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Raw material supplier selection in a glove manufacturing: Application of AHP and fuzzy AHP

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A B S T R A C T

This paper considered a case of supplier selection problem in a glove manufacturer located at Yogyakarta, Indonesia that uses genuine sheep leather as the raw material. The problem is solved using both Analytical Hierarchy Process (AHP) and Fuzzy AHP, in which three versions of Fuzzy AHP are applied i.e. Extent Analysis proposed by Chang (1996) [Chang, D. Y. (1996). Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research*, *95*(3), 649-655.], Extent Analysis proposed by Wang (2008) [Wang, Y. M., Luo, Y., & Hua, Z. (2008). On the extent analysis method for fuzzy AHP and its applications. *European Journal of Operational Research*,*186*(2), 735-747.], and the modified Fuzzy LLSM proposed by Wang (2006) [Wang, Y. M., Elhag, T. M., & Hua, Z. (2006). A modified fuzzy logarithmic least squares method for fuzzy analytic hierarchy process. *Fuzzy Sets and Systems*, *157*(23), 3055-3071.]. Moreover, the research is conducted by incorporated four expert respondents, who have more than 12 years of experience in the problem. It is found that the top four priorities obtained from AHP are similar with those from Fuzzy AHP with Extent Analysis proposed by Chang (1996) and Fuzzy AHP with the modified Fuzzy LLSM proposed by Wang (2006). This priority list of supplier can be used by the manufacturer to select the raw material supplier.

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1. Introduction

Raw material places many important roles in the production process. Without enough quantity of raw material, the production process can be interrupted. In addition, the quality of raw material affects the quality of finished product. The case presented in this paper took place in a glove manufacturer company located at Yogyakarta, Indonesia, which produces gloves from genuine sheep leather as the raw material. From initial observation, it is known that the quality of glove is directly affected by the quality of the sheep leather used. If the sheep leather contains scratch and or stain then the quality of the glove produced would also be reduced. As a company usually receives raw material from its supplier(s) therefore having a good supplier that would enable the company to have the material at the right quantity, in the right time, and in the right quality is needed. According to Yadav and Sharma (2016) it is impossible for a company to reach its competitive advantage, i.e. providing product or service with low cost, without having appropriate supplier. In addition, the appropriate vendor may lead to the better performance of the company (Weber et al., 1991; Choi & Hartley, 1996). Yu and Wong (2014) also stated that competitiveness of a supply chain is influenced by the performance of its suppliers. Therefore a process to select the best supplier is important for the company (Chen et al., 2006; Gencer & Gürpinar, 2007; Kang & Lee, 2010; Agarwal et al., 2011). Research on supplier selection have been conducted in various type of industry, such as automotive industries (Choi &

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Hartley, 1996; Sagar & Singh, 2012; Yadav & Sharma, 2015), electronic firm (Gencer & Gürpinar, 2007), semiconductor industries (Chan & Chan, 2004), fast changing fashion market (Chan & Chan, 2010), furniture sectors (Liu & Hai, 2005), electrical-electronic sector (Hou & Su, 2006), pharmaceutical manufacturing firm (Asamoah et al., 2012), and railway industry (Bruno et al., 2012). Qiang and Li (2015) conducted research on information technology provider selection. Unlike previous mentioned researches, the research in this paper was conducted in a glove manufacturer located in Yogyakarta, Indonesia. In this glove manufacturer, their fulfillment order strategy is make-to-order where most of their customers usually specify quality of leather they want to use. This company has multiple suppliers to supply the leather. The quality of leather is leveled from level 1 until level 11 (I, II, III, IV, V, VI, VII, VIII, R1, R2, R3) where level 1 represents the best quality of leather. The unique characteristics of the suppliers in this company are that each supplier cannot guarantee that they are supplying the same quality of leather from one period to other period. It is because the quality of the leather depends on the quality of their livestock. Therefore, the existing procedure of supplier selection in this company requires a longer time in order for the company to check the whole suppliers regarding availability and quality of leather that they are able to provide. For example if the company received an order from a particular customer where the customer prefer to use level 2 leather as raw material, then if the company do not have stock of level 2 leather, they will check which suppliers that are able to provide them level 2 leather. The procedure is as follows: first the company selects arbitrarily one of their suppliers. Then, they ask if the selected supplier is able to provide level 2 leather with right quantity and right time. If it is not, then the company starts searching for other supplier. They keep doing this activity until the company get or find the supplier that are able to provide the leather with the right quality, in the right quantity, and in the right time as they are expected. Therefore, this current company's procedure to find supplier is not efficient yet. Beside the efficiency issues, other important things is that if the customer prefer to order gloves using level 2 leather, product price has set according to price of level 2 leather. However if the company is not able to provide level 2 leather but level 1 leather, therefore, it generates higher raw material cost. In addition, it is not possible to increase product price that has been offered to the customer. An alternative for overcoming this situation is by providing the company with the priority list of their supplier. Therefore, they will refer to that priority whenever they are looking for the right supplier. It is expected that the effort for searching appropriate vendor can be minimized and the company profit will not be reduced due to unavailability of appropriate raw material. This fact emphasizes the importance of this problem of vendor selection in a glove manufacturer located in Yogyakarta, Indonesia.

This paper is organized as follows: Section 2 presents a literature review in supplier selection problem including its methods and its application. Section 3 explains the problem description, Section 4 report the case result using AHP, Section 5 report the case result using Fuzzy AHP, Section 6 discuss the result obtained, and followed by Section 7 that present the conclusion.

2. Literature Review

In this intense business competition, supplier plays important role that enable the company to reach its competitive advantages (Liu & Hai, 2005; Chen et al., 2006; Yadav & Sharma, 2016). Therefore, the process to select the best supplier is crucial for every organization. Supplier selection itself is one the activity in the purchasing process. According to de Boer et al. (2001) purchasing process has to be done systematically. Research on supplier selection problem received much attention from the researchers. Numerous works in this area have been discussed in the literature. Weber et al. (1991) reviewed previous researches on vendor selection in Just-in-Time environment. In addition, Weber et al. (1991) stated that the supplier selection problem considers multi criteria. Timmerman (1987), Ghodsypour and O'Brien (1998), Agarwal et al. (2011), Yadav and Sharma (2016), Yildiz and Yayla (2015) have also stated that vendor selection problem is a multi criteria decision making problem. It can be seen that in most of cases, supplier selection problem use more than one criteria as a basis for selection the best supplier (Choi & Hartley, 1996; Fawcett et al., 1997, Li et al., 1997; Motwani et al.,1998; Olhager & Selldin, 2004; Mendoza et al., 2008). According to Liu and Hai (2005), different companies might apply different criteria concerning supplier selection. Based on those previous researches, it can be concluded that the step in supplier selection process started with the selection of criteria that have to be used to select the best supplier. According to de Boer et al. (2001) this step is called as pre-qualification stage in the supplier process. Several methods have been reported to deal with the problem of determining the suitable criteria for vendor selection, such as: cluster analysis (Holt, 1998; Che, 2010) and case base reasoning (Choy et al., 2003). After selecting criteria, then the next step is final choice. Numerous researches have been conducted dealing with the final choice step in the supplier selection process. Five methods have been reported previous researches dealing with decision models for the final choice-phase (de Boer, 2001). They are: Linear Weighting Model, Total Cost Ownership (Degraeve et al., 2000), Mathematical Programming (Talluri & Narasimhan, 2003; Choy et al., 2003; Talluri, 2002; Ghodsypour & O'Brien, 1998; Zhu, 2004), Statistical Models, Artificial Intelligence (AI) - based models (Choy et al., 2003). de Boer (2001) reported that Analytical Hierarchy Process (AHP) and Analytic Network Process (ANP) are included in the linear weighting model. Recently, Mohaghar et al. (2013) proposed an integration of fuzzy VIKOR and AR-DEA for the final choice. Some methods can be considered as optimization approach where in order to use those methods, the quantitative criteria are needed. However, in the supplier selection problem sometimes the company has to consider both quantitative criteria such as product price and qualitative data such as vendor reputation. In that case, AHP method developed by Saaty (1980) is a powerful tool for supplier selection problem. Previous researches have been found related to the use of AHP for supplier selection problem such as Chan (2003), Liu and Hai (2005), Asamoah et al. (2012), Bruno et al. (2012), Perçin (2006), Ramanathan (2007), Sevkli et al. (2007), Kokangul and Susuz (2009), Chamodrakas et al. (2010), Rajesh and Malliga (2013), Chan and Kumar (2007), Killincci and Onal (2011), Khorasani and Bafruei (2011), Rezaei et al. (2014). The criteria and sub criteria discussed in the previous research can be seen in Table 1.

Table 1
Criteria and sub criteria used in the previous researches on supplier selection

	Criteria	Sub criteria
	Qualitative	
1	**Service** Wilson, 1994; Bhutta and Huq, 2002; Mirabi et al., 2010; Mendoza, 2007; Li et al., 2013	**Flexibility** Wilson, 1994; Çebi and Bayraktar, 2003; Nayak et al., 2011; Mirabi et al., 2010, Thakkar et al., 2012 **Capability of managing risk related to:** **Low quality product** Azizi and Modarres, 2010 **Increase in production cost** Azizi and Modarres, 2010 **Delay delivery of material** Azizi and Modarres, 2010 **Delivery** Wilson, 1994; Kumar Kar and Pani, 2014; Çebi and Bayraktar, 2003; Paksoy et al., 2013; Vonderembse and Tracey, 1999; Mafakheri et al., 2011; Choi and Chang, 2006; Nazari-Shirkouhi, et al., 2013; Kannan et al., 2013 **Technical Support** Wilson, 1994
2	**Quality** Wilson, 1994; Kumar Kar and Pani, 2014; Jayaraman et al., 1999; Bhutta and Huq, 2002; Gnanasekaran et al., 2006; Paksoy et al., 2013; Vonderembse and Tracey, 1999; Asamoah et al., 2012; Gonzales et al., 2004; Weber and Elram, 1993; Hsu et al., 2014; Mirabi et al., 2010; Thakkar et al., 2012; Mendoza, 2007; Mafakheri et al., 2011; Choi and Chang, 2006; Nazari-Shirkouhi et al., 2013; Kannan et al., 2013; Li et al., 2013	**Financial power** Kumar Kar and Pani, 2014, Çebi and Bayraktar, 2003 **Reputation and vendor position in the market** Wilson, 1994; Çebi and Bayraktar, 2003; Asamoah et al., 2012; Li et al., 2013 **Management and compatibility** Çebi and Bayraktar, 2003; Vonderembse and Tracey, 1999; Asamoah et al., 2012 **Relationship with the vendor** (Çebi and Bayraktar, 2003) **such as**: ***Communication*** Çebi and Bayraktar, 2003; Asamoah et al., 2012 ***Past experience*** Çebi and Bayraktar, 2003; Li et al., 2013 ***Sales representative competence*** Kumar Kar and Pani, 2014, Çebi and Bayraktar, 2003; Nayak et al., 2011; Thakkar et al., 2012; Li et al., 2013 ***Dedication*** Nayak et al., 2011 ***Trust*** Nayak et al., 2011

Table 1

Criteria and sub criteria used in the previous researches on supplier selection (Continued)

	Criteria	Sub criteria
3	Technological capability Kumar Kar and Pani, 2014	**Technology** Kumar Kar and Pani, 2014; Bhutta and Huq, 2002; Çebi and Bayraktar, 2003; Kannan et al., 2013 Production facility Asamoah et al., 2012
4	Delivery Wilson, 1994; Kumar Kar and Pani, 2014; Mendoza, 2007; Mafakheri et al., 2011	**Delivery time** Gnanasekaran et al., 2006; Asamoah et al., 2012; Gonzales et al., 2004; Weber and Elram, 1993; Mirabi et al., 2010
5	**Price** Kumar Kar and Pani, 2014; Jayaraman et al., 1999; Kannan et al., 2013; Asamoah et al., 2012; Weber and Elram, 1993; Thakkar et al., 2012; Li et al., 2013; Nazari-Shirkouhi et al., 2013	
6	**Economy**	**Cost** Azizi and Modarres, 2010; Mafakheri et al., 2011; Choi and Chang, 2006; Nazari-Shirkouhi et al, 2013; Songhori et al., 2011; Li et al., 2013; Ruiz-Torres et al., 2013; Nayak et al., 2011 **Material handling cost** Gonzales et al., 2004; Songhori et al., 2011 **Reprocessing cost** Paksoy et al., 2013 **Purchasing cost** Paksoy et al., 2013; Mirabi et al, 2010; Songhori et al, 2011 **Warehouse cost** Azizi and Modarres, 2010; Mafakheri et al., 2011; Choi and Chang, 2006; Nazari-Shirkouhi et al, 2013; Songhori et al., 2011; Li et al., 2013; Ruiz-Torres et al., 2013; Nayak et al., 2011 **Transportation cost** Azizi and Modarres, 2010; Paksoy et al., 2013; Mirabi et al., 2010; Songhori et al., 2011 **Customs cost** Azizi and Modarres, 2010 **Process cost** Azizi and Modarres, 2010 **Gather raw material cost** Azizi and Modarres, 2010; Gnanasekaran et al., 2006 **Contract fees** Paksoy et al., 2013 Mirabi et al., 2010 **Reliability cost** Mirabi et al., 2010 **Response cost** Mirabi et al., 2010 **Controlling cost** Mirabi et al., 2010 **Rework cost** Mirabi et al., 2010 **Effect of pollution cost** Jabbour and Jabbour 2009 **Environmental cost** Jabbour and Jabbour, 2009 **Financial condition of supplier** Nayak et al., 2011; Asamoah et al., 2012 **Financial conditions of company** Nayak et al., 2011 **Payment method** Asamoah et al., 2012; Mirabi et al., 2010
7	**Capacity** Jayaraman et al., 1999; Gnanasekaran et al., 2006 Paksoy et al., 2013; Asamoah et al., 2012; Nazari-Shirkouhi et al., 2013; Ruiz-Torres et al., 2013; Songhori et al., 2011; Li et al., 2013; Kannan et al., 2013	**Production capability** Kumar Kar and Pani, 2014; Bhutta and Huq, 2002; Mirabi et al., 2010 **Storage capacity** Jayaraman et al., 1999; Songhori, 2011 **Availability of product** Çebi and Bayraktar, 2003; Gnanasekaran et al., 2006; Vonderembse and Tracey, 1999; Gonzales et al., 2004; Mirabi et al., 2010; Thakkar et al., 2012; Ruiz-Torres et al., 2013; Songhori et al., 2011; Li et al., 2013; Kannan et al., 2013 **Supplier lead time** Jayaraman et al., 1999; Çebi and Bayraktar, 2003; Thakkar et al., 2012; Mendoza, 2007; Songhori et al., 2011; Li et al., 2013; Kannan et al., 2013 **Probability of defect product** Mirabi et al., 2010; Mendoza 2007; Li et al., 2013

Kahraman et al. (2003) stated that "*though the purpose of AHP is to capture expert's knowledge, the conventional AHP still cannot reflect the human thinking style*". In addition, the decision maker is also facing the fuzziness dealing with certain problem (Kabir & Hasin, 2011). Kabir and Hasin (2011) also stated that for assessing qualitative aspect that is not supported by quantitative data, the human being tends to be subjective. Therefore, if the human being is asked to judge the qualitative aspect it might be imprecise. The research on fuzzy AHP especially in the area of supplier selection problem have been found such as: Kahraman et al. (2003), Shaw et al. (2012), Kilinci and Onal (2011), Chamodrakas et al. (2010), Benyoucef and Canbolat (2007), Chan et al. (2008), Haq and Kannan (2006), Kuo et al. (2010), and Tyagi et al. (2015). Some other research also tried to conduct comparative analysis between fuzzy AHP and AHP in the case study, i.e. Kabir and Hasin (2011), Özdağoğlu and Özdağoğlu (2007). If one compared the total priority obtained from AHP and fuzzy AHP in both researches, it is found that the top priorities, i.e. the first three priorities, from both methods are actually the same. Therefore, if someone is facing a decision making problem that require selecting only one alternative, the conclusion from both AHP and fuzzy AHP are indifferent. In other words, using fuzzy AHP is meaningless. However, if the decision making problem requires ranking of alternatives as the result, the output from AHP and fuzzy AHP may different in the middle to low priorities. In this research, another comparative analysis between AHP and fuzzy AHP in the case of supplier selection problem is conducted by using experts in the field who has more than 12 years experiences of selecting supplier in the company. It is expected that this research is able to study the effect of expertise on the differences between AHP and fuzzy AHP results.

3. Problem Description

The company observed in this study is a glove manufacturer located in Yogyakarta Indonesia. The raw material is leather that is supplied by 10 suppliers. As it is mentioned in previous section, the suppliers are able to supply with a wide range of qualities from level 1 to level 11 namely level I, II, III, IV, V, VI, VII, VIII, R1, R2, R3. The division is based on the quality of the percentage of the number of defects in one sheet of leather. The supplier is not exclusively supply the raw material to this company. This situation happens because they also supply the raw material to other companies. Therefore, if the decision to select the right supplier take such a long time, therefore there is possibility that the other companies that are able to make a decision faster is able to make a deal with the supplier faster. It increases the possibility for this company to have the shortage of raw material with desired specifications. Business Process of Procurement in this company is shown in Fig. 1. From the Business Process of Procurement presented in Figure 1, it can be seen that Supplier Selection is one of the activity in the business process. Recently, the process of determining the supplier this company is done intuitively and has no standard procedure yet. After knowing the supplier data such as the telephone number the purchasing staff starts calling the suppliers arbitralily. It is because the company do not have rank of suppliers. When this staff calls the supplier he asks to the supplier regarding the following information: 1) availability of raw material at the desired quantity; 2) Price.; 3) Payment term. If the supplier is able to provide the material with right quantity and right quality then, the purchasing staff inform this to the Purchasing Manager and the Purchasing Manager start negotiating the price and payment term. If everything has been agreed then the Purchasing Manager ask the Purchasing Staff to issue the Purchase Order. If it is not then the Purchasing Staff will try to call other supplier. He keeps on doing this activity until all the raw material needed are able to be supplied by the selected supplier. However, the situation that has been found in this company is that because the company do not have rank of suppleirs therefore it takes time for the Purchasing Staff to find the supplier(s) that are able to provide the raw material with the right quality, quantity and time. Looking at these conditions, it is very important for this company to determine the priority of supplier. This priority is then can be used by the company to decide which supplier that has to be called first if they need a raw material to be supplied.

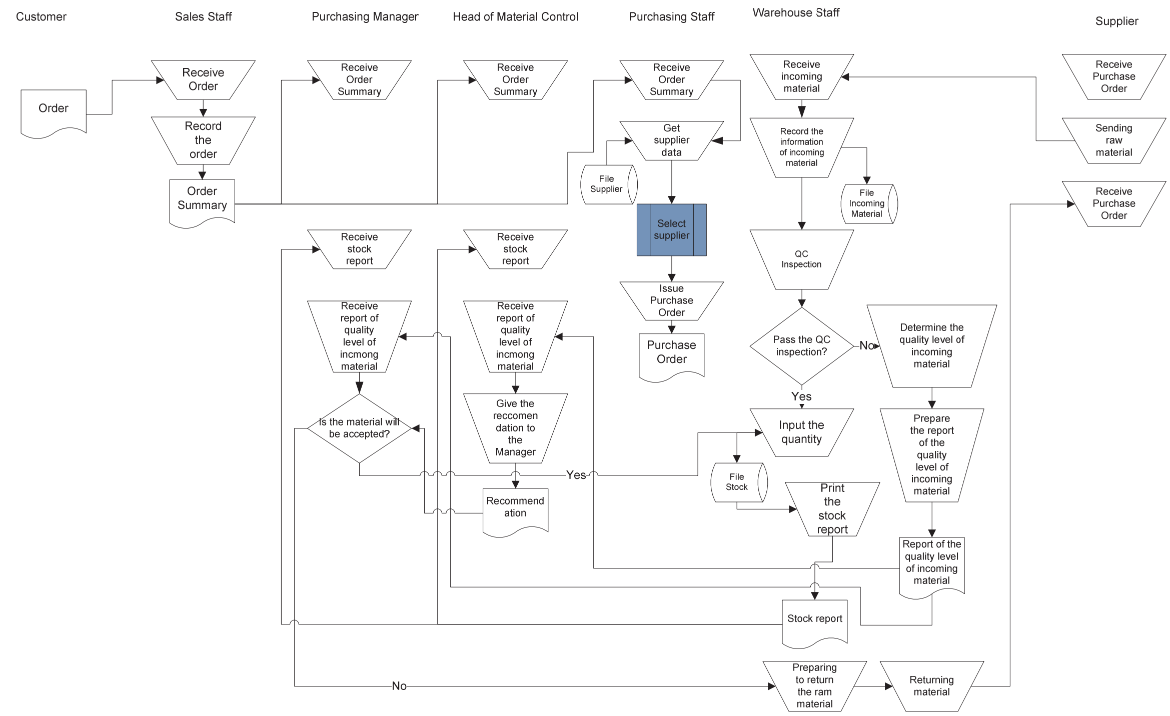

Fig. 1. Business Process of Procurement

4. AHP Methodology

In this research an observation to see the current practice of supplier selection in a glove manufacturer located in Yogyakarta Indonesia was conducted. An observation was done by observing the procurement activity in this company. The observation was conducted by:1) interviewing Purchasing Staff; 2) interviewing Head of Material Control; 3) interviewing Purchasing Manager; 3) interviewing Purchase Planner; 4) studying the procurement document which is ASA-PSM-09 Rev:00.; 5) studying the documents, forms, and reports related to the procurement activity. Purchasing Manager, Warehouse Staff, Purchasing Staff, and Head of Material Control are considered as the experts in this study. The profile for the experts in this study is shown in Table 2.

Table 2
Profile of the experts

Position	Job Description	Experience (years)
Purchasing Manager	1. Approving proposal of the procurement plan 2. Approving selected supplier 3. Determining raw material price 4. Determining quantity of the purchased raw material 5. Determining whether the quality of the goods received meet the specification	16
Head of Material Control	1. Processing incoming material including inspecting raw material 2. Recording the quantity of incoming material	13
Supervisor/ Purchasing staff	1. Creating purchase orders of raw materials 2. Making a payment plan of purchase orders 3. Contacting suppliers of raw materials	12
Purchasing planner	1. Calculating the quantity of the raw material that need to be bought according to monthly production planning 2. Making the analysis related to the shortage of the raw material 3. Help the supplier selection process	14

The result from this step Business Process of Procurement in this company as it is presented in Figure 1 in the previous section. Once the business process of procurement was constructed then it can be identified that the problem is related to the supplier selection. Therefore, the next step was conducted related to the supplier selection in the company such as the number of suppliers they have, the performance of supplier especially the probability that the supplier was not able to meet the specified quality or it called as quality reduction. The characteristics of each supplier in the company can be seen in Table 3.

Table 3
Characteristics of the supplier

Supplier	Scale of Supplier	Quality Reduction (%)
B	Large	25
D	Large	12
E	Large	N/A
F	Large	11
H	Large	40
I	Small	15
J	Small	13
K	Small	20
L	Small	N/A
M	Small	N/A

From Fig. 1 it is seen that Supplier Selection is one of activity in the Procurement activity in this company. The next step was structuring the problem of Supplier Selection. This step was conducted by conducting discussion and interview with Purchasing Staff, Head of Material Control, and Purchasing Manager. In addition, studying the Procurement document in the company which is ASA_PSM-09 Rev: 00 was also conducted. During this step it was found that several criteria that are considered by the company in conducting the supplier selection as it is explained in Table 4.

Table 4
Factors considered by the company to select their suppliers

Criteria	Description
Percentage of Quality Reduction	In this company, they classify the quality of sheep leather provided by the supplier in to several category namely: level I – IV, V, VI, VII and R1, R2, R3 When their customer place an order to this company usually they mention about the preference of the quality level of sheep leather they want. For example: a customer might place an order of 1000 pairs of gloves where the quality level of sheep leather they want is level I. The characteristic of their supplier is that their supplier might supply the sheep leather where its quality might vary from time to time. As it is mentioned in Table 1, the probability that the supplier was not able to meet the specified quality or it called as quality reduction. The company prefers to have a supplier who has smaller quality reduction.
Price	According to information received from the company it is said that the price of raw material affect up to 60% of the financial condition of the company. Therefore, selecting a supplier that provides the competitive price is expected.
Supplier capacity	This factor related to the amount of sheep leather can be provided by the supplier when there is demand. When the company needs to buy sheep leather with certain quality level, actually the company prefers when they contact a supplier then that supplier will have enough raw material. Therefore there is no need for the company to find another supplier.
Transportation Cost	The transportation cost is the cost that has to be paid by the company to transport the raw material from the supplier warehouse to manufacturer warehouse. Currently, the suppliers of this company are located in East Java, Central Java and East Java.
Payment Term	Payment term related to the method of payment and duration of payment. Some suppliers allow the company to make a payment 10-14 days after the material has been received. But some other suppliers may not. For certain supplier this might be negotiable but for other supplier might not.
Delivery Time	In term of on time delivery
Supplier policy	In term of willingness of the supplier to receive the returned raw material tthat does not meet the quality
Supplier commitment	In term of the commitment from the supplier to provide the amount of raw material as it is stated in the contract document

Among those criteria that have been considered by this company, it can be seen from the Table 1 that several criteria that have been discussed in the previous research also become criteria that re used by this company. For example, criteria Price have been used in the previous research, such as Kumar Kar and Pani (2014), Jayaraman et al. (1999), Kannan et al. (2013), Asamoah et al. (2012), Weber and Elram (1993), Thakkar et al. (2012), Li et al. (2013), Nazari-Shirkouhi et al. (2013). Transportation cost have been studied by Azizi and Modarres (2010), Paksoy et al. (2013), Mirabi et al. (2010), Songhori et al. (2011). Payment method have been studied by Asamoah et al. (2012), Mirabi et al. (2010). In this research, those 3 criteria are grouped in to 1 criteria which is Economy. Other criteria such as supplier capacity have been studied by previous researches such as Çebi and Bayraktar (2003), Gnanasekaran et al. (2006), Vonderembse and Tracey (1999), Gonzales et al. (2004), Mirabi et al. (2010), Thakkar et al. (2012), Ruiz-Torres et al. (2013), Songhori et al. (2011), Li et al. (2013), Kannan et al. (2013). Other criteria which is on time delivery have been studied also by previous researchers such as Gnanasekaran et al. (2006); Asamoah et al. (2012); Gonzales et al. (2004); Weber and Elram (1993); Mirabi et al. (2010). However the criterion which is percentage of quality reduction has not studied yet in the literature. Even though previous researchers have studied yet the similar criteria related to quality such Mirabi et al. (2010), Mendoza (2007), Li et al. (2013) that mention about the probability of defect product. In this research, the criteria which is supplier capacity, on time delivery and percentage of quality reduction are grouped in to 1 criterion which is Capability. Other criteria that have been found during the interview with the company which are supplier policy and supplier commitment are grouped in to one criterion which is Service. Once all criteria have been identified then the structure of supplier company was identified as it is shown in Fig. 2.

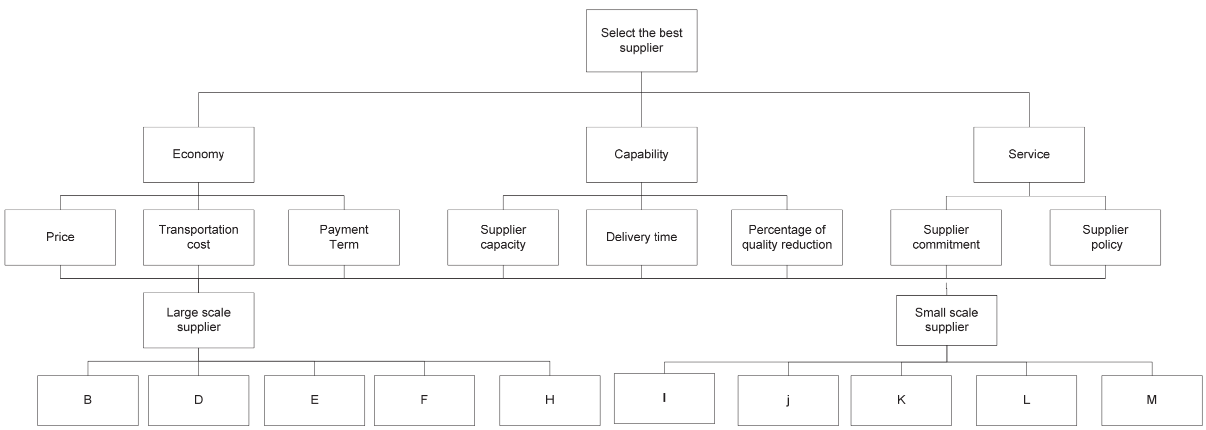

Fig. 2. AHP model for supplier selection

The next step after constructing the AHP model for supplier selection is doing pairwise comparison among criteria. Then the pairwise comparison of all sub criteria with respect to criteria is performed. Basically in this pairwise comparison, a pairwise comparison belonging to a certain level with respect to a higher level is performed. In this step, experts who are Purchasing Manager, Production Planner, Purchasing Staff and Head of Material Control were asked to express their preferences using Saaty's 1-9 scales (Saaty, 1994). Because there are 4 experts, therefore, we had 4 preferences as it is shown in Table 5.

Table 5
Pairwise-comparison among criteria

Expert 1				**Expert 3**			
Criteria	Economy	Capability	Service	Criteria	Economy	Capability	Service
Economy	1	1	4	Economy	1	1/3	4
Capability	1	1	5	Capability	3	1	6
Service	¼	1/5	1	Service	1/4	1/6	1
Expert 2				**Expert 4**			
Criteria	Economy	Capability	Service	Criteria	Economy	Capability	Service
Economy	1	1	5	Economy	1	1/4	2
Capability	1	1	5	Capability	4	1	6
Service	1/5	1/5	1	Service	1/2	1/6	1

While in the pairwise comparison matrix only needed one value, therefore, pairwise comparison of each expert are combined into one value. One of the method that can be used is using geometric mean as it is shown in Eq. (1) (Saaty, 1994).

$$\mu_{ij} = \sqrt[n]{\alpha_{ij1}\alpha_{ij2}\cdots\alpha_{ijn}} \tag{1}$$

where :

μ_{ij} = *Geometric Mean* row-*i* column-*j*

n = number of expert

The pairwise comparison matrix among criteria can be seen in Table 6.

Table 6
Pairwise comparison among criteria

Criteria	Economy	Capability	Service
Economy	1.0000	0.5373	3.5566
Capability	1.8612	1.0000	5.4772
Service	0.2812	0.1826	1.0000

The next step after comparative judgment is synthesizing. This step consists of several activities which are:

a. Normalization

Normalize the data by dividing each value in the matrix of pairwise comparison with the total value of the column. Normalization of each column in the matrix of pairwise comparison is calculated by the following formula (Mendoza, 2007):

$$r_{ij} = \frac{\alpha_{ij}}{\sum_{i=1}^{n}\alpha_{ij}} \tag{2}$$

where

r_{ij} = the value of the division of the *i*-th row *j*-th column with a total value of *j*-th column

α_{ij} = Value pairs comparison to the *i*-th row *j*-th column

$\sum_{i=1}^{n}\alpha_{ij}$ = Total value of all pairwise comparisons of column *j*

Table 7
Normalized pairwise comparison matrix

Criteria	Economy	Capability	Service
Economy	0.3182	0.3124	0.3545
Capability	0.5923	0.5814	0.5459
Service	0.0895	0.1062	0.0996

b. Calculating local priority

Compute the average of the elements in each row of the normalized pairwise comparison matrix. These averages provide an estimate of the relative priorities of the elements being compared. The result is shown in Table 8.

Table 8
Priority of criteria with respect to goal

Criteria	Economy	Capability	Service	Local Priority
Economy	0.3182	0.3124	0.3545	0.3185
Capability	0.5923	0.5814	0.5459	0.5813
Service	0.0895	0.1062	0.0996	0.1002

c. Consistency checking

The calculation of local priority is done by calculating eigenvector and eigenvalue. Eigenvector is the ratio of the weight of each factor while eigenvalue represents the value of the division between matrix multiplication and eigenvector with the eigenvector value. Mathematical expression of the eigenvector (w) and eigenvalue (λ) can be formulated as follows (Saaty, 1994):

$$A \cdot w = \lambda \cdot w \tag{3}$$

$$\begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} = \lambda \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} \tag{4}$$

Based on the results of normalization value eigenvector to economic criteria, capabilities and services in a way that is 0.3185, 0.5813, and 0.1002. Eigenvector value will be used to determine the eigenvalue. Eigenvalue obtained from the calculation according to equation (3) and (4) . Here is the calculation of eigenvalues on the following criteria:

$$A \cdot w = \lambda \cdot w \quad \begin{bmatrix} 1.0000 & 0.5373 & 3.5566 \\ 1.8612 & 1.0000 & 5.4772 \\ 0.2812 & 0.1826 & 1.0000 \end{bmatrix} \begin{bmatrix} 0.3185 \\ 0.5813 \\ 0.1002 \end{bmatrix} = \lambda \begin{bmatrix} 0.3185 \\ 0.5813 \\ 0.1002 \end{bmatrix} \qquad \begin{bmatrix} 0.9872 \\ 1.7229 \\ 0.2959 \end{bmatrix} = \lambda \begin{bmatrix} 0.3185 \\ 0.5813 \\ 0.1002 \end{bmatrix}$$

Therefore, there are three possible values of λ, which are 3.0997, 2.9636, and 2.9530, and the biggest one, the $\lambda_{\max}$ is equal to 3.0997. After $\lambda_{\max}$ is known then the consistency checking was performed. This checking is performed to measure the quality of the judgment during the series of pairwise comparison performed by experts. The degree of inconsistency is acceptable if the value of consistency ratio (CR) is ≤ 0.10. If CR is ≥ 0.10 then the judgment from the experts need to be evaluated (Saaty, 1994). CR value can be calculated by dividing the value of Consistency Index (CI) to the value of Random Consistency Index (RI). Value Consistency Index (CI) is derived from the equation:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{5}$$

where:

CI = *Consistency Index*
λ_{max} = *eigenvalue* maximum
n = matrix order

The average value of Random Index (RI) can be seen in Table 9. It is noted that if the matrix order is equal to 2, then it is always consistent.

Tabel 9

Random Consistency Index (RI) (Saaty, 1994)

Matrix Order (n)	1	2	3	4	5	6	7	8	9	10
Random Consistency Index (RI)	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

For this case, since $\lambda_{\max}$ is equal to 3.0997 with n is equal to 3, therefore, CI is equal to 0.0498. From Table 9, it is known that RI is equal to 0.52 the respective value of n. Therefore, CR is equal to 0.0958. Hence, this comparison is consistent.

Using similar procedure, the local priority and consistency checking for the sub criteria, alternative and sub alternatives can be obtained. The results are presented in Table 10 and 11. It is noted that Table 11 is only presenting the result of comparison with *n* greater than 2.

Table 10
Local Priority of each Comparison

Economic Criteria	**Local Priority**
Price	0.3770
Transportation Cost	0.1019
Payment Term	0.5212
Capability Criteria	**Local Priority**
Supplier Capacity	0.4263
Delivery Time	0.0909
Percentage of Quality Reduction	0.4828
Service Criteria	**Local Priority**
Supplier Commitment	0.3369
Supplier Policy	0.6631
Price Sub Criteria	**Local Priority**
Large Scale Supplier	0.5858
Small Scale Supplier	0.4142
Transportation Cost Sub Criteria	**Local Priority**
Large Scale Supplier	0.4568
Small Scale Supplier	0.5432
Payment Term Sub Criteria	**Local Priority**
Large Scale Supplier	0.5858
Small Scale Supplier	0.4142
Supplier Capacity Sub Criteria	**Local Priority**
Large Scale Supplier	0.7882
Small Scale Supplier	0.2118
Delivery Time Sub Criteria	**Local Priority**
Large Scale Supplier	0.6505
Small Scale Supplier	0.3495
Percentage of Quality Reduction Sub Criteria	**Local Priority**
Large Scale Supplier	0.4568
Small Scale Supplier	0.5432
Supplier Commitment Sub Criteria	**Local Priority**
Large Scale Supplier	0.5180
Small Scale Supplier	0.4820
Supplier Policy Sub Criteria	**Local Priority**
Large Scale Supplier	0.7883
Small Scale Supplier	0.2118
Large Scale Supplier Sub Alternative	**Local Priority**
B	0.2596
D	0.3874
E	0.0627
F	0.0655
H	0.2249
Small Scale Supplier Sub Alternative	**Local Priority**
I	0.2612
J	0.2137
K	0.2073
L	0.1467
M	0.1711

Tabel 11
Consistency checking result

	λ max	n	CI	RI	CR	Conclusion
Criteria Respect to Goal	3.0997	3	0.0498	0.52	0.0958	Consistent
Sub Criteria respect to Economy Criteria	3.1023	3	0.0512	0.52	0.0984	Consistent
Sub Criteria respect to Capability Criteria	3.0993	3	0.0497	0.52	0.0955	Consistent
Sub Alternatives respect to Large Scale Supplier Alternative	5.4331	5	0.1083	1.11	0.0975	Consistent
Sub alternatives respect to Small Scale Supplier Alternatives	5.2043	5	0.0511	1.11	0.0460	Consistent

d. Calculating Overall Priority of the sub-alternative

The overall priority for each sub-alternative is obtained by summing the product of the local priority of the criterion priority times the local priority of the sub criteria times the local priority of alternatives time the local priority of sub alternatives with respect to that alternative, sub criterion and criterion. The results are presented in Table 12.

Table 12
Overall priority of each sub alternative

Supplier	Overall priority	Rank	Supplier	Overall priority	Rank
D (Large)	0.2364	1	K (Small)	0.0808	6
B (Large)	0.1584	2	M (Small)	0.0667	7
H (Large)	0.1372	3	L (Small)	0.0572	8
I (Small)	0.1018	4	F (Large)	0.0399	9
J (Small)	0.0833	5	E (Large)	0.0383	10

5. Fuzzy AHP Methodology

After performing AHP technique and the results were obtained, in order to observe how the experts will affect the result between AHP and FAHP, the FAHP was performed. We use three approached conducting FAHP in the research in this paper. First approach is using extent analysis proposed by Chang (1998); Second approach is using extent analysis proposed by Wang (2008) and third approach is by using modified fuzzy LLSM proposed by Wang (2008).

5.1.FAHP using Extent Analysis

Detail is explained:

a. Pairwise Comparison Matrix using *Triangular Fuzzy Numbers* (TFN)
Triangular Fuzzy Numbers (TFN) is a fuzzy set theory that helps expert in doing pairwise comparisons. TFN shows the subjectivity decision makers in linguistic variables and shows a definite degree of uncertainty (fuzzy). A tilde "~" will be placed above a symbol if the symbol represents a fuzzy set (Kahraman et al, 2003). A triangular fuzzy number (TFN) is denoted as $\widetilde{M}$ and it consists of a value triplet (l,m,u) where l is a lower value, m is middle value, and u is upper grades and its membership value of TFN can be expressed as follows: (Meixner, 2009; Kahraman et al., 2003).

$$\mu\left(x\middle|\tilde{M}\right)=\begin{cases}0,\ x<l\\ \dfrac{x-l}{m-l},l\le x\le m\\ \dfrac{u-x}{u-m},m\le x\le u\\ 0,\ x>0\end{cases} \tag{6}$$

In the FAHP procedure, the pairwise comparisons in the judgment are fuzzy. The value of TFN in the fuzzy AHP are formed on the basis of a AHP pairwise comparison scale as follows and the detailed can be seen in Table 13.

$$\tilde{1}\equiv\left(1,1,1\right),\ \tilde{x}\equiv\left(x-1,x,x+1\right)\forall x=2,3,...,8\ ,\ \tilde{9}\equiv\left(9,9,9\right)$$

Tabel 13
The value of TFN in the fuzzy AHP (Huang et al., 2014)

Judgment of preferences	Description	*Triangular Fuzzy Number* (TFN)	*Reciprocal of Triangular Fuzzy Number*
1	Equally preferred	(1,1,1)	(1,1,1)
2	Equally to moderately preferred	(1,2,3)	(1/3, 1/2 ,1)
3	Moderately preferred	(2,3,4)	(1/4, 1/3 , 1/2)
4	Moderately to strongly preferred	(3,4,5)	(1/5, 1/4, 1/3)
5	Strongly preferred	(4,5,6)	(1/6, 1/5 , 1/4)
6	Strongly to very strongly preferred	(5,6,7)	(1/7, 1/6, 1/5)
7	Very strongly preferred	(6,7,8)	(1/8, 1/7 , 1/6)
8	Strongly to extremely preferred	(7,8,9)	(1/9, 1/8, 1/7)
9	Extremely preferred	(9,9,9)	(1/9, 1/9 , 1/9)

The pairwise comparison matrix FAHP can be expressed as:

$$\tilde{M}=\begin{bmatrix}(1,1,1) & . & . & . & \tilde{a}_{1n}\\ . & . & & & .\\ . & & . & & .\\ . & & & . & .\\ \tilde{a}_{n1} & & & & (1,1,1)\end{bmatrix} \tag{7}$$

where $\tilde{a}_{ij}=\left(l_{ij},m_{ij},u_{ij}\right)=\tilde{a}_{ji}^{-1}=\left(1/u_{ji},1/m_{ji},1/l_{ji}\right);\ i,j=1,2,...,n,$ and $i\neq j$

Pairwise comparison matrix FAHP among 4 experts in a glove manufacturer studied in this paper is shown Table 14.

Table 14
Pair wise comparison matrix FAHP

Expert 1									
Criteria	Economy			Capability			Service		
Economy	1.00	1.00	1.00	1.00	1.00	1.00	3.00	4.00	5.00
Capability	1.00	1.00	1.00	1.00	1.00	1.00	4.00	5.00	6.00
Service	0.20	0.25	0.33	0.17	0.20	0.25	1.00	1.00	1.00
Expert 2									
Criteria	Economy			Capability			Service		
Economy	1.00	1.00	1.00	1.00	1.00	1.00	4.00	5.00	6.00
Capability	1.00	1.00	1.00	1.00	1.00	1.00	4.00	5.00	6.00
Service	0.17	0.20	0.25	0.17	0.20	0.25	1.00	1.00	1.00
Expert 3									
Criteria	Economy			Capability			Service		
Economy	1.00	1.00	1.00	0.25	0.33	0.50	3.00	4.00	5.00
Capability	2.00	3.00	4.00	1.00	1.00	1.00	5.00	6.00	7.00
Service	0.20	0.25	0.33	0.14	0.17	0.20	1.00	1.00	1.00
Expert 4									
Criteria	Economy			Capability			Service		
Economy	1.00	1.00	1.00	0.20	0.25	0.33	1.00	2.00	3.00
Capability	3.00	4.00	5.00	1.00	1.00	1.00	5.00	6.00	7.00
Service	0.33	0.50	1.00	0.14	0.17	0.20	1.00	1.00	1.00

The next step is applying geometric mean to get the single value to be inputted in the pairwise comparison matrix using geometric mean of l_{ij}, m_{ij}, u_{ij}. According to Meixner (2009), the geometric mean can be computed as:

$$\overline{l}_{ij} = \left(\prod_{k=1}^{k} l_{ijk} \right)^{\frac{1}{k}}, \overline{m}_{ij} = \left(\prod_{k=1}^{k} m_{ijk} \right)^{\frac{1}{k}}, \overline{u}_{ij} = \left(\prod_{k=1}^{k} u_{ijk} \right)^{\frac{1}{k}} \tag{8}$$

Table 15

Geometric mean FAHP

Criteria	Economy			Capability			Service		
Economy	1.0000	1.0000	1.0000	0.4729	0.5373	0.6389	2.4495	3.5566	4.6058
Capability	1.5651	1.8612	2.1147	1.0000	1.0000	1.0000	4.4721	5.4772	6.4807
Service	0.2171	0.2812	0.4082	0.1543	0.1826	0.2236	1.0000	1.0000	1.0000

b. Determine local priority using *fuzzy synthetic extent* $\left(\tilde{S}_i\right)$

In order to compute *fuzzy synthetic extent* $\left(\tilde{S}_i\right)$ to obtain local priority can be done using either the equation proposed by Chang (1998) or Wang (2008), which are presented in Equation 9 or 10, respectively. In this research of this paper, both two equations will be used and the result will be compared. The results are presented in Table 16.

$$\tilde{S}_i = \sum_{j=1}^{m} \tilde{M}_i^j \odot \left[\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{M}_i^j \right]^{-1} \tag{9}$$

where

$$\sum_{j=1}^{m} \tilde{M}_i^j = \sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \qquad \left[\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{M}_i^j \right]^{-1} = \frac{1}{\sum_{j=1}^{m} u_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} l_j}$$

$$\tilde{S}_i = \frac{RS_i}{\sum_{j=1}^{n} RS_j} = \left(\frac{\sum_{j=1}^{n} l_{ij}}{\sum_{j=1}^{n} l_{ij} + \sum_{k=1,k\neq 1}^{n} \sum_{j=1}^{n} u_{kj}}, \frac{\sum_{j=1}^{n} m_{ij}}{\sum_{k=1}^{n} \sum_{j=1}^{n} m_{kj}}, \frac{\sum_{j=1}^{n} l_{ij}}{\sum_{j=1}^{n} u_{ij} + \sum_{k=1,k\neq 1}^{n} \sum_{j=1}^{n} l_{kj}} \right), i = 1,...,n \tag{10}$$

Table 16

Local priority using *fuzzy synthetic extent* $\left(\tilde{S}_i\right)$ using Chang (1996) and Wang (2008) method

Method	Chang (1996)			Wang (2008)		
$\left(\tilde{S}_i\right)$	Economy	Capability	Service	Economy	Capability	Service
Economy	0.224498	0.341962	0.506423	0.258911	0.341962	0.426163
Capability	0.402772	0.559771	0.778153	0.471861	0.559771	0.644454
Service	0.078492	0.098267	0.132333	0.079679	0.098267	0.129596

c. Compute the degree of possibility of $\tilde{S}_i \geq \tilde{S}_j$ by the following equation:

$$V\left(\tilde{S}_i \geq \tilde{S}_j\right) = \begin{cases} 1, & \text{if } m_i \geq m_j \\ \dfrac{u_i - l_j}{\left(u_i - m_i\right) + \left(m_j - l_j\right)}, & \text{if } l_j \leq u_i \qquad i, j = 1,...,n; j \neq i \\ 0, & \text{others,} \end{cases} \tag{11}$$

where $\tilde{S}_i = (l_i, m_i, u_i)$ and $\tilde{S}_i = (l_j, m_j, u_j)$

Calculation result of the degree of possibility is presented in Table 17.

Table 17
Degree of possibility

Method	Chang (1996)			Wang (2008)		
$V(\tilde{S}_i \geq \tilde{S}_j)$	Economy	Capability	Service	Economy	Capability	Service
Economy	–	0.3224	1.0000	–	0.0000	1.0000
Capability	1.0000	–	1.0000	1.0000	–	1.0000
Service	0.0000	0.0000	–	0.0000	0.0000	–

d. Calculate the degree of possibility of $\tilde{S}_i$ over all the other $(n-1)$ fuzzy number by

$$V\left(\tilde{S}_i \geq \tilde{S}_j \middle| j = 1,...,n; j \neq 1\right) = \min_{j \in \{1,...,n\}, j \neq 1} V\left(\tilde{S}_i \geq \tilde{S}_j\right), i = 1,...,n \tag{12}$$

The result is presented in Table 18.

Table 18
Degree of possibility over all the other fuzzy number

Method	Chang (1996)	Wang (2008)
Economy	0.3224	0
Capability	1	1
Service	0	0

e. Calculate the priority vector $W = (w_1,...,w_n)^T$ of the fuzzy comparison matrix $\tilde{M}$

$$w_1 = \frac{V\left(\tilde{S}_i \geq \tilde{S}_j \middle| j = 1,...,n; j \neq i\right)}{\sum_{k=1}^{n} V\left(\tilde{S}_k \geq \tilde{S}_j \middle| j = 1,...,n; j \neq k\right)}, i = 1,...,n \tag{13}$$

Hence, based on Eq. (13), the priority vector based on Chang and Wang method are $W = (0.2438, 0.7562, 0)^T$ and $W = (0,1,0)^T$, respectively. All steps above were performed and the result of the priority for each alternatives using Chang (1996)'s methods and Wang (2008)'s methods are presented in Table 19.

Table 19
Comparison of Local Priority Obtained by Chang (1996) and Wang (2008) method

Chang (1996) method			Wang (2008) method		
Supplier	Local Priority	Rank	Supplier	Local Priority	Rank
D (Large)	0.2752	1	I(Small)	0.5430	1
B(Large)	0.2121	2	K(Small)	0.1444	2
H(Large)	0.1823	3	J(Small)	0.1421	3
I(Small)	0.1131	4	D(Large)	0.1027	4
K(Small)	0.0800	5	B(Large)	0.0392	5
J(Small)	0.0734	6	H(Large)	0.0286	6
M (Small)	0.0472	7	E(Large)	0	7
L(Small)	0.0167	8	F(Large)	0	8
E(Large)	0.0000	9	L(Small)	0	9
F(Large)	0.0000	10	M(Small)	0	10

5.2. FAHP using LLSM

Fuzzy LLSM developed following nonlinear optimization model proposed by Wang (2006) to criticize the extent analysis proposed by Chang (1996) as follows:

$$\text{Min } J = \sum_{i=1}^{n} \sum_{j=1, j\neq i}^{n} \left(\ln w_i^L - \ln w_j^U - \ln l_{ij}\right)^2 + \left(\ln w_i^M - \ln w_j^M - \ln m_{ij}\right)^2 + \left(\ln w_i^M - \ln w_j^M - \ln u_{ij}\right)^2$$

subject to

$$\begin{aligned}
& w_i^L + \sum_{j=1, j\neq i}^{n} w_j^U \geq 1, \quad i = 1,\ldots,n \\
& w_i^U + \sum_{j=1, j\neq i}^{n} w_j^L \leq 1, \quad i = 1,\ldots,n \\
& \sum_{i=1}^{n}\left(w_i^L + w_i^U\right) = 2, \quad i = 1,\ldots,n \\
& w_i^U \geq w_i^M \geq w_i^L > 0, \quad i = 1,\ldots,n \\
& \sum_{i=1}^{n} w_i^M = 1
\end{aligned} \tag{14}$$

According to Wang (2008), the above model can produce normalized triangular fuzzy weight $\tilde{w}_i = \left(w_i^L, w_i^M, w_i^U\right), i = 1,\ldots,n.$ Global fuzzy weight of alternative $A_k\,(k = 1,\ldots,K)$ can be obtained by solving two sets of linear programming and one equation below:

$$\begin{aligned}
& w_{A_k}^L = \min \sum_{j=1}^{m} w_{kj}^L w_j \\
& \text{subject to} \\
& w_j^L \leq w_j \leq w_j^U, \quad j = 1,\ldots,m \\
& \qquad \sum_{j=1}^{m} w_j = 1
\end{aligned} \tag{14}$$

$$\begin{aligned}
& w_{A_k}^U = \max \sum_{j=1}^{m} w_{kj}^U w_j \\
& \text{subject to} \\
& w_j^L \leq w_j \leq w_j^U, \quad j = 1,\ldots,m \\
& \qquad \sum_{j=1}^{m} w_j = 1
\end{aligned} \tag{15}$$

$$w_{A_k}^M = \sum_{j=1}^{m} w_{kj}^M w_j^M \tag{16}$$

To solve the problem presented in this paper, the fuzzy LLSM model proposed by Wang (2006) was solved using optimization software which is Lingo 7 and the results are presented in Table 20 and 21.

Table 20
Priority Vectors Resulted by the Fuzzy LLSM Model

Criteria	w_j^L	w_j^M	w_j^U
Economy	0.289506	0.328213	0.366565
Capability	0.548532	0.573484	0.589703
Service	0.084903	0.098304	0.120791
Sub Criteria Economy			
Price	0.368124	0.388624	0.406764
Transportation cost	0.083972	0.100446	0.125762
Payment Term	0.500609	0.510929	0.514770

Table 20
Priority Vectors Resulted by the Fuzzy LLSM Model (Continued)

Criteria	w_j^L	w_j^M	w_j^U
Sub Criteria Capability			
Supplier Capacity	0.348642	0.432410	0.462625
Delivery Time	0.083854	0.095083	0.101231
Quality Reduction	0.453522	0.472506	0.550127
Sub Criteria Service			
Supplier Commitment	0.311200	0.336928	0.372885
Supplier Policy	0.627115	0.663072	0.688800
Price Sub Criteria			
Large Scale Supplier	0.431765	0.456786	0.500000
Small Scale Supplier	0.500000	0.543214	0.568235
Transportation Cost Sub Criteria			
Large Scale Supplier	0.568235	0.585786	0.599254
Small Scale Supplier	0.400746	0.414214	0.431765
Payment Term Sub Criteria			
Large Scale Supplier	0.568235	0.585786	0.599254
Small Scale Supplier	0.400746	0.414214	0.431765
Supplier Capacity Sub Criteria			
Large Scale Supplier	0.730517	0.788244	0.825441
Small Scale Supplier	0.174559	0.211756	0.269483
Delivery Time Sub Criteria			
Large Scale Supplier	0.610149	0.650498	0.678946
Small Scale Supplier	0.321054	0.349502	0.389851
Percentage of Quality Reduction Sub Criteria			
Large Scale Supplier	0.431765	0.456786	0.500000
Small Scale Supplier	0.500000	0.543214	0.568235
Supplier Commitment Sub Criteria			
Large Scale Supplier	0.482028	0.517972	0.557019
Small Scale Supplier	0.442981	0.482028	0.517972
Supplier Policy Sub Criteria			
Large Scale Supplier	0.730517	0.788244	0.825441
Small Scale Supplier	0.174559	0.211756	0.269483
Large Scale Supplier Sub Alternative			
B	0.256923	0.279581	0.314403
D	0.325833	0.361506	0.387512
E	0.054482	0.058482	0.065412
F	0.062402	0.068834	0.078839
H	0.211522	0.231597	0.242672
Small Scale Supplier Sub Alternative			
I	0.250010	0.262719	0.278964
J	0.179447	0.207343	0.229702
K	0.188431	0.210347	0.237566
L	0.132616	0.148737	0.167196
M	0.160110	0.170854	0.175959

Table 21
Global Fuzzy Weights

Supplier A_k	$w_{A_k}^L$	$w_{A_k}^M$	$w_{A_k}^U$
D	0.176385	0.216564	0.251166
B	0.139081	0.167486	0.203781
H	0.114504	0.138741	0.157288
I	0.087966	0.105334	0.127951
K	0.066299	0.084336	0.108963
J	0.063138	0.083132	0.105356
M	0.056335	0.068502	0.080706
L	0.046661	0.059635	0.076687
F	0.033780	0.041236	0.051100
E	0.029493	0.035034	0.042397

6. Discussion

Table 22 merged all the priority rank obtained from AHP method and Fuzzy AHP methods. It is clearly shown that the result of AHP method, Fuzzy AHP using Chang's (1996) Extent Analysis, and Fuzzy AHP LLSM are quite similar, in which priority rank 1–4 (Supplier D, B, H, I) and 7–8 (Supplier M, L) are exactly the same. For the purpose of decision making in the company, therefore, the company can utilize this priority list, i.e. supplier D is the first priority, supplier B is the second priority, etc.

Once again the result of this research is raising the question whether fuzzy AHP is necessary to apply, especially when the decision is involving qualified expert, i.e. this research were using experts who has more than 12 years experiences. This research emphasizes some comparative analysis between fuzzy AHP and AHP, i.e. Kabir and Hasin (2011), Özdağoğlu and Özdağoğlu (2007), that the top priorities from both methods are actually the same. In particular, the first four priorities are the same.

Table 22
Comparison of Priority Rank Among Methods

Priority Rank	AHP	Fuzzy AHP Extent Analysis Chang (1996)	Fuzzy AHP Extent Analysis Wang (2008)	Fuzzy AHP LLSM
1	D	D	I	D
2	B	B	K	B
3	H	H	J	H
4	I	I	D	I
5	J	K	B	K
6	K	J	H	J
7	M	M	E	M
8	L	L	F	L
9	F	E	L	F
10	E	F	M	E

It is also shown from the Table 22 above that the result of Fuzzy AHP using Wang's (2008) Extent Analysis is totally different with the result of three other methods. Although this method is claimed as the mathematical correction of the Chang's (1996) Extent Analysis, however, it is caused a lot of zero value of possibility. This zero value of possibility caused some of the local priority is also zero and finally affecting the final priority rank.

For this particular case study, therefore, one does not need to apply Fuzzy AHP for developing the priority list of supplier due to theses three following reasons: a) the top priorities resulted from AHP and Fuzzy AHP are the same, b) the mathematical arguable on which fuzzy methods should be applied, c) the Fuzzy AHP requires more complicated process and takes longer time than AHP.

7. Conclusion

The supplier selection problem for this company can be formulated as hierarchy presented in Figure 2, which is consist of 4 level with three criteria, eight sub criteria, two alternatives, and ten sub alternatives. Finally, the company can use the priority rank of supplier as the basis of their procurement process, which is summarized in Table 22, i.e. supplier D, B, H, I, K or L, M, L, and F or E.

In the AHP methodology, this research emphasizes the unnecessary use of the Fuzzy AHP, especially whenever the decision making process is supported by 'expert' respondents. In such case, the AHP is sufficient for making the decision.

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