Evaluation of Potential Manufacturing Suppliers Using Analytical Hierarchy Process and Cluster Analysis for Benchmarking

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Abstract

This paper proposes an assessment method for the potential outsourcees (suppliers) in agreement with the benchmark evaluated for a set of surveyed UK based companies. The results of the survey are ordered using Analytical Hierarchy Process (AHP) and Cluster Analysis (CA). The partial and total evaluation score of each supplier is compared with the benchmark. The outsourcee that achieves the highest total score could be considered as the most suitable match. The result of integrating AHP and CA may be applied as an effective method for matching and evaluating the right outsourcee in the manufacturing sector.

Keywords: Analytical Hierarchy Process (AHP), Cluster Analysis, Decision, Outsourcee, Outsourcing, Outsourcer, Outsourcee Selection

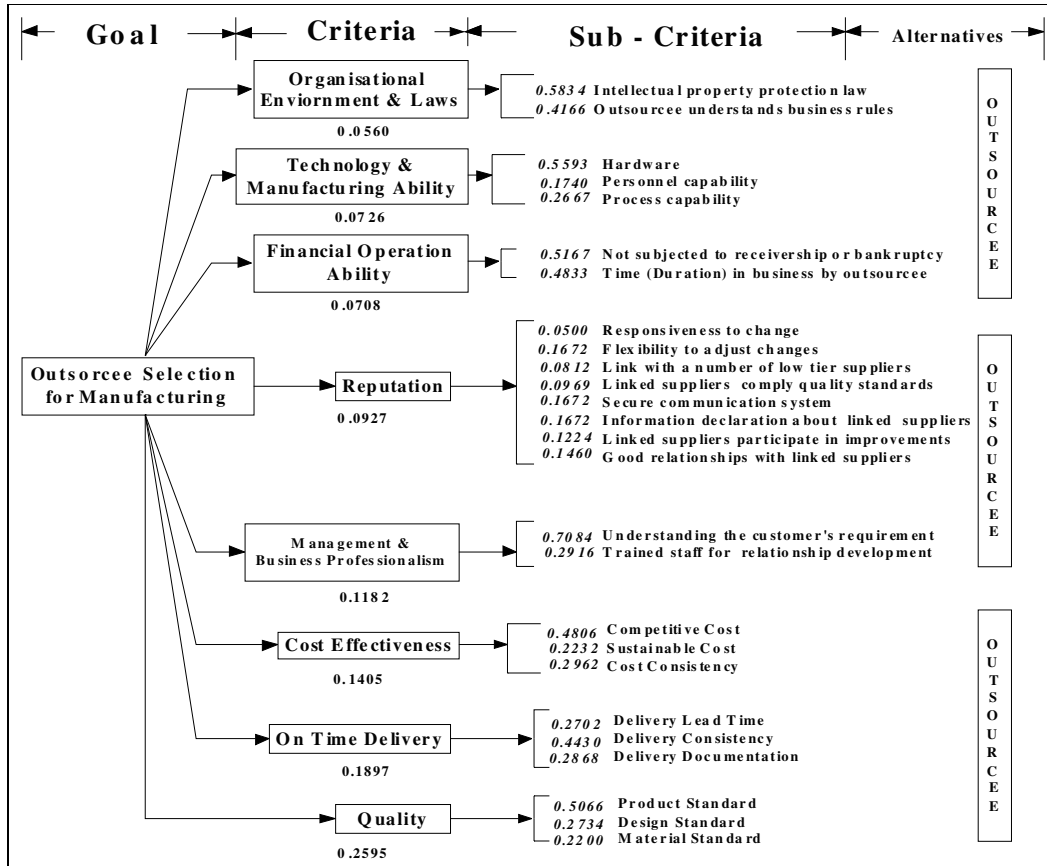A. Adnan, A. Cazan, M. Safa, A.W.M Lung & G. Williams

FIGURE 1: The weighted hierarchy structure for outsourcee selection

Figure 1 is a result of survey of around twenty British manufacturing companies practicing outsourcing. The order and weightings of the criteria are the result of the application of AHP & CA to the survey results. Therefore, the order and the values listed in Figure 1 are the benchmark representative for the companies surveyed.

1. Introduction

The main objective of the outsourcing is to compliment participants manufacturing ability by maximising the utility of available resources. Due to differences between outsourcer (company) and outsourcee (supplier) regarding their locations, management methods, legal and taxation system, there are difficulties in practicing outsourcing effectively. The communications (applications) are also vulnerable to attack by malicious applications [11]. The need to protect communications from prying eyes is greater than before [10]. The success of the outsourcing depends upon the ability of the outsourcee in delivering good quality products on time at a competitive cost.

Since over the last decade researchers have increased their attention for improving outsourcing by implementing improvement models and algorithms to survive in dynamic Global market. In this regard an improvement model was proposed that was formulated by integrating 'Theory of Constraints' with outsourcing in order to exploit the existing resources [1]. The outcome of the outsourcing is the acquisition of the quality products at competitive sustainable cost and short lead time [7]. The initial problem of the outsourcing arises when the desires or the goals of the outsourcer and the outsourcee conflicts or their preferences are different. Therefore, improvement in outsourcing is not guaranteed without the participation of right outsourcee. The outsourcees must be evaluated according to the criteria that are in line with the outsourcer organisation's outsourcing strategies.

A wrong decision choice makes the outsourcing fail to achieve reduction in manufacturing lead time, cost and enhance quality [5]. The analytical hierarchy process was developed by Thomas Saaty in 1971 [6]. Bhutta and Huq applied total cost of ownership and AHP for supplier selection [2]. The supplier selections have been carried out by applying AHP [2], [3]. Ting and Cho suggested that the suppliers be selected according to their global performances [8]. Outsourcing participant evaluation is one of the most important factors. This study encompasses the application of the AHP-CA method on one of the European Manufacturing Company 'EMC' for suitable outsourcee evaluation. The information used in this case study is line with real data but the names of the companies have been changed for business security.

2. Outsourcee Evaluation

The objective of EMC is to become a reputable player in its local market and expand its business globally as part of strategic planning. Having achieved a great share of its local market business, EMC is offering after sales service and maintenance to other organisations as an outsourcee. Due to dynamic nature of the markets, it is always desirable searching new outsourcee for successful and sustainable outsourcing operations. In order to expand its activities EMC decided outsourcing in 2004. There were uncertainties due to a number of cases of outsourcing failures because of hidden problems. It was essential to search for an outsourcee that understands EMC's market requirements and participates in development and manufacture of the products according to European standards.

In the initial search approximately more than 6000 suppliers were identified and anyone could be a potential outsourcee candidate. In order to refine the search an evaluation method is developed that is based on comparing the outsourcer's requirement criteria with supplier's (candidate outsourcee) capability criteria. According to the supplier's database, there are thousands of suppliers willing to be outsourcee candidate and everyday their number is increasing. It is very important to choose a supplier that is most appropriate for the company, as soon as possible and at the expense of minimum cost. The problem of evaluating an outsourcee becomes difficult when constraints such as minimum cost, short search time and accuracy are applicable. Due to Globalisation, companies all around the World are competing to supply despite their specifications are in different formats due to difference in language and standards.

The evaluation method is applied to rank the suppliers enabling equality of access as a free trade market. During outsourcee (supplier) evaluation, the attributes are matched and Decision Makers assign relative priority / importance weight. Each outsourcee (supplier) is assessed by employing eight criteria and twenty-six sub-criteria. The suppliers are ranked in a logical order according to their total importance weights which are calculated from their criteria and sub-criteria weights. As an illustration, application of the evaluation method is shown for comparing four (candidate outsourcee) suppliers.

3. Assigning Ranking Scale (S)

Prioritised the criteria based on their relative importance and used as a filter in short-listing the manufacturers as candidate outsourcee. Quality is the first criteria on the importance list. The outsourcee's capability to comply quality is scaled from 1 to 10; 10 for conforming ISO or European standards, 7 for American standards and 5 for Chinese standards. On time delivery criterion is composed of consistent delivery, flexible delivery within reasonable lead time and complete documentation. The 'On Time Delivery' ability is scaled from 1-10; 1 for worst and 10 for excellent ability. The criterion of cost effectiveness is used for consistent, competitive cost that is sustainable. Similarly, cost effectiveness ability of the outsourcee is scaled 1 to 10; 1 for worst and 10 for most acceptable price quotations. The fourth selection criterion is Organisational environment & laws that scales the organisation's ability from the intellectual property protection law and business law. It is also scaled from 1 to 10; 1 having worst and 10 for the best ability. Technology & manufacturing ability encompasses the hardware, personnel capability and process capability. For selecting an outsourcee Technology & manufacturing ability is scaled from 1 to 10; 1 having worst and 10 for the best ability. Management & business professionalism criterion evaluates the training programme and the professional behaviour of an organisation. Like other criteria, it is also scaled from 1 to 10; 1 having worst and 10 for the best ability. Financial operation ability is ranked seventh according to importance in decision making. This criterion evaluates an outsourcee's financial stability and professional accreditation of its accounting staff. Similar to other criterion, it is also scaled from 1 to 10; 1 for least ability and 10 for the excellence. Reputation is the eighth criterion that identifies an outsourcee's ability for implementing a contract and its acknowledgement in the community it operates. Like other criterion, it is also scaled from 1 to 10; 1 for least ability and 10 for the excellence.

4. Application of the AHP-CA Method

The evaluation method is developed to facilitate small and medium size manufacturing organisations in assessing candidate outsourcee. As a test case method is applied on EMC that specialises in designing, manufacturing and assembling motorcycles, mopeds and their parts to select an outsourcee based in China. The process of outsourcee selection is based on multi-criteria such as cost, delivery, quality and reputation etc. The abbreviations of all the criteria, sub-criteria and their corresponding scores which are used in the formula/ expressions are listed in the appendix Table. Total outsourcee priority weights are evaluated using equation 1.

$$\sum_{i=1}^{8} W_i \times \sum_{j=1}^{ns} w_{ij} \times S_{kij} \quad \dots (1)$$

Where

W = Priority weight of criterion

i = Criterion's number $(i = 1, 2, \dots, 8)$

w = Priority weight of sub-criterion

j = Number of sub-criterion $(j = 1, 2, \dots ns; j \in i)$

S = Outsourcee's ranking score

k = Candidate outsourcee's Number $(k = 1, 2, \dots m; k \in i)$

'ns' is the total number of sub-criteria for certain criterion. The numbers of sub-criteria range from two to eight for a particular criterion in the given formulated matching algorithm. 'm' is the total numbers of outsourcee candidate applicants.

The values of 'k' are:
For SUPD $k = 1$, for SUPK $k = 2$, for SUPW $k = 3$ and for SUPB $k = 4$
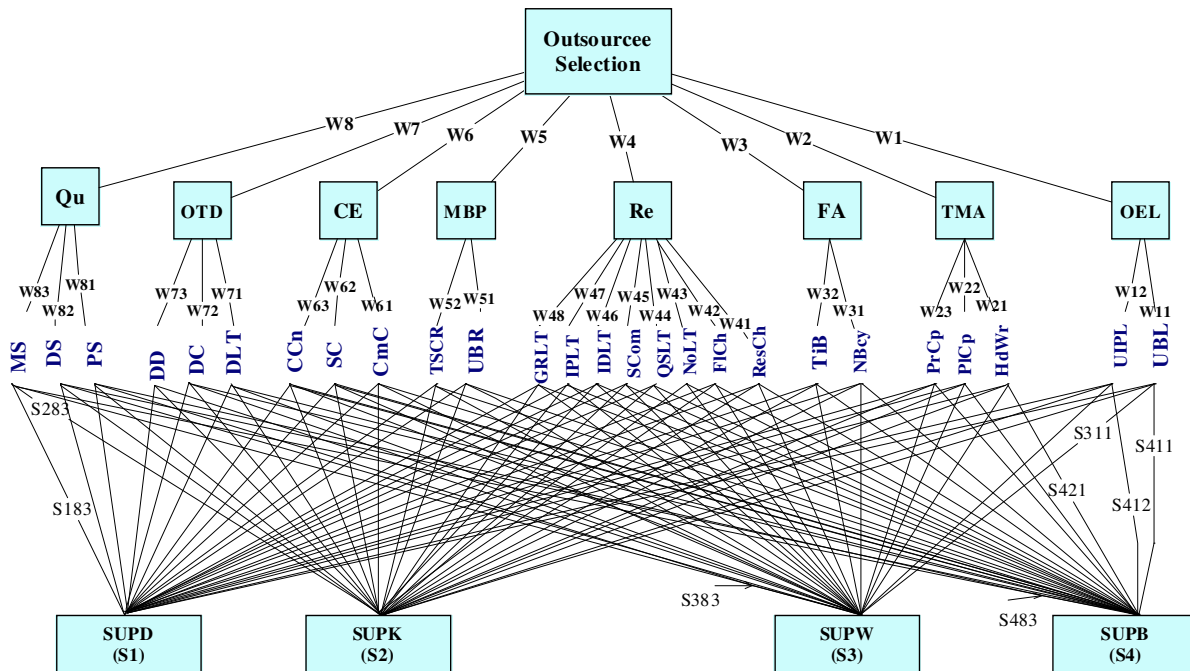The abbreviations of all the criteria and sub-criteria are tabulated as follows.

FIGURE 2: Figure showing criteria, sub-criteria for evaluating outsourcing participant (joint)

The Figure 2 shows the four layers of outsourcee selection hierarchy process. The top layer represents the goal/ objective. The second and the third hierarchy layers represent outsourcee selection criteria and sub-criteria. The fourth layer shows four short listed candidate outsourcees: SUPD, SUPK, SUPW and SUPB.

The Figure 2 displays 8 criteria and 26 sub-criteria connections corresponding to each outsourcee. For more clarity, the Figure 2 is split into further four Figures. For each of the detailed four Figures the hierarchy level 1, level 2 and level 3 are common. In each of the Figures 3 to 6, the level 4 of the hierarchy displays a single candidate outsourcee.

SUPD's priority weight evaluation components are shown in Figure 3, SUPK's priority weight evaluation components in Figure 4 and SUPW's priority weight evaluation components in Figure 5 and SUPB's priority weight evaluation components in Figure 6. In order to perform the calculations, formula 1 is expanded to expression 2 and the numerical calculation is illustrated in expression 3 for SUPD, expressions 4 & 5 for SUPK, expressions 6 & 7 for SUPW and expressions 8 & 9 for SUPB.

The final total priority weights results are calculated as:
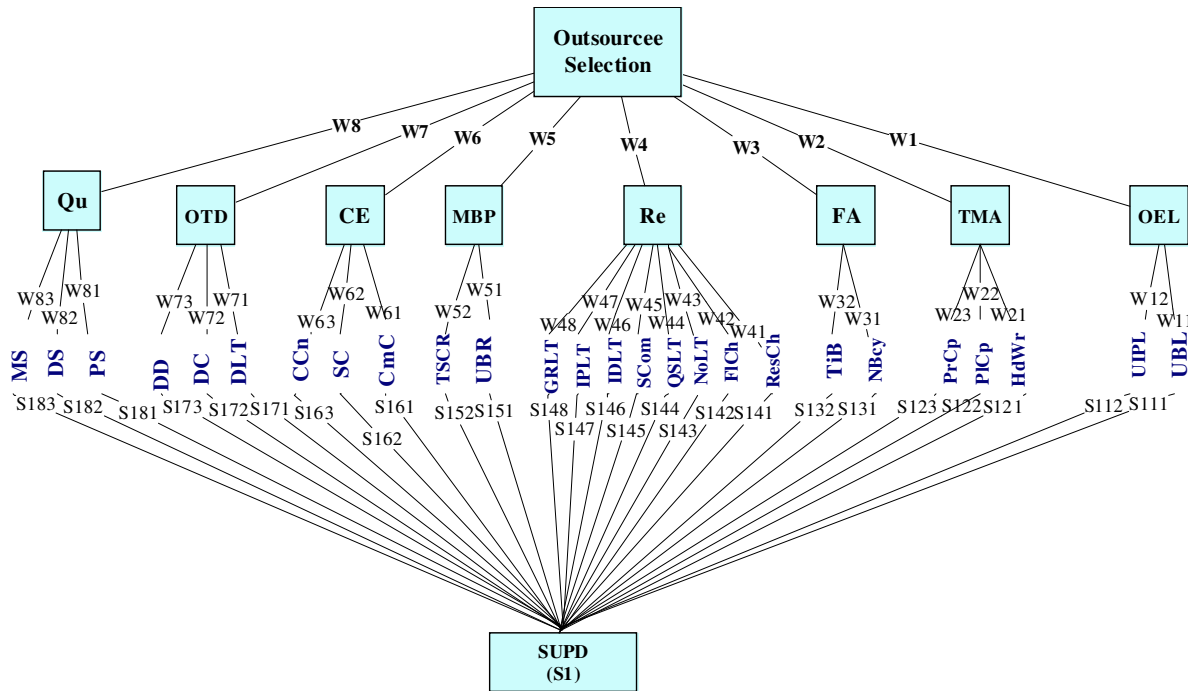SUPD 7.0342, SUPK's 6.5991, SUPW's 6.3464, SUPB's 5.3905.

FIGURE 3: Figure showing criteria, sub-criteria for evaluating outsourcing participant (SUPD)

$$
\begin{aligned}
\text{SUPD (S1)} = \; & W_1\left[w_{11}\times S_{111}+w_{12}\times S_{112}\right]+W_2\left[w_{21}\times S_{121}+w_{22}\times S_{122}+w_{23}\times S_{123}\right]+W_3\left[w_{31}\times S_{131}+w_{32}\times S_{132}\right]+ \\
& W_4\left[w_{41}\times S_{141}+w_{42}\times S_{142}+w_{43}\times S_{143}+w_{44}\times S_{144}+w_{45}\times S_{145}+w_{46}\times S_{146}+w_{47}\times S_{147}+w_{48}\times S_{148}\right]+ \\
& W_5\left[w_{51}\times S_{151}+w_{52}\times S_{152}\right]+W_6\left[w_{61}\times S_{161}+w_{62}\times S_{162}+w_{63}\times S_{163}\right]+W_7\left[w_{71}\times S_{171}+w_{72}\times S_{172}+w_{73}\times S_{173}\right]+ \\
& W_8\left[w_{81}\times S_{181}+w_{82}\times S_{182}+w_{83}\times S_{183}\right]
\end{aligned}
\quad \dots (2)
$$

$$
\begin{aligned}
& 0.0560\times[0.5834\times10+0.4166\times10]+0.0726\times[0.5593\times10+0.1740\times10+0.2667\times10]+0.0708\times[0.5167\times10+0.4833\times6]+ \\
& 0.0927\times[0.0500\times5+0.1672\times0+0.0812\times10+0.0969\times5+0.1672\times0+0.1672\times10+0.1224\times0+0.1460\times0]+ \\
& 0.1182\times[0.7084\times10+0.2916\times10]+0.1405\times[0.4806\times7+0.2232\times0+0.2962\times0]+0.1897[0.2702\times5+0.4430\times0+0.2868\times10]+ \\
& 0.2595\times[0.5066\times10+0.2734\times10+0.2200\times7]=7.0342
\end{aligned}
\quad \dots (3)
$$

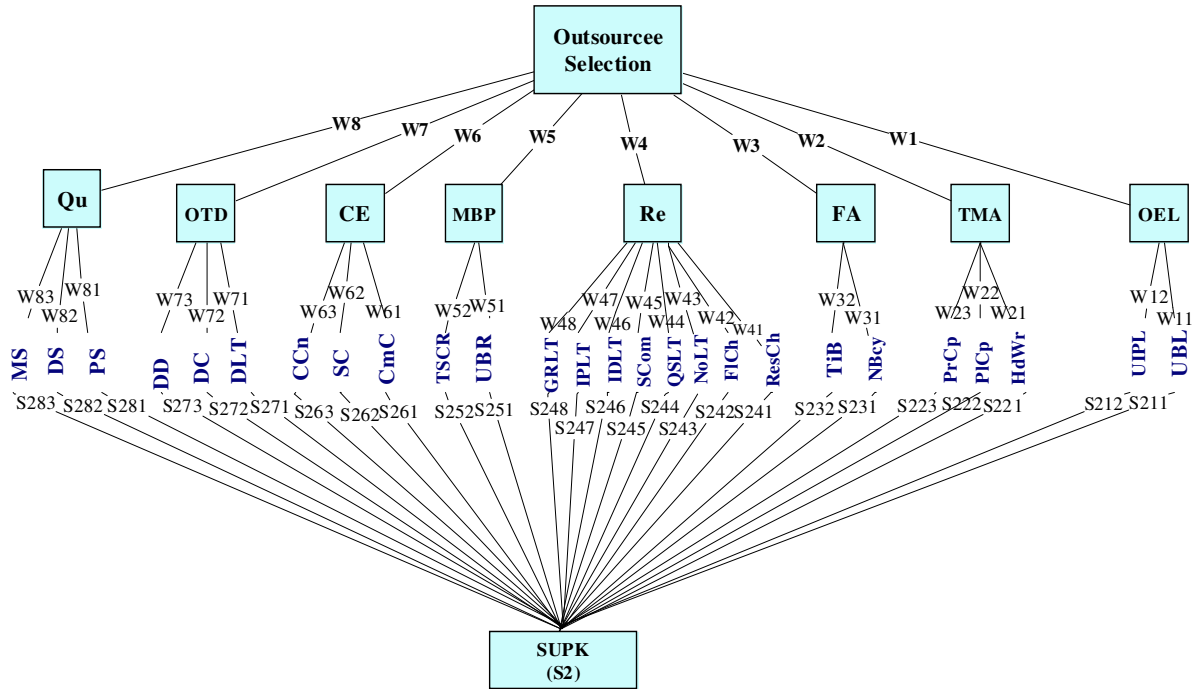**Total Priority Weight of SUPD = 7.0342**

FIGURE 4: Figure showing criteria, sub-criteria for evaluating outsourcing participant (SUPK)

$$\begin{aligned} \text{SUPK (S2)} = {} & W_1[w_{11} \times S_{211} + w_{12} \times S_{212}] + W_2[w_{21} \times S_{221} + w_{22} \times S_{222} + w_{23} \times S_{223}] + W_3[w_{31} \times S_{231} + w_{32} \times S_{232}] + \\ & W_4[w_{41} \times S_{241} + w_{42} \times S_{242} + w_{43} \times S_{243} + w_{44} \times S_{244} + w_{45} \times S_{245} + w_{46} \times S_{246} + w_{47} \times S_{247} + w_{48} \times S_{248}] + \\ & W_5[w_{51} \times S_{251} + w_{52} \times S_{252}] + W_6[w_{61} \times S_{261} + w_{62} \times S_{262} + w_{63} \times S_{263}] + W_7[w_{71} \times S_{271} + w_{72} \times S_{272} + w_{73} \times S_{273}] + \\ & W_8[w_{81} \times S_{281} + w_{82} \times S_{282} + w_{83} \times S_{283}] \end{aligned} \quad \cdots (4)$$

$$\begin{aligned} & 0.0560 \times [0.5834 \times 9 + 0.4166 \times 9] + 0.0726 \times [0.5593 \times 10 + 0.1740 \times 8 + 0.2667 \times 10] + 0.0708 \times [0.5167 \times 10 + 0.4833 \times 7] + \\ & 0.0927 \times [0.0500 \times 0 + 0.1672 \times 0 + 0.0812 \times 10 + 0.0969 \times 5 + 0.1672 \times 0 + 0.1672 \times 10 + 0.1224 \times 0 + 0.1460 \times 0] + \\ & 0.1182 \times [0.7084 \times 7 + 0.2916 \times 7] + 0.1405 \times [0.4806 \times 10 + 0.2232 \times 0 + 0.2962 \times 0] + 0.1897 [0.2702 \times 5 + 0.4430 \times 0 + 0.2868 \times 10] + \\ & 0.2595 \times [0.5066 \times 10 + 0.2734 \times 7 + 0.2200 \times 7] = 6.5991 \end{aligned} \quad \cdots (5)$$
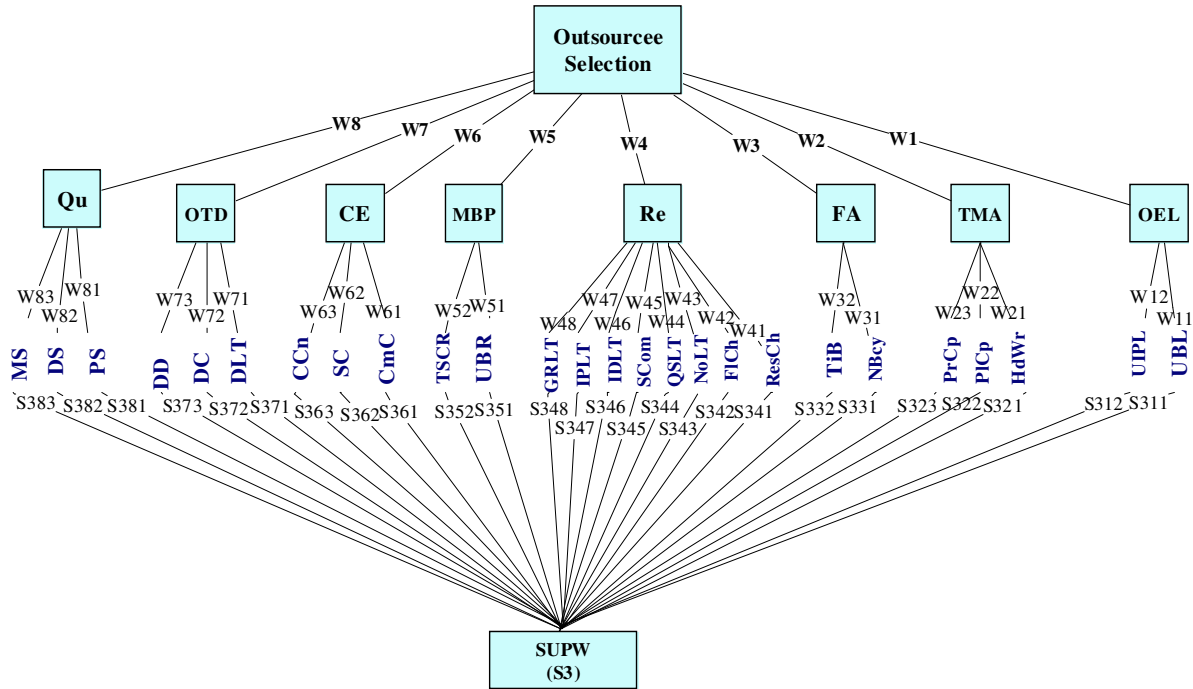
Total Priority Weight of SUPK = 6.5991

FIGURE 5: Figure showing criteria, sub-criteria for evaluating outsourcing participant (SUPW)

$$
\begin{aligned}
\text{SUPW (S3) =}\ & W_1\big[w_{11} \times S_{311} + w_{12} \times S_{312}\big] + W_2\big[w_{21} \times S_{321} + w_{22} \times S_{322} + w_{23} \times S_{323}\big] + W_3\big[w_{31} \times S_{331} + w_{32} \times S_{332}\big] + \\
& W_4\big[w_{41} \times S_{341} + w_{42} \times S_{342} + w_{43} \times S_{343} + w_{44} \times S_{344} + w_{45} \times S_{345} + w_{46} \times S_{346} + w_{47} \times S_{347} + w_{48} \times S_{348}\big] + \qquad \dots (6) \\
& W_5\big[w_{51} \times S_{351} + w_{52} \times S_{352}\big] + W_6\big[w_{61} \times S_{361} + w_{62} \times S_{362} + w_{63} \times S_{363}\big] + W_7\big[w_{71} \times S_{371} + w_{72} \times S_{372} + w_{73} \times S_{373}\big] + \\
& W_8\big[w_{81} \times S_{381} + w_{82} \times S_{382} + w_{83} \times S_{383}\big]
\end{aligned}
$$

$$
\begin{aligned}
& 0.0560 \times [0.5834 \times 10 + 0.4166 \times 10] + 0.0726 \times [0.5593 \times 10 + 0.1740 \times 8 + 0.2667 \times 10] + 0.0708 \times [0.5167 \times 10 + 0.4833 \times 10] + \\
& 0.0927 \times [0.0500 \times 0 + 0.1672 \times 0 + 0.0812 \times 10 + 0.0969 \times 5 + 0.1672 \times 0 + 0.1672 \times 10 + 0.1224 \times 0 + 0.1460 \times 0] + \qquad \dots (7) \\
& 0.1182 \times [0.7084 \times 10 + 0.2916 \times 5] + 0.1405 \times [0.4806 \times 5 + 0.2232 \times 0 + 0.2962 \times 0] + 0.1897[0.2702 \times 5 + 0.4430 \times 0 + 0.2868 \times 10] + \\
& 0.2595 \times [0.5066 \times 10 + 0.2734 \times 5 + 0.2200 \times 5] = 6.3464
\end{aligned}
$$

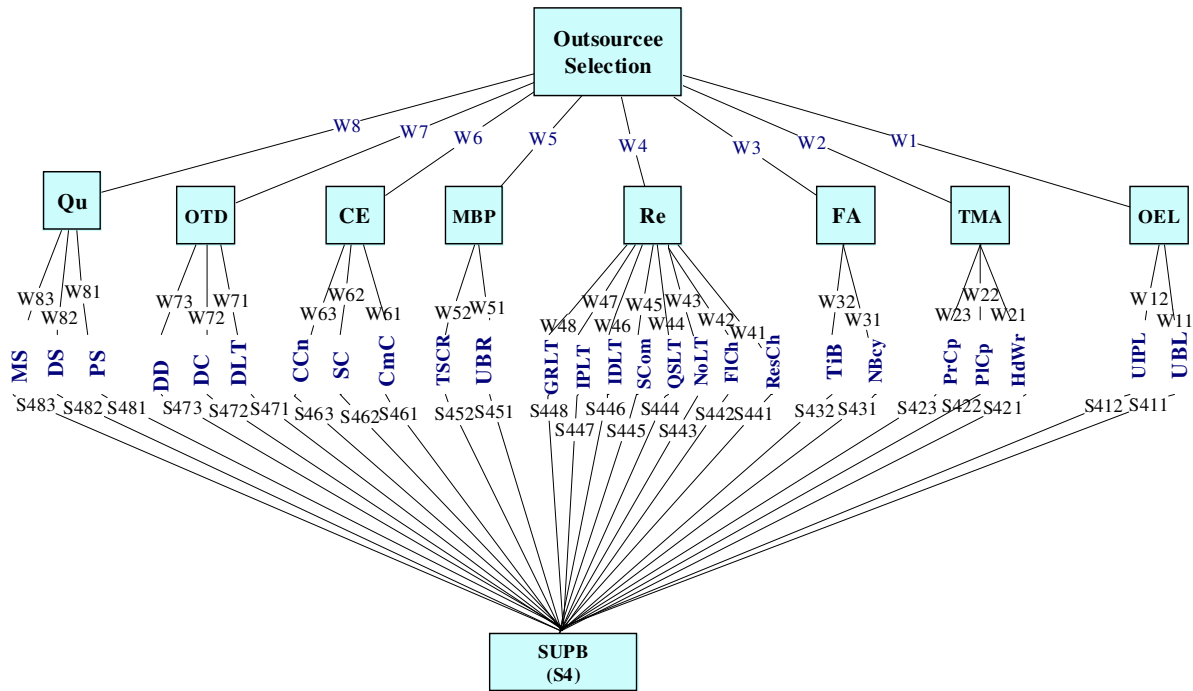**Total Priority Weight of SUPW= 6.3464**

FIGURE 6: Figure showing criteria, sub-criteria for evaluating outsourcing participant (SUPB)

$$W_1[w_{11}\times S_{411}+w_{12}\times S_{412}]+W_2[w_{21}\times S_{421}+w_{22}\times S_{422}+w_{23}\times S_{423}]+W_3[w_{31}\times S_{431}+w_{32}\times S_{432}]+$$

$$\text{SUPB (S4)}=W_4[w_{41}\times S_{441}+w_{42}\times S_{442}+w_{43}\times S_{443}+w_{44}\times S_{444}+w_{45}\times S_{445}+w_{46}\times S_{446}+w_{47}\times S_{447}+w_{48}\times S_{448}]+ \quad \text{… (8)}$$

$$W_5[w_{51}\times S_{451}+w_{52}\times S_{452}]+W_6[w_{61}\times S_{461}+w_{62}\times S_{462}+w_{63}\times S_{463}]+W_7[w_{71}\times S_{471}+w_{72}\times S_{472}+w_{73}\times S_{473}]+$$

$$W_8[w_{81}\times S_{481}+w_{82}\times S_{482}+w_{83}\times S_{483}]$$

$$0.0560\times[0.5834\times 9+0.4166\times 10]+0.0726\times[0.5593\times 8+0.1740\times 7+0.2667\times 10]+0.0708\times[0.5167\times 10+0.4833\times 3]+ \quad \text{… (9)}$$

$$0.0927\times[0.0500\times 0+0.1672\times 0+0.0812\times 10+0.0969\times 5+0.1672\times 0+0.1672\times 10+0.1224\times 0+0.1460\times 0]+$$

$$0.1182\times[0.7084\times 10+0.2916\times 5]+0.1405\times[0.4806\times 6+0.2232\times 0+0.2962\times 0]+0.1897[0.2702\times 5+0.4430\times 0+0.2868\times 10]+$$

$$0.2595\times[0.5066\times 5+0.2734\times 5+0.2200\times 5]=5.3905$$

Total Priority Weight of SUPB = 5.3905

5. Results and Discussions

The priority weights of selection criteria for SUPB, SUPW, SUPK and SUPD are tabulated in Table 1 and plotted in Figure 7. According to 'organisational Environment & Laws' criteria SUPK achieves the lowest score, whereas, both SUPW and SUPD achieves the highest score. When assessing companies according to 'Technology & Manufacturing Ability' criteria, it is found out that SUPB is the least suitable and SUPD is the most suitable because it has achieved the highest score. From 'Financial Operation Ability' criteria SUPW is the most stable and SUPB is the least stable. According to 'Financial Operation Ability' criteria's priority weight SUPD has low financial stability. It needs investments in order to sustain its activities. Therefore, for a suitable outsourcee having low 'Financial Operation Ability' is a positive point. SUPD achieves the highest 'Reputation' criteria priority weight. When analysing sub-criteria of 'Reputation' it is highlighted that a suitable company is flexible, responsive to change and linked with a number of low tier suppliers. The linked suppliers follow quality standards, labour laws and business rules. According to 'Management & Business Professionalism' criteria SUPD achieves the highest score and SUPK the lowest. The 'Cost Effectiveness' criteria evaluates an organisation's capability to manufacture a product at competitive cost that is consistent and sustainable. From 'Cost effectiveness' perspective SUPK is most suitable and SUPD is the second best choice. But when comparing companies from 'Quality' point of view SUPD manufacture better quality than SUPK. On account of overall score SUPD is the first choice and SUPK is the second choice as candidate outsourcee for EMC.

Criteria	SUPB	SUPW	SUPK	SUPD
Organisational Environment & Laws	0.5273	0.5600	0.5040	0.5600
Technology & Manufacturing Ability	0.6069	0.7007	0.7007	0.7260
Financial Operation Ability	0.4685	0.7080	0.6053	0.5711
Reputation	0.2752	0.2752	0.2752	0.2984
Management & Business Professionalism	1.0097	1.0097	0.8274	1.1820
Cost Effectiveness	0.4051	0.3376	0.6752	0.4727
On Time Delivery	0.8003	0.8003	0.8003	0.8003
Quality	1.2975	1.9548	2.2109	2.4237
Total:	5.3905	6.3464	6.5991	7.0342

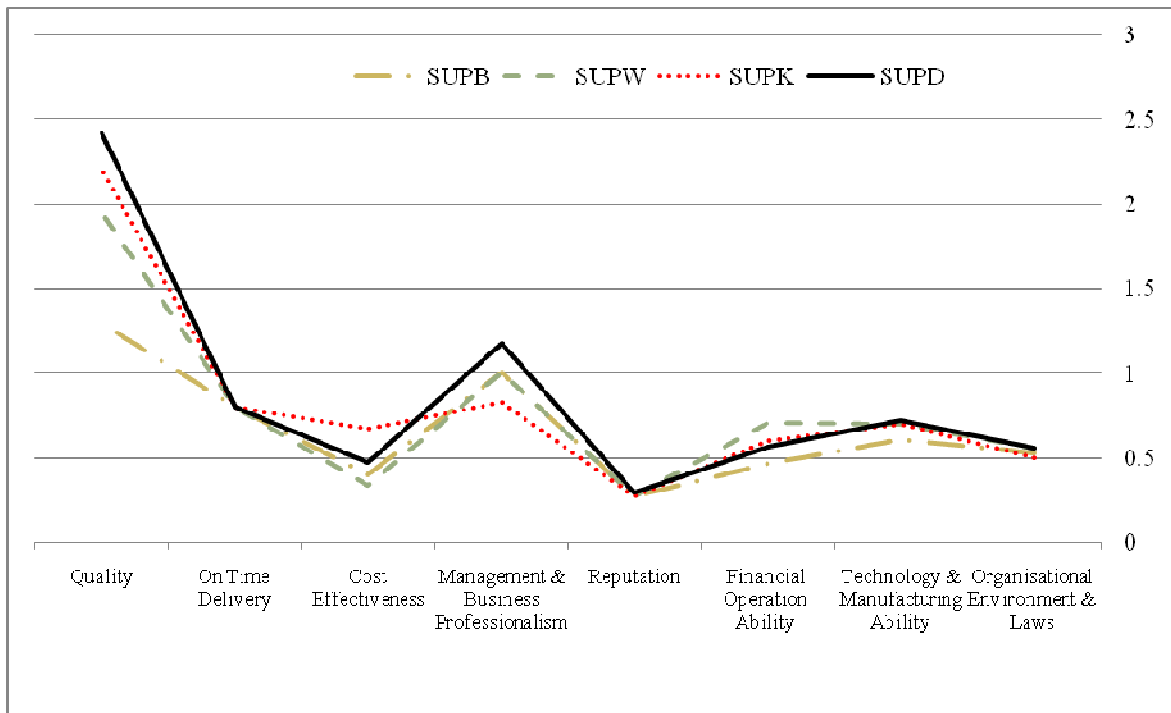**Table 1:** Table listing Supplier (outsourcee) comparison Model

FIGURE 7: Line graph for outsourcee selection criteria weights

6. Conclusions

The AHP-CA method has been applied successfully to evaluate outsourcee for a real manufacturing company 'EMC'. The results have satisfied the management of the company and earned their approval. They recommended introducing some modifications according to types of products manufactured, locations of candidate outsourcees and relationship between outsourcee and the outsourcer. One of the important recommendations was to prepare a Performa that includes manufacturing level agreement that could be signed with any company, only by incorporating participant company name. The second recommendation was to arrange the benchmarks by their priority order. Furthermore, establishing the assessment/ evaluation criteria and their weighting factors are influenced by the subjective opinions of the experts. The effect of the subjective opinion is mitigated by applying AHP-CA method. In addition, the accuracy of the evaluation

method results depend upon assessment criteria, comparison data received from experts and the interpretation of the decision maker. This research reveals the importance of the AHP-CA method and extent to which decision makers are facilitated in outsourcee evaluation. It also reveals the alternative outsourcing participant if their relative capabilities are to be assessed correctly.

7. References

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Appendix:

CE: Cost Effectiveness	**OEL**: Organisational & Environment Laws
CmC: Competitive Cost	**OTD**: On Time Delivery
CnC: Consistent Cost	**PlCp**: Personnel Capability
DCn: Delivery Consistency	**PrCp**: Process Capability
DD: Delivery Documentation	**PSd**: Product Standard
DLT: Delivery Lead Time	**QSdLS**: Linked Suppliers Comply Quality Standards
DSd: Delivery Standard	**Qu**: Quality
FA: Financial Operation Ability	**Re**: Reputation
FlCh: Flexibility to Adjust Changes	**ResCh**: Responsiveness to Change
GRLS: Good Relationships with Linked Suppliers	**SCom**: Secure Communication System
HdWr: Hardware	**SuC**: Sustainable Cost
IDLS: Information Declaration about Linked Suppliers	**TIB**: Time (Duration) in Business by Outsourcee
IPLS: Linked Suppliers Participate in Improvements	**TMA**: Technology and Manufacturing Ability
MBP: Management & Business Professionalism	**TSCR**: Trained Staff for Relationship Development
MSd: Material Standard	**UBL**: Outsourcee Understands Business Rules
Nbcy: Not Subjected to Receivership or Bankruptcy	**UCBR**: Understanding of Customer's Requirement
NoLS: Link with a No of Suppliers	**UIBL**: Outsourcee Understands Intellectual Property Protection Law

W_1	W_{OEL}	Weight value of Organisational & Environment Laws Criterion
W_2	W_{TMA}	Weight value of Technology & Manufacturing Ability Criterion
W_3	W_{FA}	Weight value of Financial Operation Ability Criterion
W_4	W_{Re}	Weight value of Reputation Criterion
W_5	W_{MBP}	Weight value of Management & Business Professionalism Criterion
W_6	W_{CE}	Weight value of Cost Effectiveness Criterion
W_7	W_{OTD}	Weight value of On Time Delivery Criterion
W_8	W_{Qu}	Weight value of Quality Criterion
W_{11}	W_{UIBL}	Weight value of Intellectual Property Protection Laws sub –criterion
W_{12}	W_{UBL}	Weight value of Outsourcee Understands Business Rules sub-criterion
W_{21}	W_{HdWr}	Weight value of Hardware sub-criterion
W_{22}	W_{PlCp}	Weight value of Personnel Capability sub-criterion
W_{23}	W_{PrCp}	Weight value of Process Capability sub-criterion
W_{31}	W_{NBcy}	Weight value of not subjected to Receivership or Bankruptcy sub-criterion
W_{32}	W_{TIB}	Weight value of Time (Duration) in Business by Outsourcee sub-criterion
W_{41}	W_{ResCh}	Weight value of Responsiveness to Change by Outsourcee sub-criterion
W_{42}	W_{FlCh}	Weight value of Flexibility to Adjust Changes by Outsourcee sub-criterion
W_{43}	W_{NoLS}	Weight value of Link with a Number of Suppliers sub-criterion
W_{44}	W_{QSdLS}	Weight value of Linked Suppliers Comply Quality Standards sub-criterion
W_{45}	W_{SCom}	Weight value of Secure Communication System sub-criterion
W_{46}	W_{IDLS}	Weight value of Information Declaration about Linked Supplier sub-criterion
W_{47}	W_{IPLS}	Weight value of Linked Supplier participate in improvements sub-criteria
W_{48}	W_{GRLS}	Weight value of Good Relationships with Linked Suppliers sub-criteria
W_{51}	W_{UCBR}	Weight value of Understanding of Customer's Requirements sub-criteria
W_{52}	W_{TSCR}	Weight value of Trained Staff for Relationship Development sub-criteria
W_{61}	W_{CmC}	Weight value of Competitive Cost sub-criteria
W_{62}	W_{CnC}	Weight value of Consistent Cost sub-criteria
W_{63}	W_{SuC}	Weight value of Sustainable Cost sub-criteria
W_{71}	W_{DLT}	Weight value of Delivery Lead Time sub-criteria
W_{72}	W_{DCn}	Weight value of Delivery Consistency sub-criteria
W_{73}	W_{DD}	Weight value of Delivery Documentation sub-criteria
W_{81}	W_{PSd}	Weight value of Product Standard sub-criteria
W_{82}	W_{DSd}	Weight value of Design Standard sub-criteria

W_{E3}	W_{MSd}	Weight value of Material Standard sub-criteria
S_{k11}	S_{UIPL}	Ranking Score of Intellectual Property Protection Laws for kth outsourcee
S_{k12}	S_{UBL}	Ranking Score of Outsourcee Understands Business Rules for kth outsourcee
S_{k21}	S_{Hdwr}	Ranking Score of Hardware for kth outsourcee
S_{k22}	S_{PlCp}	Ranking Score of Personnel Capability for kth outsourcee
S_{k23}	S_{PrCp}	Ranking Score of Process Capability for kth outsourcee
S_{k31}	S_{NBcy}	Ranking Score of not subjected to Receivership or Bankruptcy for kth outsourcee
S_{k32}	S_{TIB}	Ranking Score of Time (Duration) in Business by Outsourcee for kth outsourcee
S_{k41}	S_{ResCh}	Ranking Score of Responsiveness to Change by Outsourcee for kth outsourcee
S_{k42}	S_{FlCh}	Ranking Score of Flexibility to Adjust Changes by kth outsourcee
S_{k43}	S_{NbLS}	Ranking Score of Link with a Number of Suppliers for kth outsourcee
S_{k44}	S_{QSdLS}	Ranking Score of Linked Suppliers Comply Quality Standards for kth outsourcee
S_{k45}	S_{SCom}	Ranking Score of Secure Communication System for kth outsourcee
S_{k46}	S_{IDLS}	Ranking Score of Information Declaration about Linked Supplier for kth outsourcee
S_{k47}	S_{IPLS}	Ranking Score of Linked Supplier participate in improvements for kth outsourcee
S_{k48}	S_{GRLS}	Ranking Score of Good Relationships with Linked Suppliers for kth outsourcee
S_{k51}	S_{UCRR}	Ranking Score of Understanding of Customer's Requirements for kth outsourcee
S_{k52}	S_{TSRD}	Ranking Score of Trained Staff for Relationship Development for kth outsourcee
S_{k61}	S_{CmpC}	Ranking Score of Competitive Cost for kth outsourcee
S_{k62}	S_{CnC}	Ranking Score of Consistent Cost for kth outsourcee
S_{k63}	S_{SuC}	Ranking Score of Sustainable Cost for kth outsourcee
S_{k71}	S_{DLT}	Ranking Score of Delivery Lead Time for kth outsourcee
S_{k72}	S_{DCn}	Ranking Score of Delivery Consistency for kth outsourcee
S_{k73}	S_{DD}	Ranking Score of Delivery Documentation for kth outsourcee
S_{k81}	S_{PSd}	Ranking Score of Product Standard for kth outsourcee
S_{k82}	S_{DSd}	Ranking Score of Design Standard for kth outsourcee
S_{k83}	S_{MSd}	Ranking Score of Material Standard for kth outsourcee