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Six Sigma Project Selection Using Extent Fuzzy AHP: An Empirical Study

S.K. Tiwari*, R.K. Singh, S.C. Srivastava
Department of Production Engineering, Birla Institute of Technology, Mesra.

A R T I C L E I N F O

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A B S T R A C T

Six sigma is a project driven approach that concentrates on reducing variations, defects and improving the quality of products, processes as well as services. The selection of right project in a six sigma program is a major concern for the early success and long term acceptance within any organization, as projects are expensive and require considerable human effort, money, and time. Selection of critical six sigma project, however, is a real challenge in practice. This study aims to develop a novel approach for the identification of critical six sigma project based on extent analysis method of fuzzy AHP. To explore effectiveness of the approach, an empirical case study of a manufacturing firm which produces various types of precision machined components, is demonstrated.

1. Introduction

In the world of increasing global competition, overall operational excellence is one of the most significant key requirements for any business/organization to survive in the highly competitive market. Due to this the companies around the globe are forced to change the manner of doing business. Various approaches and practices were adopted by the companies to enhance the quality level of the product at minimum cost and eventually to achieve higher customer satisfaction. Among them six sigma has been recognized as one of the most effective method. Six sigma has been launched all over the world and many companies testify to its pivotal role in their success [1]. Its application focuses on reducing variation in all processes, including manufacturing, service, administration, etc. Eminent examples of six sigma successes are Motorola, General Electric, Honeywell, Lockheed Martin, Polaroid, Sony, Honda, America Express, Ford, Solectron, etc [2].
Six sigma can be defined as a systematic business management philosophy which concentrates on identifying and eliminating defects, mistakes and variations in a product, process, or service in order to improve the quantity at minimum cost. Six sigma began in 1979 as a statistically based method to reduce variation in electronic manufacturing processes

*Corresponding author
E-mail address: sanjivtiwari@bitmesra.ac.in

in Motorola Inc. in the USA. Statistically, the term ‘Six Sigma’ means that processes are working nearly perfectly, delivering only 3.4 defects per million opportunities (DPMO).

The success of six sigma deployment lies in its two methodologies - DMAIC and DMADV. DMAIC (Define-Measure-Analyze-Improve-Control) is used for projects aimed at improving an existing business process. However, DMADV (Define-Measure-Analyze-Design-Verify) is used for projects aimed at creating new product or process designs. But the success or failure of six sigma deployment in an organization is pivoted with the appropriate selection of project that can be accomplished within a reasonable time span and which delivers tangible business benefits in financial terms, or will enhance customer satisfaction [3].

Thus, the main objective of this paper is to emphasize the significance of the project selection process in the successful deployment of six sigma program within an organization as well as to develop a model for the identification of critical six sigma project. For this reason, in this study we adopted an integrated decision framework based on Extent Fuzzy Analytic Hierarchy Process (EFAHP) for selecting the most appropriate six sigma project alternative.

In the flow of the paper, Section 2 covers a brief review on six sigma project selection methodologies, which assists in the identification of various methods for the project selection in the six sigma deployment and understanding the existing gap in quality management literatures on the project selection methodology. Section 3 introduces the Chang’s extent analysis method of fuzzy AHP and its application in the research and academia literatures. In section 4, a case example is used to validate the above approach. In section 5, results of the case are discussed and finally section 6 concludes the paper.

2. Six Sigma Project Selection: A Review

Selection of the right six sigma projects is one of the most sensitive elements in the deployment of six sigma program [4, 5, 6, 7]. According to Snee [8], “six sigma project is a problem scheduled for solution that has a set of metrics that can be used to set project goal and monitor progress”. Selecting the right project is generally considered as a key factor for the early success and long term acceptance of six sigma within the organization [9, 10].

In fact, six sigma is a quality enhancement program that takes place project by project [11]. Six sigma benchmarks the target in terms of figures which can be then utilized for scrutiny of the improvement. Once a target is set an assortment of right project is carried out, which is one of the most vital aspects for the success of a six sigma project. Project selection, as a vital decision requires like capital, labor, etc., is one of the most critical success factors for the effective deployment of a six sigma program [12].

Recently, six sigma project selection problems become one of the most prominent areas among the researchers and academia. Most recently, Buyukozkan and Ozturkacn [13] develop a novel approach based on a combined analytic network process (ANP) and decision making trial and evaluation laboratory (DEMATEL) technique to help companies determine critical six sigma projects and identify the priority of these projects, especially in logistics companies. Yang and Hsieh [2] proposed a methodology for the project selection using national quality criteria and Delphi fuzzy multiple criteria decision making method. Kumar et al. [14] presented a hybrid methodology combining AHP for six sigma project selection.

Tkac and Lyocsa [15] outlined six sigma project characteristics and presented a new mathematical model for evaluating six sigma projects. Hu et al. [16] developed a unique decision support system that utilizes a multi-objective formulation for project portfolio section problem in manufacturing companies. Bonila et al. [17] developed a modified quality function deployment (QFD) to select and prioritize projects by weighting an internal staff assessment and mapping this against a patient survey. Mahmoodzadeh et al. [18] proposed a new methodology to provide a simple approach to assess alternative projects and help decision maker to select the best one by using improved fuzzy AHP and TOPSIS technique. Kumar et al. [19] provide the identification of important inputs and outputs for six sigma projects that are then analyzed using data envelopment analysis (DEA) to identify projects, which result in maximum benefit. Banuelas et al. [20] use survey as a method of investigation, respondents were asked what criteria are considered to select projects and how potential projects are identified, prioritized, selected and evaluated.

Although selecting the right six sigma projects is one of the most sensitive elements in the deployment of six sigma, in spite of this, only rare focus could be found in the previous six sigma literatures. However, some literatures focused on the six sigma project selection problems but none of them concentrates on handling the ambiguity and vagueness associated with the decision makers. Thus, the main aim of this study is to cope the ambiguity and vagueness associated with the decision makers' while selecting the right six sigma projects by adopting an integrated decision framework based on Extent Fuzzy Analytic Hierarchy Process (EFAHP) for selecting the most appropriate six sigma project alternative.

3. Extent Fuzzy Analytic Hierarchy Process (EFAHP): The Proposed Framework

Analytic hierarchy process (AHP) has been widely used as a powerful tool for multiple criteria decision making (MCDM) in many areas such as selection, evaluation, planning, resource allocations, resolving conflict, optimization, etc [21]. Inspite of being a powerful tool, AHP has some limitations like; (1) Use of crisp values only, (2) Unbalanced scale of judgment, (3) Uncertainty and ambiguity associated with the judgment of decision makers, (4) Imprecise ranking method, (5) Influences of decision makers on the judgment [22].

One of the main limitations of AHP is the judgment scale for the pairwise comparison, which is basically crisp numerical judgmental, induces impreciseness/uncertainty in the evaluation. Thus, to handle the vague, imprecise and uncertainty associated with the judgment of the decision makers, fuzzy-logic [23] is integrated with the AHP and this variant of AHP is called Fuzzy AHP (FAHP). The FAHP approach provides a more accurate and realistic picture of the decision making process and due to which FAHP increasingly attracts industry applications and scholarly research [24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34].

FAHP can be viewed as a sophisticated analytical method developed from the traditional AHP. Generally, it is impossible to reflect the decision makers' uncertain preferences through crisp values. Therefore, FAHP is proposed to relieve the uncertainness of AHP method, where the fuzzy comparison ratios are used. There are several procedures to attain the priorities in FAHP in which some are: fuzzy least square method [32], method based on the fuzzy modification of the LLSM [25], geometric mean method [35], the direct fuzzification of the method of [36], synthetic extent analysis [37], Mikhailov's fuzzy preference programming [38] and two-stage logarithmic programming [39].

Chang [40] introduced a new approach for handling pairwise comparison scale based on triangular fuzzy numbers followed by the use of extent analysis method for synthetic extent value of the pairwise comparison [37]. EFAHP is an improved version of FAHP. Similar to the FAHP, EFAHP also converts the linguistic assessment of decision makers into triangular fuzzy numbers, which are used to build the pairwise comparison matrix of AHP. Then the EFAHP uses the extent analysis method and principles of comparison of fuzzy numbers to drive weight vectors. This improves the hitherto imprecise works which used the conventional AHP and the fuzzy AHP. The enhanced fuzzy AHP with extent analysis refers to the "extent" to which an object satisfies a goal and where "satisfied extent" is defined by means of triangular fuzzy numbers. The weight vectors of the fuzzy AHP can be calculated using extent analysis and the principles of comparison of fuzzy numbers. Compared to eigenvectors which are used to calculate weight vectors in the conventional AHP, the enhanced fuzzy AHP is simple and easy to implement for the purpose of prioritizing.

Consider a triangular fuzzy comparison matrix expressed by:

$$A = (a_{ij})_{n\times n} = \begin{bmatrix} (1,1,1) & (l_{12}, m_{12}, u_{12}) & \cdots & (l_{1n}, m_{1n}, u_{1n}) \\ (l_{21}, m_{21}, u_{21}) & (1,1,1) & \cdots & (l_{2n}, m_{2n}, u_{2n}) \\ \vdots & \vdots & \ddots & \vdots \\ (l_{n1}, m_{n1}, u_{n1}) & (l_{n2}, m_{n2}, u_{n2}) & \cdots & (1,1,1) \end{bmatrix} \quad (1)$$

where, $a_{ij} = \left(l_{ij}, m_{ij}, u_{ij}\right) = a_{ji}^{-1} = \left(\frac{1}{u_{ji}}, \frac{1}{m_{ji}}, \frac{1}{l_{ji}}\right)$ for $i, j = 1, \dots\dots, n$ and $i \neq j$.

To calculate a priority vector of the above triangular fuzzy comparison matrix, Chang (1996) [37] suggested an extent analysis method, which is summarized as follows:

STEP 1: Sum up each row of the fuzzy comparison matrix A by fuzzy arithmetic operations:

$$RS_i = \sum_{j=1}^{n} a_{ij} = \left(\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij}\right), \qquad i = 1, \dots\dots, n. \quad (2)$$

STEP 2: Normalize the above row sums by:

$$S_i = \frac{RS_i}{\sum_{j=1}^{n} RS_j} = \left(\frac{\sum_{j=1}^{n} l_{ij}}{\sum_{k=1}^{n}\sum_{j=1}^{n} u_{kj}}, \frac{\sum_{j=1}^{n} m_{ij}}{\sum_{k=1}^{n}\sum_{j=1}^{n} m_{kj}}, \frac{\sum_{j=1}^{n} u_{ij}}{\sum_{k=1}^{n}\sum_{j=1}^{n} l_{kj}}\right) \qquad i = 1, \dots\dots, n. \quad (3)$$

STEP 3: Compute the degree of possibility of $S_i \geq S_j$ by the following equation:

$$V\left(S_i \geq S_j\right) = f(x) = \begin{cases} 1, & if\ m_i \geq m_j \\ \frac{u_i - l_j}{(u_i - m_i) + (m_j - l_j)}, & if\ l_j \leq u_i \\ 0, & others \end{cases} \qquad i, j = 1, \dots\dots., n; j \neq i \quad (4)$$

where, $S_i = (l_i, m_i, u_i)$ and $S_j = (l_j, m_j, u_j)$. The definition of possibility degree is shown in Figure 1.

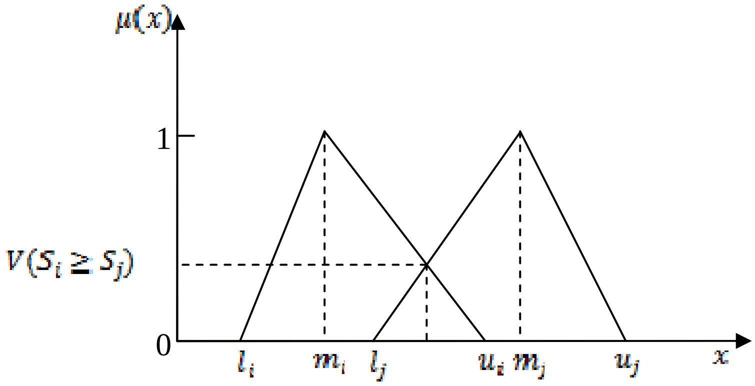

Figure 1. Definition of the degree of possibility of $V(S_i \geq S_j)$

STEP 4: Calculate the degree of possibility of S_i over all the other $(n-1)$ fuzzy numbers by:

$$V\left(S_i \geq S_j | j = 1, \dots, n; j \neq i\right) = \min_{j\in\{1,\dots\dots,n\}, j\neq i} V(S_i \geq S_j) \qquad i = 1, \dots\dots, n. \qquad (5)$$

STEP 5: Finally, define the priority vector $W = (w_1, \dots\dots, w_n)^T$ of the fuzzy comparison matrix A as:

$$W_i = \frac{V\left(S_i \geq S_j | j=1,\dots,n; j\neq i\right)}{\sum_{k=1}^{n} V\left(S_k \geq S_j | j=1,\dots,n; j\neq k\right)} \qquad i = 1, \dots\dots, n. \qquad (6)$$

4. Case Example

4.1.Company Background

In this study, a case of die-casting unit is taken. The company is engaged in designing and manufacturing various types of precision machined components using pressure and gravity die-casting processes. The main customers of the company are automobile industries. Due to increase in the demand of product due to globalization and a boom in the automobile sector, company was facing stiff challenges from its competitors. The company was struggling to identify the areas for improvement and prioritizing projects that were aligned to the strategic goals of the business. There was no formal, established decision-making procedure or criteria for evaluating the importance of different projects within the company. As a result, many projects failed to achieve the desired results and were terminated before completion due to the change in management focus and priority. Top management realized the threat the company from its competitors and thus accentuated the identification of projects that could have a higher impact on the business financially and strategically, with minimum efforts. Thus, this paper aims to propose a formal approach for the selection of six sigma projects by the application of EFAHP.

4.2.Project Selection Using EFAHP

After the discussion with the top management, managers and shop floor personnel, author analyzed numerous dimensions for selecting the right six sigma project and categorized those dimensions under four criteria and each criterion has four sub-criteria and total of 16 sub-criteria. The general evaluation model of six sigma project selection is shown in Figure 2.

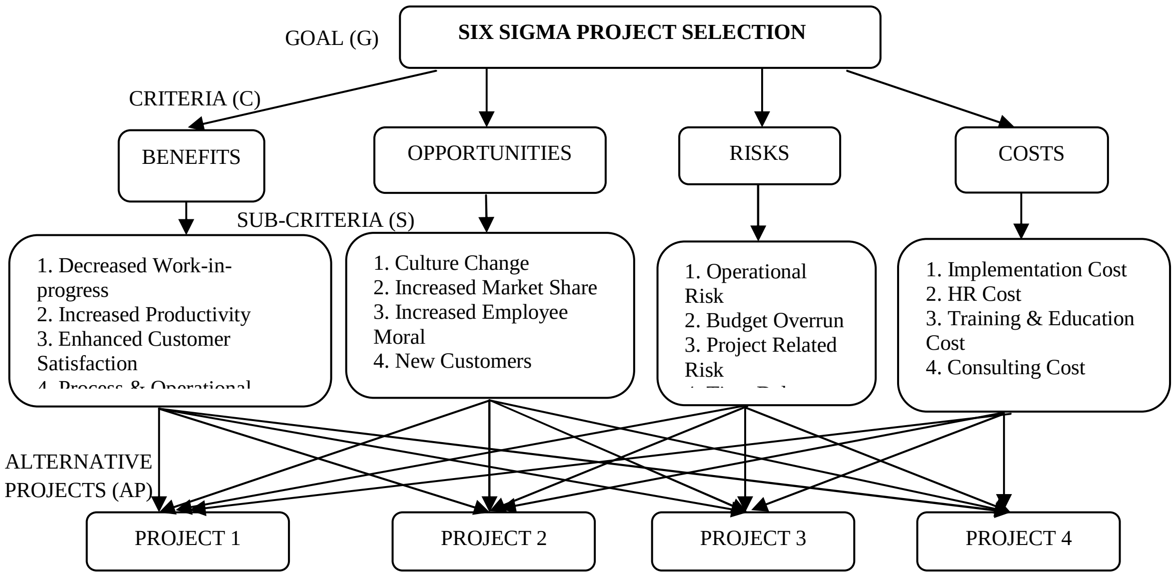

Figure 2. General six sigma project evaluation model

4.3.Development of Fuzzy Comparison Matrix

In order to take the vagueness of assessment of pairwise comparison into consideration, triangular numbers $A_1, A_3, A_5, A_7, \& A_9$ as shown in Figure 3, are used to represent the assessment for *"equal, moderate, strong, very strong and extremely"*. Tables 1-21 show the comparison matrices between various criteria, sub-criteria and project alternatives.

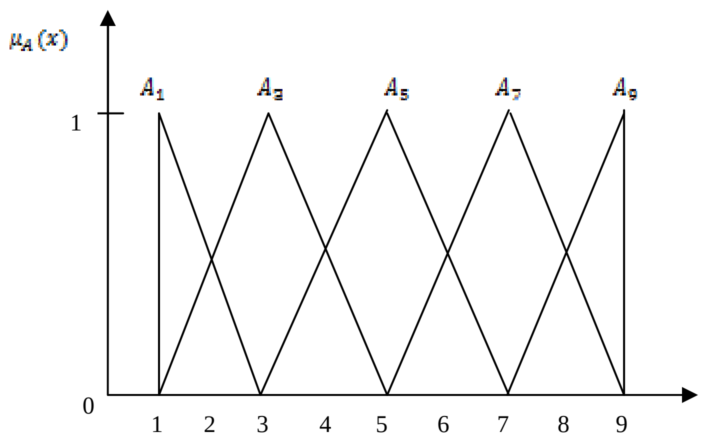

Figure 3. Membership functions of the triangular numbers

Table 1. Evaluation of criteria with respect to goal

	Benefits (C1)	Opportunities (C2)	Risks (C3)	Costs (C4)
Benefits (C1)	(1, 1, 1)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)
Opportunities (C2)	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)	(1, 3, 5)
Risks (C3)	(0.11, 0.14, 0.2)	(0.33, 1, 1)	(1, 1, 1)	(1, 1, 3)
Costs (C4)	(0.11, 0.14, 0.2)	(0.2, 0.33, 1)	(0.33, 1, 1)	(1, 1, 1)

Table 2. Evaluation of sub-criteria of benefits

	S1	S2	S3	S4
S1	(1, 1, 1)	(1, 1, 3)	(3, 5, 7)	(5, 7, 9)
S2	(0.33, 1, 1)	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)
S3	(0.14, 0.2, 0.33)	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)
S4	(0.11, 0.14, 0.2)	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)

Table 3. Evaluation of sub-criteria of opportunities

	S5	S6	S7	S8
S5	(1, 1, 1)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)
S6	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)	(1, 1, 3)
S7	(0.11, 0.14, 0.2)	(0.33, 1, 1)	(1, 1, 1)	(1, 1, 3)
S8	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(0.33, 1, 1)	(1, 1, 1)

Table 4. Evaluation of sub-criteria of risks

	S9	S10	S11	S12
S9	(1, 1, 1)	(0.33, 1, 1)	(1, 3, 5)	(5, 7, 9)
S10	(1, 1, 3)	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)
S11	(0.2, 0.33, 1)	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)
S12	(0.11, 0.14, 0.2)	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)

Table 5. Evaluation of sub-criteria of costs

	S13	S14	S15	S16
S13	(1, 1, 1)	(3, 5, 7)	(5, 7, 9)	(1, 1, 3)
S14	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)	(0.2, 0.33, 1)
S15	(0.11, 0.14, 0.2)	(0.33, 1, 1)	(1, 1, 1)	(0.14, 0.2, 0.33)
S16	(0.33, 1, 1)	(1, 3, 5)	(3, 5, 7)	(1, 1, 1)

Table 6. Evaluation of six sigma project alternatives with respect to decreased work-in progress

	A1	A2	A3	A4
A1	(1, 1, 1)	(3, 5, 7)	(1, 1, 3)	(1, 1, 3)
A2	(0.14, 0.2, 0.33)	(1, 1, 1)	(0.14, 0.2, 0.33)	(0.2, 0.33, 1)
A3	(0.33, 1, 1)	(3, 5, 7)	(1, 1, 1)	(1, 1, 3)
A4	(0.33, 1, 1)	(1, 3, 5)	(0.33, 1, 1)	(1, 1, 1)

Table 7. Evaluation of six sigma project alternatives with respect to increased productivity

	A1	A2	A3	A4
A1	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)
A2	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)	(1, 3, 5)
A3	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)	(1, 1, 3)
A4	(0.11, 0.14, 0.2)	(0.2, 0.33, 1)	(0.33, 1, 1)	(1, 1, 1)

Table 8. Evaluation of six sigma project alternatives with respect to enhanced customer satisfaction

	A1	A2	A3	A4
A1	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)
A2	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)	(1, 1, 3)
A3	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)	(1, 1, 3)
A4	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(0.33, 1, 1)	(1, 1, 1)

Table 9. Evaluation of six sigma project alternatives with respect to process and operational excellence

	A1	A2	A3	A4
A1	(1, 1, 1)	(1, 1, 3)	(3, 5, 7)	(5, 7, 9)
A2	(0.33, 1, 1)	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)
A3	(0.14, 0.2, 0.33)	(0.14, 0.2, 0.33)	(1, 1, 1)	(0.33, 1, 1)
A4	(0.11, 0.14, 0.2)	(0.14, 0.2, 0.33)	(1, 1, 3)	(1, 1, 1)

Table 10. Evaluation of six sigma project alternatives with respect to culture change

	A1	A2	A3	A4
A1	(1, 1, 1)	(0.33, 1, 1)	(0.11, 0.14, 0.2)	(1, 1, 3)
A2	(1, 1, 3)	(1, 1, 1)	(0.14, 0.2, 0.33)	(1, 3, 5)
A3	(5, 7, 9)	(3, 5, 7)	(1, 1, 1)	(5, 7, 9)
A4	(0.33, 1, 1)	(0.2, 0.33, 1)	(0.11, 0.14, 0.2)	(1, 1, 1)

Table 11. Evaluation of six sigma project alternatives with respect to increased market share

	A1	A2	A3	A4
A1	(1, 1, 1)	(0.33, 1, 1)	(3, 5, 7)	(5, 7, 9)
A2	(1, 1, 3)	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)
A3	(0.14, 0.2, 0.33)	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)
A4	(0.11, 0.14, 0.2)	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)

Table 12. Evaluation of six sigma project alternatives with respect to increased employee moral

	A1	A2	A3	A4
A1	(1, 1, 1)	(1, 3, 5)	(3, 5, 7)	(3, 5, 7)
A2	(0.2, 0.33, 1)	(1, 1, 1)	(1, 1, 3)	(1, 1, 3)
A3	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)	(1, 1, 3)
A4	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(0.33, 1, 1)	(1, 1, 1)

Table 13. Evaluation of six sigma project alternatives with respect to new customers

	A1	A2	A3	A4
A1	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)
A2	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)	(1, 1, 3)
A3	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)	(1, 1, 3)
A4	(0.11, 0.14, 0.2)	(0.33, 1, 1)	(0.33, 1, 1)	(1, 1, 1)

Table 14. Evaluation of six sigma project alternatives with respect to operational risk

	A1	A2	A3	A4
A1	(1, 1, 1)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)
A2	(0.11, 0.14, 0.2)	(1, 1, 1)	(1, 1, 3)	(1, 1, 3)
A3	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)	(0.33, 1, 1)
A4	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 3)	(1, 1, 1)

Table 15. Evaluation of six sigma project alternatives with respect to budget overrun

	A1	A2	A3	A4
A1	(1, 1, 1)	(1, 1, 3)	(3, 5, 7)	(5, 7, 9)
A2	(0.33, 1, 1)	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)
A3	(0.14, 0.2, 0.33)	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)
A4	(0.11, 0.14, 0.2)	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)

Table 16. Evaluation of six sigma project alternatives with respect to project related risk

	A1	A2	A3	A4
A1	(1, 1, 1)	(1, 1, 3)	(1, 1, 3)	(5, 7, 9)
A2	(0.33, 1, 1)	(1, 1, 1)	(1, 1, 3)	(3, 5, 7)
A3	(0.33, 1, 1)	(0.33, 1, 1)	(1, 1, 1)	(3, 5, 7)
A4	(0.11, 0.14, 0.2)	(0.14, 0.2, 0.33)	(0.14, 0.2, 0.33)	(1, 1, 1)

Table 17. Evaluation of six sigma project alternatives with respect to time delay

	A1	A2	A3	A4
A1	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)
A2	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)	(1, 3, 5)
A3	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)	(1, 1, 3)
A4	(0.11, 0.14, 0.2)	(0.2, 0.33, 1)	(0.33, 1, 1)	(1, 1, 1)

Table 18. Evaluation of six sigma project alternatives with respect to implementation cost

	A1	A2	A3	A4
A1	(1, 1, 1)	(0.33, 1, 1)	(3, 5, 7)	(5, 7, 9)
A2	(1, 1, 3)	(1, 1, 1)	(5, 7, 9)	(3, 5, 7)
A3	(0.14, 0.2, 0.33)	(0.11, 0.14, 0.2)	(1, 1, 1)	(0.33, 1, 1)
A4	(0.11, 0.14, 0.2)	(0.14, 0.2, 0.33)	(1, 1, 3)	(1, 1, 1)

Table 19. Evaluation of six sigma project alternatives with respect to HR cost

	A1	A2	A3	A4
A1	(1, 1, 1)	(0.33, 1, 1)	(1, 3, 5)	(3, 5, 7)
A2	(1, 1, 3)	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)
A3	(0.2, 0.33, 1)	(0.14, 0.2, 0.33)	(1, 1, 1)	(1, 1, 3)
A4	(0.14, 0.2, 0.33)	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)

Table 20. Evaluation of six sigma project alternatives with respect to training and education cost

	A1	A2	A3	A4
A1	(1, 1, 1)	(0.33, 1, 1)	(0.11, 0.14, 0.2)	(0.33, 1, 1)
A2	(1, 1, 3)	(1, 1, 1)	(0.14, 0.2, 0.33)	(1, 1, 3)
A3	(5, 7, 9)	(3, 5, 7)	(1, 1, 1)	(5, 7, 9)
A4	(1, 1, 3)	(0.33, 1, 1)	(0.11, 0.14, 0.2)	(1, 1, 1)

Table 21. Evaluation of six sigma project alternatives with respect to consulting cost

	A1	A2	A3	A4
A1	(1, 1, 1)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)
A2	(0.11, 0.14, 0.2)	(1, 1, 1)	(1, 1, 3)	(1, 1, 3)
A3	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(1, 1, 1)	(1, 1, 3)
A4	(0.11, 0.14, 0.2)	(0.33, 1, 1)	(0.33, 1, 1)	(1, 1, 1)

5. Results and Discussion

Tables 22-24 show the priority weight vectors of the above triangular fuzzy comparison matrices by using extent fuzzy AHP.

Table 22. Weight vectors for the various criteria

	C1	C2	C3	C4
Weight	0.417993	0.083273	0.301644	0.197090

Table 23. Weight vectors for the various sub criteria

Sub-Criteria	Weight	Sub-Criteria	Weight
S1	0.333228	S9	0.319786
S2	0.296364	S10	0.319786
S3	0.046235	S11	0.066320
S4	0.324174	S12	0.294107
S5	0.321070	S13	0.531483
S6	0.040272	S14	0.046428
S7	0.317588	S15	0.008133
S8	0.321070	S16	0.413956

Table 24. Weight vectors for the various project alternatives for each sub-criterion

Sub-Criteria	Weight			
	Project 1	Project 2	Project 3	Project 4
S1	0.352275	0.011068	0.352275	0.284381
S2	0.393040	0.121307	0.292609	0.193045
S3	0.431293	0.103367	0.034046	0.431293
S4	0.331974	0.295249	0.331974	0.040803
S5	0.301644	0.083273	0.417993	0.197090
S6	0.346007	0.313749	0.003639	0.336605
S7	0.388481	0.155018	0.084357	0.372145
S8	0.322382	0.040436	0.322382	0.314800
S9	0.321013	0.036962	0.321013	0.321013
S10	0.333228	0.296364	0.046235	0.324174
S11	0.375291	0.319745	0.304964	0.000000
S12	0.393040	0.121307	0.292609	0.193045
S13	0.250000	0.250000	0.250000	0.250000
S14	0.405942	0.455401	0.107320	0.031336
S15	0.327422	0.004523	0.335942	0.332113
S16	0.335379	0.000898	0.335379	0.328344

Now, the total weights of the six sigma project selection can be derived as (see Table 25):

$$TW_{P1} = W_{C1} \times W_{S1} \times W_{P1}, \dots \dots \dots, TW_{P4} = W_{C1} \times W_{S1} \times W_{P4}, TW_{P5} = W_{C1} \times W_{S2} \times W_{P5},$$
$$\dots \dots \dots, TW_{P8} = W_{C1} \times W_{S2} \times W_{P8}, \dots \dots \dots, TW_{P20} = W_{C2} \times W_{S5} \times W_{P20}, \dots \dots \dots,$$
$$TW_{P40} = W_{C3} \times W_{S10} \times W_{P40}, \dots \dots \dots, TW_{P64} = W_{C4} \times W_{S16} \times W_{P64}$$

Table 25. Total weights of each project alternatives corresponding to each sub-criteria

	Project 1	Project 2	Project 3	Project 4
S1	0.0491	0.0015	0.0491	0.0396
S2	0.0487	0.0150	0.0362	0.0239
S3	0.0083	0.0020	0.0007	0.0083
S4	0.0450	0.0400	0.0450	0.0055
S5	0.0081	0.0022	0.0112	0.0053
S6	0.0012	0.0011	0.0000	0.0011
S7	0.0103	0.0041	0.0022	0.0098
S8	0.0086	0.0011	0.0086	0.0084
S9	0.0310	0.0036	0.0310	0.0310
S10	0.0321	0.0286	0.0045	0.0313
S11	0.0075	0.0064	0.0061	0.0000
S12	0.0349	0.0108	0.0260	0.0171
S13	0.0262	0.0262	0.0262	0.0262
S14	0.0037	0.0042	0.0010	0.0003
S15	0.0005	0.0000	0.0005	0.0005
S16	0.0274	0.0001	0.0274	0.0268
SUM	**0.3425**	**0.1468**	**0.2756**	**0.2352**

As it is shown in Table 25, Project 1 gains the best score among all the alternative projects. It means that the company has to choose the project 1 in order achieve maximum competitive advantages.

6. Conclusions

Organizations continuously seek ways to improve the quality of processes and products and differentiate themselves from their competitors to raise customer satisfaction and revenues. Six Sigma is one of the methodologies that utilize information and statistical analysis to measure and improve a company's operational performance and systems by identifying and preventing defects in manufacturing and service-related processes in order to exceed expectations of customers. One of main consideration for the success of six sigma program is the proper selection of project from various alternatives.

This study aims to provide a simple approach based on EFAHP to help the decision makers for identifying the most appropriate project alternative especially in manufacturing companies.

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