Chapter 5

Supplier Selection in Stochastic Environments

Supplier selection problem is a classical MCDM problem which deals with conflicting between tangible and intangible factors to select the best supplier(s) (Xia and Wu, 2007). This problem is complicated from regarded various criteria and imprecise judgments by DMs. Many researchers have proposed many methods to solve this problem, nevertheless there are some deficiencies that affect the quality of results (Lam et al., 2010). This chapter proposed MCDM approaches to effectively select material suppliers as a case-based study. These approaches enabled to gain insight into how the imprecision in judgment ratios which might affect their alternatives toward the best solution and also might subsequently improve the reliability of the decision.

5.1 Relevant Criteria

This section was mainly aimed to indication of the criteria that needed to be considered in material supplier selection. The relevant criteria had been widely discussed in the literature and a series of informal discussion with a few scholars and industry personnel. These criteria formed the basis for development the research model as presented in Table 5.1 with briefly definition. The literature on material supplier selection accorded a very high level of significance to price (PR), quality (QLT), compatibility (CPT), and service (SV). In addition, there was almost

Table 5.1 Summary of the criteria for a material supplier selection from literature

No.	Criteria	Explanation	References
1	Price (PR)	Regarding cost aspects of procuring from supplier.	(Muralidharan et al., 2002), (Sarkis and Talluri, 2002), (Jharkharia and Shankar, 2007) and (Lam et al., 2010)
2	Quality (QLT)	The supplier may not only provide good products to the user but may also foster a long-term relationship with the user.	(Xia and Wu, 2007), (Shen and Yu, 2009) and (Lam et al., 2010)
3	Compatibility (CPT)	It refers to the ability of the user and the supplier to work together in close coordination to achieve some common objectives.	(Jharkharia and Shankar, 2007) and (Shen and Yu, 2009)
4	Service (SV)	Regarding service aspects from supplier.	(Cebi and Bayraktar, 2003), (Percin, 2006) and (Lam et al., 2010)
5	Total cost (TTC)	It refers to the total cost of material, which should be minimum.	(Jharkharia and Shankar, 2007) and (Lam et al., 2010)
6	Price stability (PST)	Price levels sufficiently stable so that expectations of change do not become major factors in cost decisions.	(Xia and Wu, 2007) and (Lam et al., 2010)
7	Payment term (PMT)	Suitability of terms and conditions regarding payment of invoices, open accounts, sight drafts, credit letter and payment schedule.	(Noorul Haq and Kannan, 2006) and (Lam et al., 2010)
8	Appearance and functions (A&F)	It refers to the material can readily use in manufacturing process.	(Lam et al., 2010)
9	On time delivery (OTD)	Ability to meet delivery due dates.	(Cebi and Bayraktar, 2003) and (Lam et al., 2010)
10	Flexibility in billing and payment (FBP)	Flexibility in billing and payment conditions increase goodwill between the user and the supplier.	(Sarkis and Talluri, 2002), (Noorul Haq and Kannan, 2006), (Percin, 2006), (Jharkharia and Shankar, 2007) and (Shen and Yu, 2009)
11	Flexibility in operation and delivery (FOD)	Flexibility in operations and delivery may enable the user to give customized service to its customers, particularly in special requests.	(Muralidharan et al., 2002), (Cebi and Bayraktar, 2003), (Jharkharia and Shankar, 2007), (Shen and Yu, 2009) and (Lam et al., 2010)
12	Failure prevention (FPV)	The materials/products are identified, handled, labeled, etc. in such a manner that a change or deterioration is prevented.	(Muralidharan et al., 2002), (Sarkis and Talluri, 2002), (Xia and Wu, 2007) and (Shen and Yu, 2009)
13	Technical assistance and support (TAS)	It refers to the technical capability for supporting and assisting for customer about characteristic and property of material.	(Muralidharan et al., 2002), (Sarkis and Talluri, 2002), (Noorul Haq and Kannan, 2006), (Percin, 2006) and (Lam et al., 2010)
14	Cooperation and communication (C&C)	Communication capability maintained by each supplier.	(Cebi and Bayraktar, 2003), and (Lam et al., 2010)

unanimity among the industry and academic fields that these four main criteria were supported by remaining criteria. A graphical summary is presented in Figure 5.1.
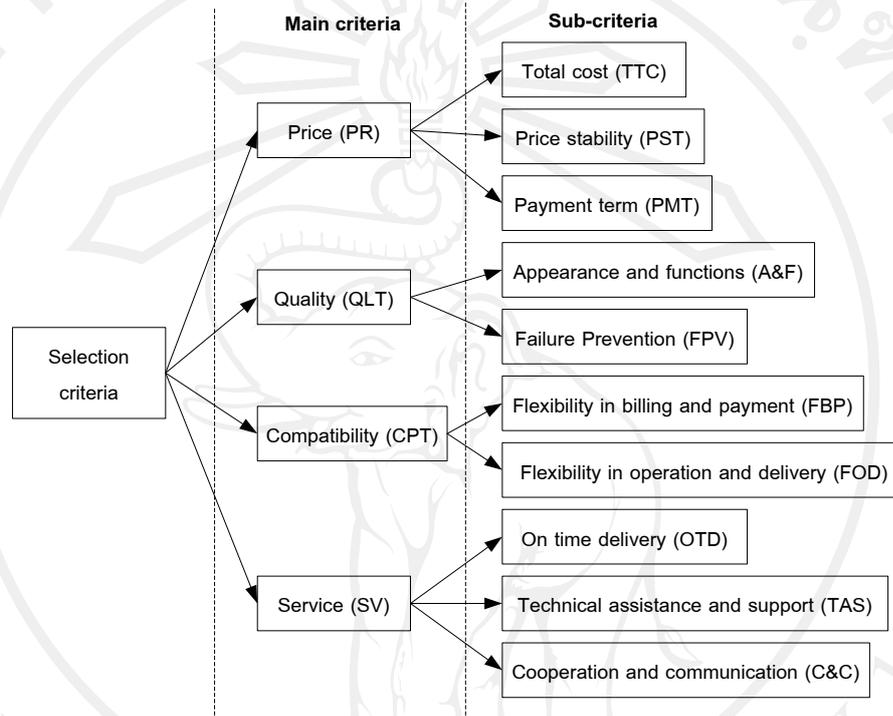

Figure 5.1 Selection criteria of the material supplier selection problem

5.2 Identification the Potential Suppliers

An aptness analysis often appears in generating a number of feasible alternatives in the first round. Based on the determined selection criteria, the potential suppliers' performance data were collected. On the one hand, the quantitative data e.g. total cost, payment term, and on time delivery could be collected from suppliers' information directly. On the other hand, the qualitative data e.g. communication, flexibility, technical support, etc. were provided by the subjective judgments given by the engineering manager and the purchasing manager who acted as DMs. Both of

DMs shared their decision to rate the eight suppliers on each of criteria by adopting
Table 3.5 (See Appendix C for the scenario and rating score).

5.3 Initial Screening

The conjunctive constraint method was applied for initial screening. As stated
in Equation 3.4, this research used "Fair" (F) as the cut-off value to all criteria. It
meant that the qualified suppliers had to be rated greater than or equal to F. From
initial screening, three candidate suppliers were used for the final selection. Table 5.2
exhibits linguistic evaluation data of them.

Table 5.2 Linguistic evaluation data related to candidate suppliers

Criteria	TTC	PST	PMT	A&F	FPV	FBP	FOD	OTD	TAS	C&C
Supplier A	F	G	G	G	G	G	VG	F	G	G
Supplier B	G	G	F	VG	G	F	G	G	G	G
Supplier C	F	F	G	G	G	G	F	VG	F	VG

5.4 Determining Normalized Weights

In this section, both DMs gave opinions for comparing each criterion in the
same level. The equal importance weights of individual DMs were assigned. Table
5.3 shows a matrix pairwise comparison of main criteria for computing by two
methods as previously described in Chapter 3. Each sub-criteria group evaluation
matrix states in Appendix D.

5.4.1 The Classical Method

The fuzzy procedure was adopted to solve the imprecise hierarchical problem.
The average relation decision matrix in Table 5.4 was calculated as

Table 5.3 The fuzzy evaluation matrix of the main criteria

	Price	Quality	Compatibility	Service
Price	(1, 1, 1)	(1, 3/2, 2)	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)
		(1/2, 1, 3/2)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)
Quality	(1/2, 2/3, 1)	(1, 1, 1)	(1/3, 2/5, 1/2)	(2/5, 1/2, 2/3)
	(2/3, 1, 2)		(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)
Compatibility	(3/2, 2, 5/2)	(2, 5/2, 3)	(1, 1, 1)	(1/2, 1, 3/2)
	(3/2, 2, 5/2)	(3/2, 2, 5/2)		(1/2, 1, 3/2)
Service	(3/2, 2, 5/2)	(3/2, 2, 5/2)	(2/3, 1, 2)	(1, 1, 1)
	(2, 5/2, 3)	(3/2, 2, 5/2)	(2/3, 1, 2)	

$$A_i = \frac{1}{n}\left(\sum_{j=1}^{n} a_{ij}\right) \tag{5.1}$$

Table 5.4 Transforming results from Table 5.3

Criteria	Price			Quality			Compatibility			Service		
Price	1.000	1.000	1.000	0.750	1.250	1.750	0.400	0.500	0.667	0.364	0.444	0.571
Quality	0.571	0.800	1.333	1.000	1.000	1.000	0.364	0.444	0.571	0.400	0.500	0.667
Compatibility	1.500	2.000	2.500	1.750	2.250	2.750	1.000	1.000	1.000	0.500	1.000	1.500
Service	1.750	2.250	2.750	1.500	2.000	2.500	0.667	1.000	2.000	1.000	1.000	1.000
Summation	**4.821**	**6.050**	**7.583**	**5.000**	**6.500**	**8.000**	**2.430**	**2.944**	**4.238**	**2.264**	**2.944**	**3.738**

An important weight calculation for each main criterion was applied by Formula 3.8. The relative weight for price was illustrated as a sample computation, thus

$$W_{PR} = \left[\left(\frac{1.000}{7.583}+\frac{0.750}{8.000}+\frac{0.400}{4.238}+\frac{0.364}{3.738}\right),\left(\frac{1.000}{6.050}+\frac{1.250}{6.500}+\frac{0.500}{2.944}+\frac{0.444}{2.944}\right),\right.$$
$$\left.\left(\frac{1.000}{4.821}+\frac{1.750}{5.000}+\frac{0.667}{2.430}+\frac{0.571}{2.264}\right)\right]/4$$

$$= (0.104, 0.170, 0.271) \approx 0.182$$

Hence, each criterion was used this approach to find its weight. Nevertheless, each calculated weight had to translate into normalized form by using Equation 3.9. Table 5.5 displays the normalized weight with respect to the main criteria as

Table 5.5 Normalization weight of main criteria

Goal	Relative weights	Local weights	Normalized local weights
Price	(0.104, 0.170, 0.271)	0.182	0.168
Quality	(0.098, 0.152, 0.252)	0.167	0.154
Compatibility	(0.197, 0.339, 0.536)	0.357	0.329
Service	(0.211, 0.340, 0.584)	0.378	0.349
Total		1.084	1.00

Next, the study of consistency was crucial for avoiding misleading solutions. As part of the fuzzy AHP procedure, a consistency check was required to identify inconsistency matrix. Equations from 3.10 to 3.14 were employed to check a consistency value of main criteria as

$$
T = [0.168] \begin{bmatrix} (1.000, 1.000, 1.000) \\ (0.571, 0.800, 1.333) \\ (1.500, 2.000, 2.500) \\ (1.750, 2.250, 2.750) \end{bmatrix} + [0.154] \begin{bmatrix} (0.750, 1.250, 1.750) \\ (1.000, 1.000, 1.000) \\ (1.750, 2.250, 2.750) \\ (1.500, 2.000, 2.500) \end{bmatrix}
$$

$$
+ [0.329] \begin{bmatrix} (0.400, 0.500, 0.667) \\ (0.364, 0.444, 0.571) \\ (1.000, 1.000, 1.000) \\ (0.667, 1.000, 2.000) \end{bmatrix} + [0.349] \begin{bmatrix} (0.364, 0.444, 0.571) \\ (0.400, 0.500, 0.667) \\ (0.500, 1.000, 1.500) \\ (1.000, 1.000, 1.000) \end{bmatrix}
$$

$$
= \begin{bmatrix} (0.542, 0.680, 0.856) \\ (0.509, 0.609, 0.798) \\ (1.025, 1.360, 1.696) \\ (1.093, 1.364, 1.854) \end{bmatrix}
$$

$$Z = \begin{bmatrix} \left(\dfrac{0.542}{0.168} + \dfrac{0.509}{0.154} + \dfrac{1.025}{0.329} + \dfrac{1.093}{0.349} \right) \\[2mm] \left(\dfrac{0.680}{0.168} + \dfrac{0.609}{0.154} + \dfrac{1.360}{0.329} + \dfrac{1.364}{0.349} \right) \\[2mm] \left(\dfrac{0.856}{0.168} + \dfrac{0.798}{0.154} + \dfrac{1.696}{0.329} + \dfrac{1.854}{0.349} \right) \end{bmatrix} / 4$$

$$\lambda_{\max} = (3.195, 4.012, 5.188) \approx 4.132$$

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{(4.132-4)}{(4-1)} = 0.044$$

$$CR = \frac{CI}{RI} = \frac{0.044}{0.9} = 0.049, (RI = 0.9 \ \textit{from Table } 3.6)$$

The DMs then compared the sub-criteria with respect to main criteria. The other tables are given in Appendix E because the calculation is similar. The normalized local priority weights of main criteria and sub-criteria were synthesized together for acquiring the global composite priority weights as shown in Table 5.6.

Table 5.6 Composite priority weights for sub-criteria

Main Criteria	Normalized local weights	Sub-criteria	Normalized local weights	Global weights
PR	0.168	TTC	0.280	0.047
		PST	0.202	0.034
		PMT	0.518	0.087
QLT	0.154	A&F	0.713	0.110
		FPV	0.287	0.044
CPT	0.329	FBP	0.337	0.111
		FOD	0.663	0.219
SV	0.349	OTD	0.333	0.116
		TAS	0.333	0.116
		C&C	0.333	0.116
		Total:		1.000

After computing the global weights of sub-criteria, they were rearranged in descending order of priority, as shown in Table 5.7. It could be seen that the main criteria as compatibility and service played a crucial role in the list. The compatibility criterion was in the top five rankings including flexibility in operation and delivery, which was the top rank and flexibility in billing and payment. There were also three service criteria in the top five rankings, namely failure prevention, technical assistance and support, and cooperation and communication.

Table 5.7 Ranking of sub-criteria

Rank	Sub-criteria	Global weights	Rank	Sub-criteria	Global weights
1	FOD	0.219	7	PMT	0.087
2	OTD	0.116	8	TTC	0.047
3	TAS	0.116	9	FPV	0.044
4	C&C	0.116	10	PST	0.034
5	FBP	0.111			
6	A&F	0.110		**Total**	1.000

As described in Section 3.2, all scale were translated into the largest Eigen value problem and the resulting priority weights of VP, P, F, G, and VG were found as 1.000, 1.500, 2.000, 2.500 and 3.000, respectively. Similarly local or relative weights of the three qualified suppliers were found out by using the pair wise comparisons using FAHP and the results for the three vendors as shown in Table 5.8.

Finally, adding the weights per alternatives multiplied by the weights of the corresponding criteria, a final score is obtained for each alternative. Table 5.9 shows these scores.

Table 5.8 Normalized local weights of candidate alternatives in each sub-criterion

Criteria	TTC	PST	PMT	A&F	FPV	FBP	FOD	OTD	TAS	C&C
Supplier A	0.308	0.357	0.360	0.313	0.330	0.360	0.400	0.267	0.360	0.313
Supplier B	0.385	0.357	0.280	0.375	0.330	0.280	0.333	0.333	0.360	0.313
Supplier C	0.308	0.280	0.360	0.313	0.340	0.360	0.267	0.400	0.280	0.375

Table 5.9 Application of the classical fuzzy AHP for material supplier selection

Main criteria	Global	Supplier A		Supplier B		Supplier C	
Sub-criteria	weights	Local weights	Global weights	Local weights	Global weights	Local weights	Global weights
Price							
TTC	0.047	0.308	0.014	0.385	0.018	0.308	0.014
PST	0.034	0.357	0.012	0.357	0.012	0.280	0.009
PMT	0.087	0.360	0.031	0.280	0.024	0.360	0.031
Quality							
A&F	0.110	0.313	0.034	0.375	0.041	0.313	0.034
FPV	0.044	0.330	0.015	0.330	0.015	0.340	0.015
Compatibility							
FBP	0.111	0.360	0.040	0.280	0.031	0.360	0.040
FOD	0.219	0.400	0.087	0.333	0.073	0.267	0.058
Service							
OTD	0.116	0.267	0.031	0.333	0.039	0.400	0.047
TAS	0.116	0.360	0.042	0.360	0.042	0.280	0.033
C&C	0.116	0.313	0.036	0.313	0.036	0.375	0.044
Final score			**0.344**		**0.331**		**0.325**
Sequencing			**1**		**2**		**3**

5.4.2 The Extent Analysis Method

Via pairwise comparison of main criteria in Table 5.4, the extent analysis method on fuzzy AHP was adopted to calculate the weight vector for main criteria. Table 5.10 shows values by applying Equations 3.17 and 3.18 for calculating the

value of fuzzy synthetic extent. Thus, the following values were obtained by applying

Equation 3.16.

Table 5.10 Preparation data for the fuzzy synthetic extent value

Equation	l_{ij}	m_{ij}	u_{ij}
$\sum_{j=1}^{4} M_{PR}^{j}$	2.52	3.20	4.00
$\sum_{j=1}^{4} M_{QLT}^{j}$	2.35	2.78	3.75
$\sum_{j=1}^{4} M_{CPT}^{j}$	4.75	6.25	7.75
$\sum_{j=1}^{4} M_{SV}^{j}$	4.92	6.25	8.25
$\left[\sum_{i=1}^{4} \sum_{j=1}^{4} M_{i}^{j} \right]$	14.54	18.48	23.75

$$S_{PR} = (2.52, 3.20, 4.00) \otimes \left(\frac{1}{23.75}, \frac{1}{18.48}, \frac{1}{14.54} \right) = (0.11, 0.17, 0.28),$$

$$S_{QLT} = (2.35, 2.78, 3.75) \otimes \left(\frac{1}{23.75}, \frac{1}{18.48}, \frac{1}{14.54} \right) = (0.10, 0.15, 0.26),$$

$$S_{CPT} = (4.75, 6.25, 7.75) \otimes \left(\frac{1}{23.75}, \frac{1}{18.48}, \frac{1}{14.54} \right) = (0.20, 0.34, 0.53),$$

$$S_{SV} = (4.92, 6.25, 8.25) \otimes \left(\frac{1}{23.75}, \frac{1}{18.48}, \frac{1}{14.54} \right) = (0.21, 0.34, 0.57)$$

Next, Equations 3.20 and 3.21 were used to obtain the degree of possibility of

$M_1 \geq M_2$, then

$$V(S_{PR} \geq S_{QLT}) = 1.00,$$

$$V(S_{PR} \geq S_{QLT}) = \frac{0.20 - 0.28}{(0.17 - 0.28) - (0.34 - 0.20)} = 0.31,$$

$$V(S_{PR} \geq S_{SV}) = \frac{0.21 - 0.28}{(0.17 - 0.28) - (0.34 - 0.21)} = 0.29,$$

$$V(S_{QLT} \geq S_{PR}) = \frac{0.11 - 0.26}{(0.15 - 0.26) - (0.17 - 0.11)} = 0.87,$$

$$V(S_{QLT} \geq S_{CPT}) = \frac{0.20 - 0.26}{(0.15 - 0.26) - (0.34 - 0.20)} = 0.24,$$

$$V(S_{QLT} \geq S_{SV}) = \frac{0.21 - 0.26}{(0.15 - 0.26) - (0.34 - 0.21)} = 0.21,$$

$$V(S_{CPT} \geq S_{PR}) = 1.00, V(S_{CPT} \geq S_{QLT}) = 1.00,$$

$$V(S_{CPT} \geq S_{SV}) = \frac{0.21 - 0.53}{(0.34 - 0.53) - (0.34 - 0.21)} = 1.00,$$

$$V(S_{SV} \geq S_{PR}) = 1.00, V(S_{SV} \geq S_{QLT}) = 1.00, V(S_{SV} \geq S_{CRT}) = 1.00$$

The weight vector was given by adopting Equations 3.23 and 3.24, respectively

$$W' = \begin{pmatrix} \min(1.00, 0.31, 0.29), \min(0.87, 0.24, 0.21), \min(1.00, 1.00, 1.00), \\ \min(1.00, 1.00, 1.00) \end{pmatrix}^T$$

$$W' = (0.29, 0.21, 1.00, 1.00)^T$$

The normalized weight vectors with respect to main criteria were

$$W' = (0.12, 0.08, 0.40, 0.40)^T$$

The DMs also compared the sub-criteria with respect to main criteria. The other tables are given in Appendix F. The normalized local priority weights of main criteria and sub-criteria were synthesized together for acquiring the global composite priority weights of all sub-criteria as illustration in Table 5.11.

Table 5.11 Global weights of sub-criteria

Main Criteria	Normalized local weights	Sub-criteria	Normalized local weights	Global weights
PR	0.12	TTC	0.33	0.04
		PST	0.33	0.04
		PMT	0.34	0.04
QLT	0.08	A&F	0.50	0.04
		FPV	0.50	0.04
CPT	0.40	FBP	0.50	0.20
		FOD	0.50	0.20
SV	0.40	OTD	0.33	0.13
		TAS	0.33	0.13
		C&C	0.34	0.13
			Total:	1.00

Table 5.12 displays the priority by sorting value from largest to smallest. The sub-criteria in compatibility influenced in the top rankings. Three service sub-criteria were placed in the top five rankings as previous method.

After finding the global priority weights, they could be transferred easily to a spreadsheet as shown in Table 5.13 to determine the final composite priority weights of vendor systems occupying the global weight of sub-criteria and the normalized local weights of candidate alternatives in each sub-criterion in Table 5.8.

Table 5.12 Sub-criteria positioning status

Rank	Sub-criteria	Global weights	Rank	Sub-criteria	Global weights
1	FOD	0.20	7	PMT	0.04
2	FBP	0.20	8	TTC	0.04
3	TAS	0.13	9	FPV	0.04
4	C&C	0.13	10	PST	0.04
5	OTD	0.13			
6	A&F	0.04		**Total**	1.00

Table 5.13 Application of the extent analysis method on fuzzy AHP

| Main criteria | Global | Supplier A | | Supplier B | | Supplier C | |
Sub-criteria	weights	Local weights	Global weights	Local weights	Global weights	Local weights	Global weights
Price							
TTC	0.04	0.308	0.012	0.385	0.015	0.308	0.012
PST	0.04	0.357	0.014	0.357	0.014	0.280	0.011
PMT	0.04	0.360	0.014	0.280	0.011	0.360	0.014
Quality							
A&F	0.04	0.313	0.013	0.375	0.016	0.313	0.013
FPV	0.04	0.330	0.014	0.330	0.014	0.340	0.014
Compatibility							
FBP	0.20	0.360	0.072	0.280	0.056	0.360	0.072
FOD	0.20	0.400	0.080	0.333	0.067	0.267	0.053
Service							
OTD	0.13	0.267	0.035	0.333	0.044	0.400	0.053
TAS	0.13	0.360	0.048	0.360	0.048	0.280	0.037
C&C	0.13	0.313	0.042	0.313	0.042	0.375	0.050
Final score			**0.344**		**0.326**		**0.330**
Sequencing			**1**		**3**		**2**

In Tables 5.9 and 5.13 based on the comparison of suppliers and the methods applied, it could be found that supplier A was the favored from both methods, since it had the utmost weight of [(0.344), (0.344)] among three suppliers. Results for the second place could not exactly decide because both methods propose different supplier. Figure 5.2 elucidates the overall comparison of supplier ratings using classical fuzzy AHP and the extent analysis method on fuzzy AHP in the form of bar charts.

5.5 Stochastic Approach

This section aimed to find the variance of global weights for each candidate alternative. First of all, the variance of the relative local weight error $\sigma_{w_i}^2$ was

calculated by using Equation 2.9. Here, this sample calculation was provided the extent analysis method. Then, the variance of the relative local weights error for main criteria were presented as
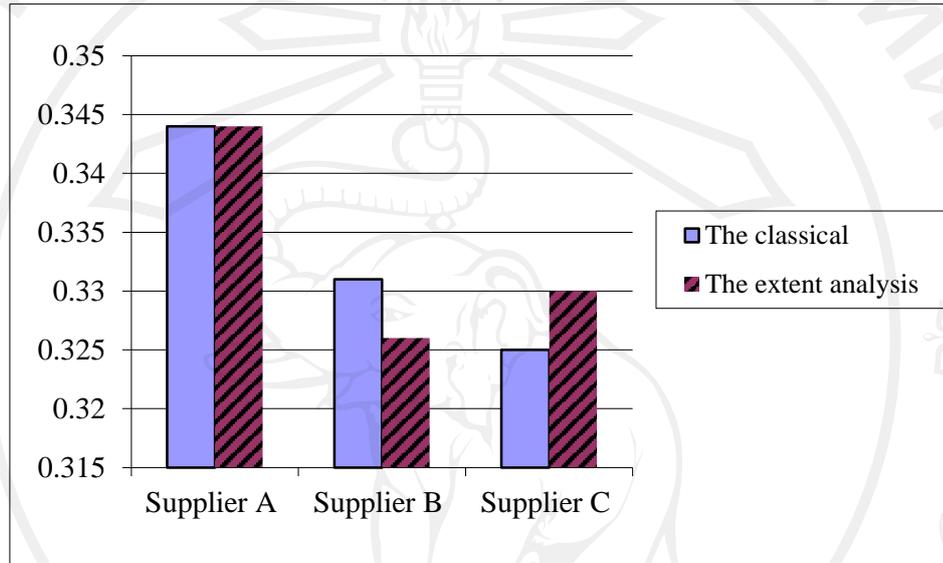

Figure 5.2 Overall comparison of material supplier rating

$$\sigma^2_{w_{PR}} = \frac{4^2-1}{4^2} \times \left(\left(0.12^2 + 0.08^2 + 0.40^2 + 0.40^2\right) - 0.12^2\right) \times \left(0.85 \times 0.12^2\right)$$

$$= 3.51 \times 10^{-3}$$

$$\sigma^2_{w_{QLT}} = \frac{4^2-1}{4^2} \times \left(\left(0.12^2 + 0.08^2 + 0.40^2 + 0.40^2\right) - 0.08^2\right) \times \left(0.85 \times 0.08^2\right)$$

$$= 1.90 \times 10^{-3}$$

$$\sigma^2_{w_{CPT}} = \frac{4^2-1}{4^2} \times \left(\left(0.12^2 + 0.08^2 + 0.40^2 + 0.40^2\right) - 0.40^2\right) \times \left(0.85 \times 0.40^2\right)$$

$$= 2.28 \times 10^{-2}$$

$$\sigma^2_{w_{SV}} = \frac{4^2-1}{4^2} \times \left(\left(0.12^2 + 0.08^2 + 0.40^2 + 0.40^2\right) - 0.40^2\right) \times \left(0.85 \times 0.40^2\right)$$

$$= 2.28 \times 10^{-3}$$

where the variance of error σ^2 equals 0.85 (see Equation 2.7). The variances of the relative local weight error σ^2 for main criteria were shown in Table 5.14.

Table 5.14 Variances of relative local weights

Main criteria	The classical fuzzy AHP	The extent analysis
Price	1.25×10^{-4}	3.51×10^{-3}
Quality	1.08×10^{-4}	1.90×10^{-3}
Compatibility	3.31×10^{-4}	2.28×10^{-2}
Service	3.34×10^{-4}	2.28×10^{-2}

Next, the variances of the global relative weights for each candidate were calculated as previous described the procedure in Section 3.2. However, the global weights in Table 5.13 were reformed as

$$w_{A,3}^{PR,2} = \frac{(0.012 + 0.014 + 0.014)}{0.12} = 0.342,$$

$$w_{A,3}^{QLT,2} = \frac{(0.013 + 0.014)}{0.08} = 0.321,$$

$$w_{A,3}^{CPT,2} = \frac{(0.070 + 0.014)}{0.40} = 0.381,$$

$$w_{A,3}^{SV,2} = \frac{(0.012 + 0.014 + 0.014)}{0.12} = 0.342,$$

$$w_{B,3}^{PR,2} = \frac{(0.015 + 0.014 + 0.011)}{0.12} = 0.340,$$

$$w_{B,3}^{QLT,2} = \frac{(0.016 + 0.014)}{0.08} = 0.353,$$

$$w_{B,3}^{CPT,2} = \frac{(0.054 + 0.068)}{0.40} = 0.307,$$

$$w_{B,3}^{SV,2} = \frac{(0.044 + 0.048 + 0.042)}{0.40} = 0.335,$$

$$w_{C,3}^{PR,2} = \frac{(0.012 + 0.011 + 0.014)}{0.12} = 0.316,$$

$$w_{C,3}^{QLT,2} = \frac{(0.013 + 0.014)}{0.08} = 0.326,$$

$$w_{C,3}^{CPT,2} = \frac{(0.070 + 0.055)}{0.40} = 0.312, and$$

$$w_{C,3}^{SV,2} = \frac{(0.053 + 0.037 + 0.050)}{0.40} = 0.352,$$

and $\sigma_{i,3}^{j,2} = 0$ which $i =$ supplier $A, B, and\ C, and\ j = PR, QLT, CPT\ and\ SV$ and $j =$ PR, QLT, CPT and SV, respectively.

The variances of global weights for suppliers were obtained by the multiplicative matrix term,

$$\begin{bmatrix} \left(\sigma_{A,3}^{1,1}\right)^2 \\ \left(\sigma_{B,3}^{1,1}\right)^2 \\ \left(\sigma_{C,3}^{1,1}\right)^2 \end{bmatrix} = \begin{bmatrix} (0.342)^2 (0.321)^2 (0.381)^2 (0.313)^2 \\ (0.340)^2 (0.353)^2 (0.307)^2 (0.335)^2 \\ (0.316)^2 (0.326)^2 (0.312)^2 (0.352)^2 \end{bmatrix} \begin{bmatrix} 3.51 \times 10^{-3} \\ 1.90 \times 10^{-3} \\ 2.28 \times 10^{-2} \\ 2.28 \times 10^{-2} \end{bmatrix} = \begin{bmatrix} 6.14 \times 10^{-3} \\ 5.36 \times 10^{-3} \\ 5.59 \times 10^{-3} \end{bmatrix}$$

The overall synthesis of the AHP and some statistics for global weights of decision alternatives based on the recommended methodology are given in Table 5.15 for both methods. These global AHP weights variances expressed the stochastic environments which might affect the rank order of decision alternatives. In addition, Figure 5.3 and 5.4 shows a graphical representation of both methods, indicating some degree of judgmental uncertainty.

Table 5.15 Statistics display for global weights

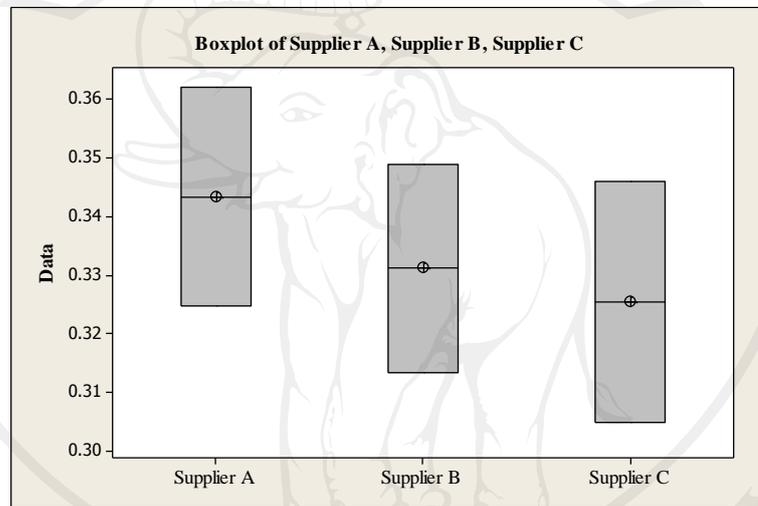|	Supplier	Mean	Standard deviation	C.I. (95%)
The classical fuzzy AHP	A	0.344	0.0095	(0.3246, 0.3619)
	B	0.331	0.0090	(0.3134, 0.3488)
	C	0.325	0.0105	(0.3048, 0.3460)
The extent analysis	A	0.344	0.0784	(0.1904, 0.4977)
	B	0.326	0.0732	(0.1826, 0.4697)
	C	0.330	0.0748	(0.1829, 0.4762)

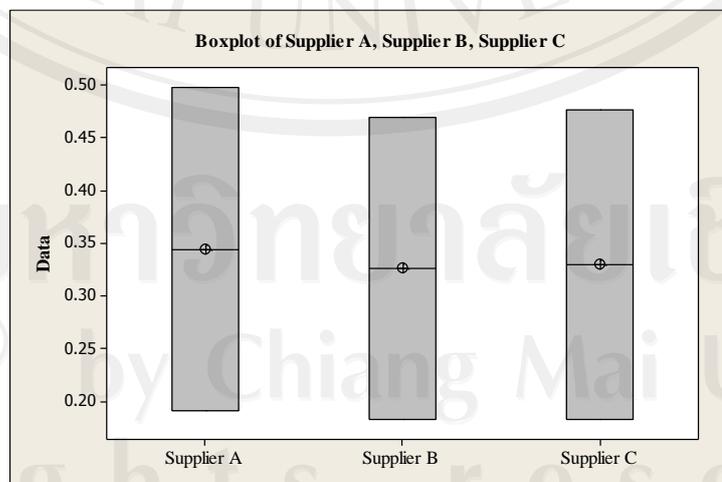Figure 5.3 Range of global weights for the classical method

Figure 5.4 Range of global weights for the extent analysis

5.6 Ranking Supplier by Using Monte Carlo Simulation

There were considerable overlaps between candidate suppliers at the obtained 95% confidence interval of the global weights in Figure 5.3 and 5.4. These overlaps implied that supplier A, B, and C were competed to occupy the first rank position. Though the alternative A should be selected as the preferred option with the highest global weight point estimate, some statistical analysis should be used for ensuring whether there was a significant difference between supplier A, B and C.

An add-in, MCSIM.xla, Monte Carlo simulation, pioneered by Barreto and Howland (2006), was adopted for observing the result. Experiment results consisted of 1,000 replications were displayed in Table 5.16 (See generated data in Appendix G). For both methods, supplier A did not dominate supplier B and C with the confidence level of 95%. Hence, the null assumption that supplier A was probabilistic optimal (versus the alternate assumption that it is not) is rejected. In this case, the stochastic analysis yields the preference ranking of supplier A, B and C, respectively considering the degree of judgmental uncertainty found in the input data.

Table 5.16 Summary of statistic and the simulation results for decision alternatives

	Supplier	**Rank**			**Rank**		
		1	2	3	1	2	3
The classical fuzzy AHP	A	689	244	67	68.9%	24.4%	6.7%
	B	215	451	334	21.5%	45.1%	33.4%
	C	96	305	599	9.6%	30.5%	59.9%
	Total	1,000	1,000	1,000	100%	100%	100%
The extent analysis	A	392	324	284	39.2%	32.4%	28.4%
	B	317	342	341	31.7%	34.2%	34.1%
	C	291	334	375	29.1%	33.4%	37.5%
	Total	1,000	1,000	1,000	100%	100%	100%

5.7 Conclusion

This Chapter proposed MCDM approaches to effectively select material alliance supplier. It was demonstrated that this uncertainty associated with subjective judgmental errors might strongly affect the results of selection procedure. The decision hierarchy was affected from the judgmental uncertainty. These variances of the global AHP weights expressed the stochastic environments which might affect the rank order of decision alternatives.

The proposed stochastic approaches had ability not only to calculate the variances of the global AHP weights, but also handled the uncertain behavior of them. The stochastic process also supported supplementary information for DMs and enhanced their confidence in final rankings as well as the stability of the rank orders.

Service and compatibility were found to be the most influential factors in the selection. These results responded a sub-question 1 "What factors will have influence effect on product delivery and variation reduction?" The selected potential supplier is an important component for minimizing makespan time.

In addition, the case study should always evaluate existing potential suppliers and new suppliers by performing the proposed tools. The overall synthesis and some statistics for global weights of decision alternatives will be adjusted to select the best supplier.

It should be noted that if there is no or only a little inconsistency $(CR < 0.01)$ in the AHP, it is not necessary to use the proposed approaches to capture the uncertain behavior of the rank orders.