 & 1 & 0.3333 \\ 0.8636 & 0.6667 & 0.6667 & 0.8636 & 0.5 & 0 & 0.5 \end{bmatrix} * \begin{bmatrix} 0.4199 \\ 0.2492 \\ 0.0972 \\ 0.0339 \\ 0.0741 \\ 0.0752 \\ 0.0506 \end{bmatrix}$$

$$R = \begin{bmatrix} 0.97994008 \\ 0.77278434 \\ 0.47236892 \\ 0.38349768 \\ 0.52427774 \\ 0.82675087 \\ 0.68519656 \end{bmatrix} = \begin{bmatrix} R1 \\ R3 \\ R6 \\ R7 \\ R5 \\ R2 \\ R4 \end{bmatrix}$$

Conclusion:

This study presents a framework for ranking and evaluating the contribution of each of the different critical success factors to the overall success of the lean production implementation program in a product assembly environment using the FAHP method. The developed framework was used in ranking the proposed critical success factors (CSFs) in the order to which they account to the overall success of the lean implementation. The result from the case study shows the contributions and ranking sequence for the each of the CSFs with Management Commitment earning the highest contributing factor to the overall lean implementation success.

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