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SELECTING LEAN SIX SIGMA MANAGER BY USING TYPE-2 FUZZY AHP WITH A REAL CASE APPLICATION IN A LOGISTICS FIRM

Ufuk Cebeci[1]

Keywords:

Type 2 fuzzy AHP; Lean six sigma; MCDM; Manager Selection; Logistics.

A B S T R A C T

The aim of this study is to develop a framework for Selecting Lean Six Sigma Manager among candidates by using Type-2 Fuzzy Sets. Some authors found that the management of six sigma projects and management's commitment are very important for the prevention of failure of them. Since the problem of selection of lean six sigma manager has various and conflicting criteria, it is a Multi Criteria Decision Making problem. The trapezoidal interval type-2 fuzzy Analytic Hierarchy Process methodology, which is one of the most used methods, is applied for an industrial manager selection. The membership functions of type-1 fuzzy sets are two-dimensional, whereas the membership functions of type-2 fuzzy sets are three-dimensional. It is the new third-dimension that provides additional degrees of freedom that make it possible to directly model uncertainties. There is no study about the selection of lean six sigma manager in literature. Logistics industry is one of the most important sectors for employment all over the world. Some logistics companies are visited and studied their processes carefully. In Lean Six Sigma Manager selection process, there are multiple criteria to consider and many candidates. In order to put those linguistic criteria in numerical presentation and ranking, AHP is a widely used MCDM tool. In this paper, the proposed criteria are leadership (C1), sectoral expertise (C2), personal and environmental analysis ability (C3), education (C4).

1. INTRODUCTION

The aim of this study is to develop a framework for Selecting Lean Six Sigma Manager by using Type-2 Fuzzy Sets. The trapezoidal interval type-2 fuzzy Analytic Hierarchy Process methodology is applied for an industrial manager selection. The key resource of a modern organization is human resources. People make differences in today's global business and economy. The performance of a Lean six sigma manager can effect almost every critical processes in a company, because lean six sigma projects focus the problematic processes, bottlenecks, and the most important processes to be improved. The author has not seen any study about the selection of a lean six sigma manager. If the selection of a manager fails it will yield too much expenses and waste of time and resources. Because of different difficulties, it is hard to find a perfect method for recruitment and selection.

Lean Six Sigma concept started to be used in year 2000 as an integration of Six Sigma and Lean Manufacturing by Sheridan (2000). Before year 2000, two concepts are used independently. Taiichi Ohno founded first lean

[1] Corresponding author: Ufuk Cebeci
Email: cebeciu@itu.edu.tr

manufacturing techniques in 1950s, Toyota Japan. Lean manufacturing is called Toyota production system, which included continuous search to eliminate waste (Japanese word is called Muda), the involvement of employees to improve their processes, to reduce inventory level, increase productivity, to prevent late deliveries, to solve the problem of bottleneck machines or operations, one piece a time production, the satisfied customers, smooth flow of a production or service system like a river, etc. Womack and Jones (1996) state lean manufacturing as "a way to specify value, line up value-creating actions in the best sequence, conduct those activities without interruption whenever someone requests them, and perform them more and more effectively. In short, lean thinking is lean because it provides a way to do more and more with less and less – less human effort, less human equipment, less time, and less space – while coming closer and closer to providing customers with exactly what they want."

It is possible to deliver products in time, at a lower cost by using lean manufacturing continuous improvement techniques.

Motorola sold its TV factory to a Japan company. The new management of the company achieved zero defect quality level, soon with the same employees and without buying new technology machines. Then Bill Smith, Motorola Engineer defined a quality control process and obtained successful results. Later, Motorola defined the approach as Six Sigma and registered this concept. Six sigma stages are Define, Measure, Analyze, Improve, and Control (DMAIC) and six sigma has some similarities of PDCA (Plan, Do, Control and Act) of Kaizen (continuous improvement cycle) which is a component of Total Quality Management. General Electric (GE) is one of the pioneering firms applying six sigma. GE group explained that they saved more money in group's service companies such as banking or insurance industry than production companies after applying six sigma projects.

Snee (1999) focused the importance of statistics and described six sigma as "a business strategy that seeks to identify and eliminate causes of errors or defects or failures in business processes by focusing on outputs that are critical to customers".

Every company can apply lean six sigma techniques. In literature, it is possible to see a lot of the applications of lean six sigma; SME (small medium size enterprise) or big, domestic or local. In addition, every sector can apply lean six sigma projects. Some examples in literature are:

- Logistics services by Gutierrez-Gutierrez et al. (2016).
- A pharmaceutical firm study By Pavlovic and Bozanic (2012).
- Family Drug Courts Information Sharing by Kovach et al. (2017).
- Klochkov et al. (2019) present various lean performance characteristics with a case study from a water pump producer for sustainable business process.
- Hospital applications; in medical records department of a hospital in India by Bhat et al. (2016) and operating room efficiency of a university students hospital by Tagge et al. (2017).
- The questionnaire of the logistics firms registered by Singapore Logistics Association by Zhang et al. (2016).
- - Carvalho et al. (2017) review logistics applications in a systematic way. - The implementation methodology of lean six sigma in supply chain management suggested by Salah and Rahim (2019).
- Telecom industry application for mobile orders by Shamsuzzaman et al. (2018).

Banking industry by Muturi et al. (2015), textile by Adikorley et al. (2017), construction by Fernández-Solís, and Gadhok (2018), ship building by Jiang et al. (2016) etc. almost every sector studies can be found in literature.

It is an important concept for both production companies and service companies. Albliwi et al. (2014), after reviewing 56 papers, report that there are some common reasons for the failure such as lack of top management commitment and involvement, lack of communication, lack of training and education. Zimmerman and Weiss (2005) state that less than 50% from aerospace companies were satisfied with its Six Sigma programs according to their survey results. Chakravorty (2009) referenced that two human issues relevant for Six Sigma failures are selective perception and illusion of control. Hastorf and Cantril (1954, p.133), a person selects those that have some significance for him from his own egocentric position in the total matrix." Selective perception is not an individual trait, but is the product of individual experience and the situation at hand (Hogarth 1987).

Dearborn and Simon (1958) found managers perceive information according to their functional background.
The flow of the paper is as follows:

- The evaluated criteria for hiring six sigma manager
- Type-2 fuzzy AHP
- The developed framework and an industrial case study in an international logistics company
- Conclusion and future study.

2. CRITERIA FOR HIRING LEAN SIX SIGMA MANAGER

Marzagão and Carvalho (2016) study critical success factors of six sigma projects and apply a survey in Brazil and Argentina with 149 respondents. Their model shows that Manager, project management and six sigma techniques used for the selected problem are very important for the success of six sigma projects. The study of Marzagão and Carvalho (2016) shows the importance of the selection lean six sigma manager which the author of this paper focuses the personnel selection topic for lean six sigma. Because improper manager may focus wrong priorities and cannot use the right techniques.

There are a lot of six sigma project selection studies in literature (Adebanjo et al. 2016, Ortíz et al. 2015). However, the author of this paper has not seen any study about the selection of lean six sigma manager. If a wrong manager is selected, the decision may affect the success of all lean six sigma projects and the motivation and moral of the employees in the organization. Business professionals and academics believe that the process of personnel selection should be on justice and with minimum subjectivity.

Rahim et al. (2018) suggest a methodology for selecting best employee by using TOPSIS method. This study is applied for the selection of already working employees in a firm. They consider "Job Responsibilities, Work Discipline, Work Quality, and Behavior" criteria.

Hababou and Martel (1998) study portfolio manager selection by using MCDM, The PROMETHEE II. They defined some criteria. One of them, which is related to this study is "past performance".

Laureani and Antony (2019) review the papers, published in 97 journals, about lean six sigma and leadership. The most publishing ones are Quality Progress, International Journal of Quality & Reliability Management, International Journal of Six Sigma and Competitive Advantage, Harvard Business Review and Total Quality Management & Business Excellence.

Raymond et al. (2006) study sales managers and representatives and their study explores that managers believe objective assessment, technical skills, experiential learning, acquired skills, college accomplishments, and extracurricular activities are more important.

Young and Lee (1997) analyzed the Information System Graduate candidate selection process. After applying the questionnaire, respondent managers state top 3 ranked hiring criteria by using the below criteria:

1- Grade point average (GPA).
2-Problem-solving skills.
3-Written and oral communications skills.
4-Leadership through extracurricular activities.
5-Self-confidence and poise during the interview process.
6-Internship or other full-time work experience.
7-Technical skills.

Bills (1992) reported employers believe to hire overqualified personnel, because they may achieve carrier targets more easily. According to Bunderson and Sutcliffe (1995), functional boundaries tend to restrict a manager's view of a problem. The criteria are determined by decision makers (sector expert top manager, academics) and literature; Hababou and Martel, (1998), Raymond et al. (2006), Young and Lee (1997), Albliwi et al. (2014), Bunderson and Sutcliffe (1995). The criteria are as follows:

- Leadership
- Sectoral Expertise
- Personal and Environmental Analysis Ability
- Education.

Leadership: This concept is very important for the success of Lean Six Sigma applications. Lean Six Sigma Manager (LSSM) needs to be involved the employees, and to increase their motivation.

Sectoral Expertise: It is another important skill to understand the processes of the company and sector. The manager can see the inputs and outputs of the system easily, and have the empathy, if he or she has a sectoral expertise. Some professionals have only the theoretical background of statistics used in six sigma; therefore, they cannot understand the problems of real world.

Personal and Environmental Analysis Ability: This skill is important to build the model to solve the problem by using analysis skill.

Education: If the manager knows statistical techniques, lean concepts from university education, he or she can understand why and how necessary these techniques are. Because, sometime we meet some lean six sigma users, even consultants that they can solve a lean six sigma problem but they do not know the knowledge behind six sigma. If the model of the problem is somewhat different, they cannot solve the problem correctly. Industrial engineers or industrial & system engineers may have an advantage for the title of lean six sigma manager, because they learn statistics focused lean six sigma and Total Quality Management, in addition, how a service system or manufacturing system works at their universities.

One of the highly used methods for Multi Criteria Decision Making (MCDM) is Analytic Hierarchy Process (AHP); in which, the most suitable alternatives are found for a defined problem. While the membership functions of type-1 fuzzy sets are two-dimensional, the membership functions of type-2 fuzzy sets are three-dimensional. It is the new third dimension that provides additional degrees of freedom that make it possible to directly model uncertainties.

Runkler et al (2017) focused on risk by considering interval type-2 fuzzy sets and applied a traffic problem example and the improved results are % 8-5 better decisions.

Görener et al (2017) present a holistic approach for vendor evaluation in an aviation maintenance industry. They use type 2 fuzzy including tangible and intangible evaluation criteria.

Özkan et al. (2015) applied a hybrid multicriteria decision making methodology based on type-2 fuzzy sets to select among energy storage alternatives.

Cebeci (2018) applied type 2 fuzzy AHP for Manager Selection, and JCI (Joint Commission International, a very common hospital quality management standard developed in USA) consultant selection by using fuzzy AHP (Cebeci, 2009).

Hmoud and Lazslo (2019) review and predict Human Resources Recruitment in Artificial Intelligence and argue that Ariticial Intelligence can be used for some routine positions and applications such as sourcing and screening. When a big company search a huge number of candidates as employees or intern, this routine task can be done by AI software quickly and effectively.

A number of studies by using MCDM techniques for the selection of personnel are done by different authors such as Saaty’s AHP (1977), Liang and Wang (1994), Saaty’s ANP method (1996).

Gungor et al. (2009) applied Fuzzy Analytic Hierarchy Process to the problem of personnel selection and they compared to the results of Yager’s weighted goals method.

Petrovic-Lazarevic (2001) applied to the problem of personnel selection “senior economic and financial analyst” and developed a software and use it for the calculations.

Özdağoğlu and Özdağoğlu (2007) applied fuzzy AHP and AHP methods and compared the results for the selection of shop floor workers.

Karabasevic et al. (2016) proposed a framework and used fuzzy MCDM SWARA (Step-wise Weight Assessment Ratio Analysis) method and ARAS (Additive Ratio Assessment) method for the selection of sales manager. They used SWARA for the determination of weighting factors and ARAS for the ranking alternatives of the sales person candidates.

2.1 Type-2 fuzzy AHP

The fuzzy set theory was introduced first by Zadeh (1965). A major contribution of fuzzy set theory is its capability of representing vague data. The theory also allows mathematical operators and programming to apply to the fuzzy domain. Fuzzy sets can convert a human’s experience and judgment to quantitative data.

One of the highly used methods for Multi Criteria Decision Making (MCDM) is Analytic Hierarchy Process (AHP); in which, the most suitable alternatives are found for a defined problem.

Classical AHP is a subjective method and form unbalanced judgement scale. Fuzzy AHP is used very commonly, because it can reflect human thinking style, whereas classical AHP cannot reflect. Fuzzy AHP can be used to prevent this risk. Özdağoğlu and Özdağoğlu (2007) concluded that “Some pessimistic people may not give any point more than four, or very optimistic people may easily give 5 even if it does not deserve it. These situations generate fuzziness within the decision making process, so fuzzy AHP method can handle these deviations concerning this fuzziness. Therefore, for the employee selection problems, if a multi-criteria decision making method with linguistic evaluations is selected, this method can be fuzzy AHP or similar methods concerning fuzzy conditions.”

The membership functions of type-1 fuzzy sets are crisp; therefore, they cannot model uncertainties directly. But the membership functions of type-2 fuzzy sets are fuzzy, they can model uncertainties.

Kahraman et al., (2014) developed trapezoidal interval type-2 fuzzy AHP method together with a new ranking method for type-2 fuzzy sets and applied the proposed method to a supplier selection problem.

While the membership functions of type-1 fuzzy sets are two-dimensional, the membership functions of type-2 fuzzy sets are three-dimensional. It is the new third-dimension that provides additional degrees of freedom that make it possible to directly model uncertainties.

An interval type-2 fuzzy set is a special case of a generalized type-2 fuzzy set. Since generalized type-2 fuzzy sets require complex and immense computational burdensome operations, the wide spread application of generalized type-2 fuzzy systems has not occurred. Interval type-2 fuzzy sets are the most commonly used type-2 fuzzy sets because of their simplicity and reduced computational effort with respect to general type-2 fuzzy sets.

In this paper, the trapezoidal interval type-2 fuzzy Analytic Hierarchy Process methodology is applied to the problem of the industrial manager selection of lean six sigma.

3. DEVELOPED FRAMEWORK AND AN INDUSTRIAL CASE STUDY APPLIED IN LOGISTICS SECTOR

Logistics industry is one of the most important sectors for employment all over the world. Turkey’s advantageous geographical location that stretches from Asia to Europe and Russia to Africa, allows it to be a hub for over USD 2 trillion freight carried in the region.

Turkey (LODER), Turkey's current logistics industry size is estimated to be USD 80-100 billion and is forecast to reach USD 108-140 billion by 2017. A strong and diversified economy will contribute to the expansion of the logistics industry. Since many industries support or rely on the logistics industry, their growth would indirectly stimulate growth in logistics. Global logistics players are keen to invest in Turkey because of the growth potential within the Turkish economy and its proximity to Europe and Asia. Turkey has already attracted big global players.

The Lean Six Sigma Manager Candidate Selection Flow Chart is shown in Figure 1.

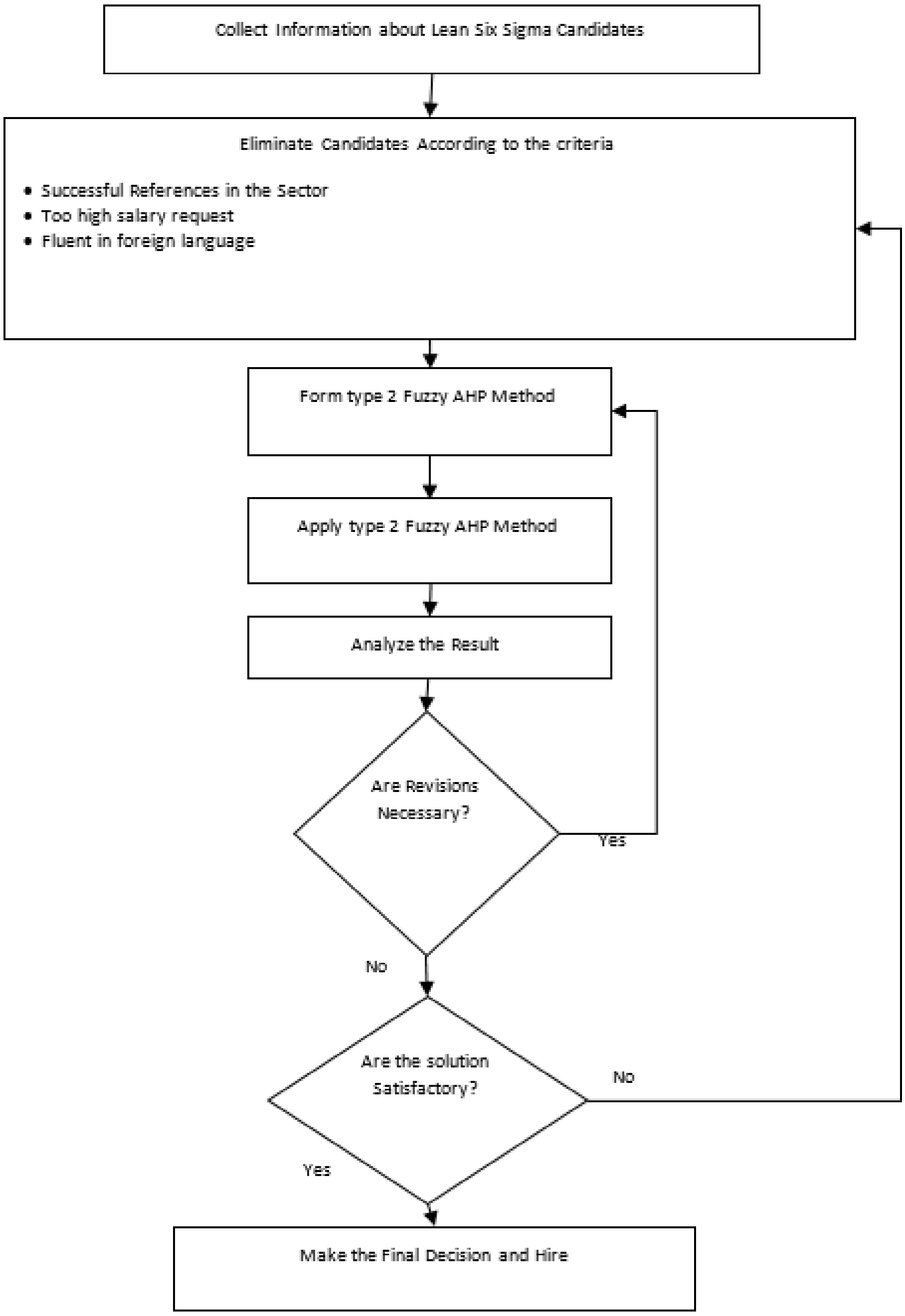

Figure 1. Lean Six Sigma Manager Candidate Selection Flow Chart

Turkey is building logistics centers/villages that will serve to lower the costs of transportation by offering various different modes of transportation within these centers/villages. It is estimated that by 2023, total freight carried in the centers/villages will reach a total of USD 500 billion. [www.invest.gov.tr/enUS/infocenter/publications/Documents/TRANSPORTATION-LOGISTICS-INDUSTRY.pdf] Turkey has a population of 76 million people and is growing with rising income levels. This makes Turkey one of the largest markets in its region, and the changing consumer habits of the younger generation boost domestic consumption. Organizations are continuously looking for the new ways to improve their performance and stay competitive in

their markets. Some logistics companies are visited and studied their processes carefully. The logistics firms visited are Hedef Logistics, Imser Logistics, TTS Logistics.Two software house (Select: http://www.selectyazilim.com and Kesit, www.kesit.info), expert about logistics software are visited and analyzed their software. Information About The Company: NMT Logistics company (http://www.nmtlojistik.com/en) was chosen to apply this study (type-2 Fuzzy AHP for selecting and hiring Lean Six Sigma Manager), because of top management's commitment. NMT Logistics, established in 2007, is a company operating in the area of supply chain management and international transportation, having R2 certificate, ISO 9001 quality management system cetificate and is a member of The Turkish Chamber of Shipping. The company, having its headquarter in Istanbul, serves through its 4 domestic cities and Antwerp offices and a network of agencies spread over 189 countries. With its wide agency network throughout the world, it continues to serve, with a sense of qualified, reliable, and professional service supply and with its wide agency connections, to many regions of Africa, Europe, and America, especially to the Far East, Middle East and Mediterranen Countries, in the areas of FCL full container,LCL partial shipments, domestic transportation, chartering, transit trade transportation, andmcombined transportation.
(http://www.nmtlojistik.com/en)
NMT's Vision: By changing the meaning of customer and providing qualified, reliable, and affordable services, to become the pioneering company of the forwarding business. (http://www.nmtlojistik.com/en/vision)

Lean six sigma candidate selection is very important for NMT Logistics, because the competition is very high in the sector and NMT has a number of branches all over the world. In addition, one of the strategies of NMT is to increase productivity of the processes and to increase customer satisfaction (including internal customer; employees) by means of lean six sigma. The top management committed this strategy and the vision and the managers share them with the employees. The company will start strategic projects to realize and to deploy the strategy. A national funding and granting organization supported the lean six sigma projects. Some KPIs (Key performance indicator) are defined;

- To reduce the lead times of the customer orders,
- To reduce average cost per order,
- To increase customer satisfaction,
- To increase employee involvement and satisfaction,
- To reduce quality problems,
- To reduce customer complaints.

NMT is a growing company, therefore they should define its processes very carefully and make them in a sustainable way. NMT bought personal computers and new licenses for a statistical software package to be used in lean six sigma projects for a better software and hardware infrastructure. A domestic ERP which is specific to logistics sector is used. In addition the firm signed a contract to improve the ERP to gather preliminary data from processes and to measure the improvement and to see the progress of key performance indicators. The ERP will be customized also according to the specific needs of the processes and to get various reports. It is obvious that if the digitalization of a company is high, a company can get real, accurate, in time, integrated data and related reports from ERP, CRM and other software.

NMT preferred to hire an industrial engineer or an industrial & system engineer, because NMT managers believe that both theoretical and practical statistics education is an advantage. After the interviews, four candidates are eliminated. One candidate is eliminated because he failed to the criterion "Successful References in the Sector" after his former employer is called, one candidate is eliminated according to the criterion "Too high salary request" and two candidates are eliminated to the criterion "Fluent in foreign language".

Finally, two candidates are left for the application of selecting the lean six sigma manager.

One of the highly used methods for Multi Criteria Decision Making (MCDM) is Analytic Hierarchy Process (AHP); in which, the most suitable alternatives are found for a defined problem. Kahraman et al., (2014) used trapezoidal interval type-2 fuzzy AHP method together with a new ranking method for type-2 fuzzy sets and applied the proposed method to a supplier selection problem. In this paper, the trapezoidal interval type-2 fuzzy Analytic Hierarchy Process methodology is applied for an industrial manager selection.

Definition 1: A trapezoidal interval type-2 fuzzy set can be illustrated as below:

$\tilde{\tilde{A}}_i = (\tilde{A}_i^U; \tilde{A}_i^L)$=(($a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U$;$H_1(\tilde{A}_i^U), H_2(\tilde{A}_i^U)$), ($a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L$;$H_1(\tilde{A}_i^L), H_2(\tilde{A}_i^L)$)) (1)

Where $\tilde{A}_i^U$ is the upper membership function, $\tilde{A}_i^L$ is the lower membership function; a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U, a_{i1}^L, a_{i2}^L,a_{i3}^L, and a_{i4}^L are the references points of the interval type-2 fuzzy set $\tilde{\tilde{A}}_i$; $H_j(\tilde{A}_i^U)$ and $H_j(\tilde{A}_i^L)$ denote the membership values of the trapezoidal membership functions.

Step 1: Structure the decision-making problem as a hierarchy as the first step in the crisp AHP approach. After the goal has been set, criterion level should be constructed. There might be sub-criterion or sub-sub-criterion level as well, which should be constructed one level below every time. The last level should be constructed for the alternatives.

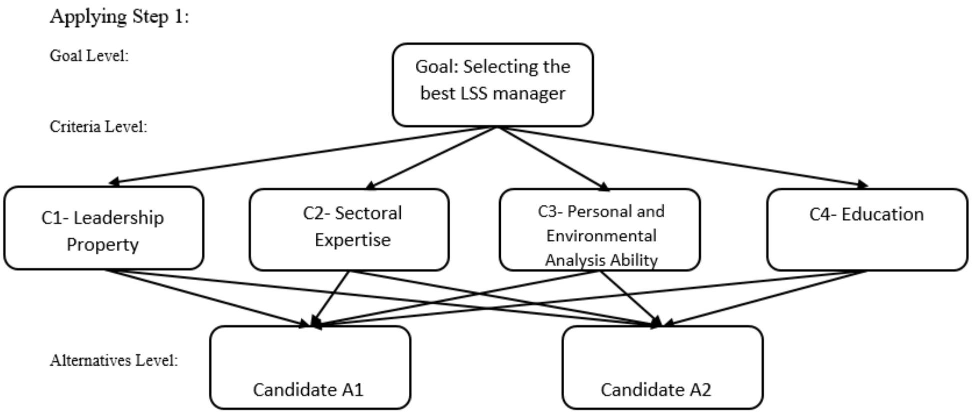

Figure 2: Hierarchy Structure

Step 2: This step is called prioritizing or weighting the criteria, here all the criteria are compared and a pairwise comparison matrix is constructed. Comparisons should be made under the consideration of the goal (i.e. While manager selection process, is sectoral experience more important or educational level?). A linguistic matrix can be constructed with the values as: AS, VS, FS, SS, E (can be seen in table below). (If criteria A is very strong (VS) with respect to criteria B, in the corresponding cell of the matrix will get a value of "VS". However, the cell corresponding to criteria B w.r.t criteria A will get a reciprocal element of "VS" (1/VS). (How to calculate those values will be shown in another step.)

Applying Step 2:
Criteria Comparison Matrix

	C1	C2	C3	C4
C1	E	1/SS	FS	VS
C2	SS	E	VS	AS
C3	1/FS	1/VS	E	SS
C4	1/VS	1/AS	1/SS	E

Step 3: With the same logic from criteria comparison matrix described in step 2, alternative comparison matrices will be constructed under the consideration of each criterion (There will be 4 matrices if there are 4 criteria).

Applying Step 3:
Alternative Matrix 1 (in relation with Criteria1)

C1	A1	A2
A1	E	1/FS
A2	FS	E

Alternative Matrix 2 (in relation with Criteria2)

C2	A1	A2
A1	E	SS
A2	1/SS	E

Alternative Matrix 3 (in relation with Criteria3)

C3	A1	A2
A1	E	AS
A2	1/AS	E

Alternative Matrix 4 (in relation with Criteria4)

C4	A1	A2
A1	E	1/VS
A2	VS	E

Step 4: Linguistic comparison matrices should be converted to trapezoidal interval type-2 fuzzy sets' numerical values as it is shown below.

Definition 2:
$(l_U, m_{1U}, m_{2U}, u_U; \alpha_U, \beta_U)(l_L, m_{1L}, m_{2L}, u_L; \alpha_L, \beta_L)$

AS Absolutely Strong
(7,8,9,9;1,1) (7.2,8.2,8.8,9;0.8,0.8)
VS Very Strong
(5,6,8,9;1,1) (5.2,6.2,7.8,8.8;0.8,0.8)
FS Fairly Strong
(3,4,6,7;1,1) (3.2,4.2,5.8,6.8;0.8,0.8)
SS Slightly Strong
(1,2,4,5;1,1) (1.2,2.2,3.8,4.8;0.8,0.8)
E Exactly Equal
(1,1,1,1;1,1) (1,1,1,1;1,1)

Cells with the reciprocal elements will be calculated as it is described below:

Definition 3:

$$1/\tilde{\tilde{a}} = \left(\left(\frac{1}{a_{14}^U}, \frac{1}{a_{13}^U}, \frac{1}{a_{12}^U}, \frac{1}{a_{11}^U}; \mathrm{H}_1(a_{12}^U), \mathrm{H}_2(a_{13}^U)\right), \left(\frac{1}{a_{24}^L}, \frac{1}{a_{23}^L}, \frac{1}{a_{22}^L}, \frac{1}{a_{21}^L}; \mathrm{H}_1(a_{22}^L), \mathrm{H}_2(a_{23}^L)\right)\right) \quad (2)$$

Applying Step 4:

Table 1. Criteria comparison matrix

	C1	C2	C3	C4
C1	(1,1,1,1;1,1) (1,1,1,1;1,1)	(0.2,0.25,0.5,1;1,1) (0.208,0.263,0.454,0.833;0.8,0.8)	(3,4,6,7;1,1) (3.2,4.2,5.8,6.8;0.8,0.8)	(5,6,8,9;1,1) (5.2,6.2,7.8,8.8;0.8,0.8)
C2	(0.2,0.25,0.5,1;1,1) (0.208,0.263,0.454,0.833;0.8,0.8)	(1,1,1,1;1,1) (1,1,1,1;1,1)	(5,6,8,9;1,1) (5.2,6.2,7.8,8.8;0.8,0.8)	(7,8,9,9;1,1) (7.2,8.2,8.8,9;0.8,0.8)
C3	(0.142,0.166,0.25,0.33;1,1) (0.147,0.172,0.238,0.312;0.8,0.8)	(0.11,0.125,0.166,0.2;1,1) (0.11,0.113,0.121,0.138;0.8,0.8)	(1,1,1,1;1,1) (1,1,1,1;1,1)	(1,2,4,5;1,1) (1.2,2.2,3.8,4.8;0.8,0.8)
C4	(0.11,0.125,0.166,0.2;1,1) (0.11,0.113,0.121,0.138;0.8,0.8)	(0.11,0.11,0.125,0.142;1,1) (0.11,0.113,0.121,0.138;0.8,0.8)	(0.2,0.25,0.5,1;1,1) (0.208,0.263,0.454,0.833;0.8,0.8)	(1,1,1,1;1,1) (1,1,1,1;1,1)

Step 5: The consistency check:

Step 5.1: The consistency should be checked for each pairwise comparison matrices. In order to do that, Defuzzified Trapezoidal Type-2 Fuzzy Set (DTraT) approach, in defuzzification, will be used. (1)

Definition 4:

$$\text{DTraT}=\frac{\frac{(u_U-l_U)+(\beta_U.m_{1U}-l_U)+(\alpha_U.m_{2U}-l_U)}{4}+l_U+\left[\frac{(u_L-l_L)+(\beta_L.m_{1L}-l_L)+(\alpha_L.m_{2L}-l_L)}{4}+l_L\right]}{2}$$

After applying the equation above for every fuzzy number, there will be crisp numbered comparison matrices (C). Those matrices will be used in order to find the consistency ratios

Applying Step 5.1:

After applying DTraT method for every fuzzy number in the criteria comparison matrix, we will get a new matrix as seen below.

	C1	C2	C3	C4
C1	1,00	0,45	4,75	6,65
C2	2,85	1,00	6,65	7,85
C3	0,21	0,14	1,00	2,85
C4	0,14	0,12	0,45	1,00

Alternative matrices do not need a consistency check, since n=2, RI=0 which means the matrix is already consistent.

Step 5.2: By eigenvector method used in all comparison matrices, the crisp priority weights (w_i) will be calculated. The eigenvector method is formulated below: The columns of given matrix are summed. Every value in a column will be divided by the calculated column's sum. This is made to normalize the crisp values.

Applying Step 5.2: Every cell value is divided by the sum of the cells in each column.

	C1	C2	C3	C4
C1	0,24	0,26	0,37	0,36
C2	0,68	0,59	0,52	0,43
C3	0,05	0,08	0,08	0,16
C4	0,03	0,07	0,03	0,05

Step 5.2: From the new matrix, each row's average values will be calculated and will be written as the weight array (W).

Applying Step 5.2:

$$\begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \end{bmatrix} = \begin{bmatrix} 0,31 \\ 0,55 \\ 0,09 \\ 0,05 \end{bmatrix} \quad (3)$$

Weight array will show the importance of the criteria as C1 has an importance of 31%, C2 has 55%, C3 has 9% and C4 has 5% of importance. It can be derived from this result that personal and environmental analysis ability (C2) is the most important criteria among all; leadership property (C1) is more important than sectoral knowledge (C3) and problem solving property (C4). Sectoral knowledge (C3) and problem solving property (C4) are very close in importance but sectoral knowledge is a more appreciated property in this case.

Step 5.2: The firstly calculated crisp comparison matrices (C) will be multiplied with their corresponding weight arrays. A new array of C*W will be obtained.

Applying Step 5.2:

$$\begin{bmatrix} a_{11} * w_1 + a_{12} * w_2 + a_{13} * w_3 + a_{14} * w_4 \\ a_{21} * w_1 + a_{22} * w_2 + a_{23} * w_3 + a_{24} * w_4 \\ a_{31} * w_1 + a_{32} * w_2 + a_{33} * w_3 + a_{34} * w_4 \\ a_{41} * w_1 + a_{42} * w_2 + a_{43} * w_3 + a_{44} * w_4 \end{bmatrix} = \begin{bmatrix} 1,3 \\ 2,4 \\ 0,4 \\ 0,2 \end{bmatrix} (4)$$

Step 5.2: CW array will be divided by the weight array(W) by using matrix division. The resulted array is eigenvector ($W_i=[\lambda_1, \lambda_2 \ldots]$) of the corresponding matrix.

(Eigenvectors will be calculated for each matrix separately.)

Applying Step 5.2:

Eigenvector of criteria comparison matrix

$$\frac{c}{w} = \begin{bmatrix}1,3\\2,4\\0,4\\0,2\end{bmatrix} / \begin{bmatrix}0,31\\0,55\\0,09\\0,05\end{bmatrix} = \begin{bmatrix}4,3\\4,4\\4,0\\4,1\end{bmatrix} = \begin{bmatrix}\lambda_1\\\lambda_2\\\lambda_3\\\lambda_4\end{bmatrix} \quad (5)$$

Step 5.3: Average of eigenvalues will be calculated (λ_{ort}).

Definition 5:

$$\lambda_{ort} = \frac{\lambda_1 + \lambda_2 + \lambda_3 + \cdots + \lambda_n}{n} \quad (6)$$

Applying Step 5.3:

$$\lambda_{ort} = \frac{4,3+4,4+4,0+4,1}{4} = 4,2 \quad (7)$$

Step 5.4: Consistency Ratio (CR) and Consistency Index (CI) will be calculated as below (RI is a pre-calculated value and can be found in the table 2). CI value should be smaller than 0.1, otherwise, corresponding matrix should be constructed again.

Definition 6:

$$\text{CR}= \frac{\lambda_{ort} - \text{n}}{\text{n}-1} \quad (8)$$

$$\text{CI}= \frac{CR}{RI} \quad (9)$$

Table 2. Random Consistency Index

n	2	3	4	5	6	7	8	9	10
RI	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.51

Applying Step 5.4:

$$\text{CR}= \frac{4,2-4}{4-1} = 0,07 \quad (10)$$

$$\text{RI}= 0,9 \quad (11)$$

$$\text{CI}= \frac{0,07}{0,9} = 0,073 < 0,1 \quad (12)$$

The criteria comparison matrix is consistent.

Step 6: Geometric mean of each row of type-2 fuzzy pairwise comparison matrices are calculated as given below;

Definition 7:

$$\tilde{\tilde{A}}_1 = ((a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1(\tilde{A}_i^U), H_2(\tilde{A}_i^U)), (a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1(\tilde{A}_i^L), H_2(\tilde{A}_i^L)))$$

$$\tilde{\tilde{A}}_2 = ((a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1(\tilde{A}_i^U), H_2(\tilde{A}_i^U)), (a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1(\tilde{A}_i^L), H_2(\tilde{A}_i^L)))$$

$$\tilde{\tilde{A}}_3 = ((a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1(\tilde{A}_i^U), H_2(\tilde{A}_i^U)), (a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1(\tilde{A}_i^L), H_2(\tilde{A}_i^L)))$$

....

$$\tilde{\tilde{A}}_n = ((a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1(\tilde{A}_i^U), H_2(\tilde{A}_i^U)), (a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1(\tilde{A}_i^L), H_2(\tilde{A}_i^L)))$$

$\tilde{\tilde{r}}_1 = [\tilde{\tilde{a}}_{11} \otimes \tilde{\tilde{a}}_{12} \otimes \tilde{\tilde{a}}_{13} \otimes \ldots \otimes \tilde{\tilde{a}}_{1n}]^{\frac{1}{n}}$ using this definition, calculation of geometric average will be;

$$\left(\prod_{i=1}^{n} \tilde{\tilde{A}}_i\right)^{\frac{1}{n}} = \Big((a_{11}^U \otimes a_{21}^U \otimes a_{31}^U \otimes \ldots \otimes a_{n1}^U)^{\frac{1}{n}}, (a_{12}^U \otimes a_{22}^U \otimes a_{32}^U \otimes \ldots \otimes a_{n2}^U)^{\frac{1}{n}}, (a_{13}^U \otimes a_{23}^U \otimes a_{33}^U \otimes \ldots \otimes a_{n3}^U)^{\frac{1}{n}}, (a_{14}^U \otimes a_{24}^U \otimes a_{34}^U \otimes \ldots \otimes a_{n4}^U)^{\frac{1}{n}}; \min\left(H_1(\tilde{A}_1^U), H_1(\tilde{A}_2^U), \ldots, H_1(\tilde{A}_n^U)\right), \min\left(H_2(\tilde{A}_1^U), H_2(\tilde{A}_2^U), \ldots, H_2(\tilde{A}_n^U)\right)\Big), \Big((a_{11}^L \otimes a_{21}^L \otimes a_{31}^L \otimes \ldots \otimes a_{n1}^L)^{\frac{1}{n}}, (a_{12}^L \otimes a_{22}^L \otimes a_{32}^L \otimes \ldots \otimes a_{n2}^L)^{\frac{1}{n}}, (a_{13}^L \otimes a_{23}^L \otimes a_{33}^L \otimes \ldots \otimes a_{n3}^L)^{\frac{1}{n}}, (a_{14}^L \otimes a_{24}^L \otimes a_{34}^L \otimes \ldots \otimes a_{n4}^L)^{\frac{1}{n}}; \min\left(H_1(\tilde{A}_1^L), H_1(\tilde{A}_2^L), \ldots, H_1(\tilde{A}_n^L)\right), \min\left(H_2(\tilde{A}_1^L), H_2(L), \ldots, H_2(\tilde{A}_n^L)\right)\Big)$$

Applying Step 6: Geometric means of criteria matrix are calculated below;

$$\begin{bmatrix}\tilde{\tilde{r}}_1\\\tilde{\tilde{r}}_2\\\tilde{\tilde{r}}_3\\\tilde{\tilde{r}}_4\end{bmatrix} = \begin{bmatrix}(1.32, 1.57, 2.21, 2.82;\ 1, 1)(1.37, 1.62, 2.13, 2.66;\ 0.8, 0.8)\\(2.43, 3.13, 4.12, 4.49;\ 1, 1)(2.59, 3.25, 4.02, 4.42;\ 0.8, 0.8)\\(0.36, 0.45, 0.64, 0.76; 1, 1)(0.38, 0.47, 0.62, 0.73;\ 0.8, 0.8)\\(0.22, 0.24, 0.32, 0.41;\ 1, 1)(0.23, 0.25, 0.31, 0.39; 0.8, 0.8)\end{bmatrix}$$

Geometric means of the alternative matrices are calculated below;

$$\begin{bmatrix}\tilde{\tilde{r}}_1\\\tilde{\tilde{r}}_2\end{bmatrix} = \begin{bmatrix}(0.4, 0.4, 0.5, 0.6;\ 1,1)(0.4, 0.4, 0.5, 0.6;\ 0.8, 0.8)\\(4.6, 2, 2.4, 4.7;\ 1, 1)(4.7, 1.8, 2.2, 2.6;\ 0.8, 0.8)\end{bmatrix}$$

$$\begin{bmatrix}\tilde{\tilde{r}}_1\\ \tilde{\tilde{r}}_2\end{bmatrix}=\begin{bmatrix}(1,1.4,2.2.2;1,1)(1.1,1.5,1.9,2.2;0.8,0.8)\\(0.4,0.5,0.7,0.5;1,1)(0.4,0.5,0.6,0.9;0.8,0.8)\end{bmatrix}$$

$$\begin{bmatrix}\tilde{\tilde{r}}_1\\ \tilde{\tilde{r}}_2\end{bmatrix}=\begin{bmatrix}(2.6,2.8,3,3;1,1)(2.7,2.9,3,3;0.8,0.8)\\(0.1,0.3,0.4,0.1;1,1)(0.1,0.3,0.3,0.4,0.8,0.8)\end{bmatrix}$$

$$\begin{bmatrix}\tilde{\tilde{r}}_1\\ \tilde{\tilde{r}}_2\end{bmatrix}=\begin{bmatrix}(0.3,0.4,0.4,0.4;1,1)(0.3,0.4,0.4,0.4;0.8,0.8)\\(6.7,2.4,2.8,6.8;1,1)(6.8,2.2,2.5,3;0.8,0.8)\end{bmatrix}$$

Step 7: Summation of the rows is required in order to make normalization by dividing each row with the sum result.

Definition 8:

$$\tilde{\tilde{w}}_i=\tilde{\tilde{r}}_i \otimes [\tilde{\tilde{r}}_1 \oplus \tilde{\tilde{r}}_2 \oplus \tilde{\tilde{r}}_3 \oplus \ldots \oplus \tilde{\tilde{r}}_n]^{-1} \quad (13)$$

Summation between the trapezoidal interval type-2 fuzzy sets;

$$\tilde{\tilde{A}}_1 \oplus \tilde{\tilde{A}}_2=\Big(\Big(a_{11}^U+a_{21}^U, a_{12}^U+a_{22}^U, a_{13}^U+a_{23}^U, a_{14}^U+a_{24}^U;\ \min\big(H_1(\tilde{A}_1^U),H_1(\tilde{A}_2^U)\big), \min\big(H_2(\tilde{A}_1^U),H_2(\tilde{A}_2^U)\big)\Big),\Big(a_{11}^L+a_{21}^L, a_{12}^L+a_{22}^L, a_{13}^L+a_{23}^L, a_{14}^L+a_{24}^L;\ \min\big(H_1(\tilde{A}_1^L),H_1(\tilde{A}_2^L)\big), \min\big(H_2(\tilde{A}_1^L),H_2(\tilde{A}_2^L)\big)\Big)\Big)$$

Applying Step 7:

$$\tilde{\tilde{w}}_1=(1.32,1.57,2.21,2.82;\ 1,1)(1.37,1.62,2.13,2.66;\ 0.8,0.8)$$
$$\otimes[(1.32,1.57,2.21,2.82;\ 1,1)(1.37,1.62,2.13,2.66;\ 0.8,0.8)$$
$$\oplus(2.43,3.13,4.12,4.49;\ 1,1)(2.59,3.25,4.02,4.42;\ 0.8,0.8)$$
$$\oplus(0.36,0.45,0.64,0.76;1,1)(0.38,0.47,0.62,0.73;\ 0.8,0.8)$$
$$\oplus(0.22,0.24,0.32,0.41;\ 1,1)(0.23,0.25,0.31,0.39;0.8,0.8)]^{-1}$$

$$\begin{bmatrix}\tilde{\tilde{w}}_{C1}\\ \tilde{\tilde{w}}_{C2}\\ \tilde{\tilde{w}}_{C3}\\ \tilde{\tilde{w}}_{C4}\end{bmatrix}=\begin{bmatrix}(0.155,0.185,0.411,0.651;\ 1,1)(0.167,0.229,0.381,0.583;\ 0.8,0.8)\\(0.287,0.369,0.764,1.037;\ 1,1)(0.316,0.460,0.719,0.969;\ 0.8,0.8)\\(0.042,0.053,0.119,0.176;\ 1,1)(0.046,0.066,0.111,0.161;\ 0.8,0.8)\\(0.026,0.029,0.059,0.095;\ 1,1)(0.028,0.035,0.055,0.085;\ 0.8,0.8)\end{bmatrix}$$

Here are the priority weights of the criteria 1,2,3 and 4 with respect to the Goal.

Priority weights of alternatives

With respect to C1

$$\begin{bmatrix}\tilde{\tilde{w}}_{A1}\\ \tilde{\tilde{w}}_{A2}\end{bmatrix}=\begin{bmatrix}(0.1,0.1,0.2,0.1;1,1)(0.1,0.2,0.2,0.1;0.8,0.8)\\(0.9,0.7,1,1,1,1)(1.5,0.7,1,0.5;0.8,0.8)\end{bmatrix}$$

With respect to C2

$$\begin{bmatrix}\tilde{\tilde{w}}_{A1}\\ \tilde{\tilde{w}}_{A2}\end{bmatrix}=\begin{bmatrix}(0.2,0.5,0.8,0.5;1,1)(0.3,0.6,0.9,0.4;0.8,0.8)\\(0.1,0.2,0.3,0.1;1,1)(0.1,0.2,0.3,0.2;0.8,0.8)\end{bmatrix}$$

With respect to C3

$$\begin{bmatrix}\tilde{\tilde{w}}_{A1}\\ \tilde{\tilde{w}}_{A2}\end{bmatrix}=\begin{bmatrix}(0.5,1,1.2,0.6;1,1)(0.8,1.1,1.3,0.6;0.8,0.8)\\(0.02,0.1,0.1,0.03;1,1)(0.04,0.1,0.1,0.1;0.8,0.8)\end{bmatrix}$$

With respect to C4

$$\begin{bmatrix}\tilde{\tilde{w}}_{A1}\\ \tilde{\tilde{w}}_{A2}\end{bmatrix}=\begin{bmatrix}(0.1,0.1,0.2,0.1;1,1)(0.1,0.1,0.2,0.1;0.8,0.8)\\(1.3,0.8,1.2,1.4;1,1)(2.1,0.8,1.1,0.6;0.8,0.8)\end{bmatrix}$$

Step 8: Construct a new Criteria-Alternative Matrix. For each alternative row, multiply each value by its corresponding criteria weight, then sum those values in order to find the priority of that alternative. Those calculations should be made for each alternative row. (In order to control, the sum of priority values will be 1.)

By applying Step 8, results shown in table 3 are calculated.

Step 9: Type-2 fuzzy and defuzzified overall weights of the alternatives. By applying Step 9, results shown in table 4 are calculated.

Table 3. Criteria-Alternative Local and Global Weights Table

Criteria	C1	C2	C3	C4
Criteria weights	(0.155,0.185,0.411,0.651; 1,1)	(0.287,0.369,0.764,1.037; 1,1)	(0.042,0.053,0.119,0.176; 1,1)	(0.026,0.029,0.059,0.095; 1,1)
	(0.167,0.229,0.381,0.583; 0.8,0.8)	(0.316,0.460,0.719,0.969; 0.8,0.8)	(0.046,0.066,0.111,0.161; 0.8,0.8)	(0.028,0.035,0.055,0.085; 0.8,0.8)
Alternatives	Local weights	Local weights	Local weights	Local weights
A1	(0.1,0.1,0.2,0.1;1,1)	(0.2,0.5,0.8,0.5;1,1)	(0.5,1,1.2,0.6;1,1)	(0.1,0.1,0.2,0.1;1,1)
	(0.1,0.2,0.2,0.1;0.8,0.8)	(0.3,0.6,0.9,0.4;0.8,0.8)	(0.8,1.1,1.3,0.6;0.8,0.8)	(0.1,0.1,0.2,0.1;0.8,0.8)
A2	(0.9,0.7,1,1,1,1)	(0.1,0.2,0.3,0.1;1,1)	(0.02,0.1,0.1,0.03;1,1)	(1.3,0.8,1.2,1.4;1,1)
	(1.5,0.7,1,0.5;0.8,0.8)	(0.1,0.2,0.3,0.2;0.8,0.8)	(0.04,0.1,0.1,0.1;0.8,0.8)	(2.1,0.8,1.1,0.6;0.8,0.8)
	Global weight	Global weight	Global weight	Global weight
A1	(0.011,0.026,0.085,0.076;1,1)	(0.054,0.177,0.635,0.467;1,1)	(0.021,0.051,0.148,0.106;1,1)	(0.002,0.003,0.01,0.009;1,1)
	(0.02,0.036,0.083,0.065;0.64,0.64)	(0.109,0.258,0.623,0.421;0.64,0.64)	(0.039,0.072,0.146,0.096;0.64,0.64)	(0.003,0.005,0.01,0.007;0.64,0.64)
A2	(0.134,0.125,0.418,0.621;1,1)	(0.024,0.063,0.224,0.095;1,1)	(0.001,0.006,0.017,0.004;1,1)	(0.033,0.024,0.07,0.131;1,1)
	(0.245,0.159,0.365,0.301;0.64,0.64)	(0.042,0.08,0.193,0.175;0.64,0.64)	(0.002,0.008,0.015,0.012;0.64,0.64)	(0.059,0.03,0.061,0.05;0.64,0.64)

Table 4. Global Weights (Tyoe-2 fuzzy, Defuzzified, Normalized Crisp)

	Type 2 fuzzy global weights	Defuzzyfied weights	Normalized crisp weights
A1	(0.088,0.257,0.878,0.658;1,1) (0.171,0.371,0.862,0.588;0.8,0.8)	0,615	0,23
A2	(0.226,0.437,0.648,3.621;1,1) (0.363,0.428,0.602,2.221;0.8,0.8)	2,083	0,77

From the case results given above, it can be seen that in the given comparisons, manager candidate A2 is a far better choice with a 0,23 points comparing to the Lean Six Sigma Manager candidate A1 with a 0,77 points.

4. CONCLUSION

The decision makers meet different factors when deciding to select the most proper lean six sigma manager candidate. If a wrong manager is selected, the decision may affect the success of lean six sigma projects and the motivation and moral of the related team members in the organization. Business professionals and academics believe that the process of personnel selection should be on justice and with minimum subjectivity. Manager, project management and six sigma techniques used for the selected problem are very important for the success of six sigma projects. This paper focuses the personnel selection topic for lean six sigma, because improper manager may focus wrong priorities and cannot use the right techniques.

The selection of the lean six sigma manager may be a different one under the different situations. The originality of the paper is using type 2 fuzzy multi criteria decision making to select the best lean six sigma candidate manager. In addition, some criteria are defined to eliminate improper candidates such as “Successful References in the Sector”, “Too high salary request” and “Fluent in foreign language” before the application of MCDM method. Since the problem of selection of lean six sigma manager has various and conflicting criteria, it is a Multi Criteria Decision Making problem. Fuzzy AHP is used very commonly, because it can reflect human thinking style, whereas classical AHP cannot reflect properly. The trapezoidal interval type-2 fuzzy Analytic Hierarchy Process methodology, which is one of the most used methods, is applied for an industrial manager selection. The membership functions of type-1 fuzzy sets are crisp; therefore, they cannot model uncertainties directly. Nevertheless, the membership functions of type-2 fuzzy sets are fuzzy, they can model uncertainties. The framework of the study is:

- Collect Information about the Candidates of Lean Six Sigma Manager position,
- Eliminate improper Candidates according to the defined criteria,
- Form type 2 Fuzzy AHP Method
- Apply type 2 Fuzzy AHP Method
- Make the Final Decision

After the evaluations of decision makers and a literature review, 4 criteria are used. Some candidates are eliminated according to the rules defined in the approach, then 2 candidates are compared. Interval type-2 fuzzy sets represent uncertainties, better. Firms can use the methodology when attempting to select both lean six sigma managers and other managers. The lessons learnt from this logistics firm case or other applications can be added into the knowledgebase of a decision support system. As a further research, some sensitivity analysis can be done and other MCDM methods can be applied and their performances can be compared.

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Ufuk Cebeci
Istanbul Technical Univercity,
Istanbul,
Turkey
cebeciu@itu.edu.tr