Performance measurement of supply chain management: A decision framework for evaluating and selecting supplier performance in a supply chain

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Abstract

Supply Chain Management (SCM) has gained significance as one of the 21st century manufacturing paradigms for improving organizational competitiveness. Supply chain ensures improved efficiency and effectiveness of not only product transfer, but also information sharing between the complex hierarchies of all the tiers. The literature on SCM that deals with strategies and technologies for effectively managing a supply chain is quite vast. In recent years, organizational performance measurement (PM) and metrics have received much attention from researchers and practitioners. Performance measurement and metrics have an important role to play in setting objectives, evaluating performance, and determining future courses of actions. Apart from the common criteria such as cost and quality, ten other performance measurements are defined, visibility, trust, innovativeness, delivery reliability, flexibility and responsiveness, resource utilization, cost, assets, technological capability, service and time to market, so total twelve criteria and fifty eight subcriteria are used to evaluate the performance in supply chain. So, for evaluating and selecting supplier a multi-attribute decision-making technique, an analytic hierarchy process (AHP), is used to make decision based on the priority of performance measures. This paper describes a decision framework for evaluating and selecting supplier performance in a supply chain. A case study from the automotive industry is used to demonstrate the AHP technique.

Keywords

Supply chain, Analytical hierarchy process (AHP), supplier selection, SCM

Introduction

The development of economy of any country is supported by growth of its manufacturing industries. Currently, the manufacturing industries are passing through a phase of very tough competition. The economic environment is becoming harsh. In order to survive, every industry has to strive to improve productivity in all spheres of activity. What is required is to devise new ways of improving manufacturing performance by optimally utilizing the resources. In this context, effective supply chain management is vital to the competitiveness of manufacturing enterprises, as it directly impacts their ability to meet changing market demands in a timely and cost effective manner. Figure1 shows the typical supply chain consisting of different levels e.g. supplier, manufacturer, distributor and consumer, who work together in an effort to acquire raw materials, convert these raw materials into specified final products and deliver these final products to retailers Beamon (1998). So, it is a network of companies which influence each other. The complexity and the large network affect one another's performance. In this context, Chan (2003) highlighted some important issues like, how would the supply chain perform? How can the managers choose the most optimum supply chain best suited for its particular industry? Karthik (2006) observed that the objective of the supply chain was to maximize the difference between worth of the final product to the customer and the effort the supply chain expended in fulfilling the customer needs.

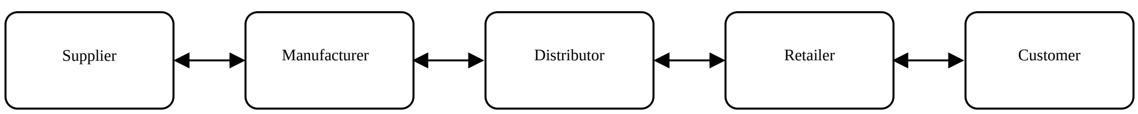

Fig.1 A typical Supply Chain

The aim of supply chain management is to gain an advantage in terms of customer service and cost over competitors. Therefore it is desirable to assess the company's performance by benchmarking. Given the inherent complexity of the typical supply chain, selecting appropriate performance measures for supply chain analysis is particularly critical, since the system of interest is generally large and complex.

The purchasing function has gained great importance in the supply chain management due to factors such as globalization, increased value added in supply, and accelerated technological change. Purchasing involves buying the raw materials, supplies, and components for the organization. The activities associated with it include selecting and qualifying supplier, rating supplier performance, negotiating contracts, comparing price, quality and service, sourcing goods and service, timing purchases, selling terms of sale, evaluating the value received, predicting price, service, and sometimes demand changes, specifying the form in which goods are to be received, etc. The key and perhaps the most important process of the purchasing function is the efficient selection of supplier/ vendors, because it brings significant savings for the organization (Ballow 1999). The objective of the supplier selection process is to reduce risk and maximize the total value for the buyer, and it involves considering a series of strategic variables. Some authors have identified several criteria for supplier/vendor selection, such as the net price, quality, delivery, historical supplier performance, capacity, flexibility, service, communication systems and geographic location (Dickson 1966, Dempsey 1978, Weber et al 1991, Noorul Haq and Kannan 2006, Sarode et al 2008). These criteria are key issues in the supplier assessment process since it measures the performance of the suppliers.

This paper present a total twelve criteria and fifty eight subcriteria for evaluating the supplier/vendor selection for the automobile manufacturing industries located at the western part of India using the analytical hierarchy process (AHP) even this paper describes a decision framework for pairwise comparison which helps to identify easily the importance of different performance measures. A case study from the automotive industry is used to demonstrate the AHP technique.

Literature Review

At present, there is a boom in supply chain management research. A large amount of publications appeared on this issue, particularly in the supplier/vendor selection problem. This problem has been extensively studied in the literature, the following paragraphs summarizes some of the contribution that are important to this paper.

In early 1986, Timmerman (1986) propose linear weighting models in which suppliers are rated on several criteria and in which these ratings are combined into a single score. These models include the categorical, the weighted point and the analytical hierarchical process (Nydick and Hill 1992). The major limitation of this approach is that it is difficult to effectively take qualitative evaluation criteria into consideration. Total cost approaches attempt to quantify all costs related to the selection of a vendor in monetary units. This approach includes cost ratio by Timmerman (1986) and total cost of ownership (Ellram 1995). Petroni and Braglia (2000), discuss the principle component analysis (PCA) method which is multiobjective approach to vendor selection that attempts to provide a useful decision support system for purchasing manager faced with multiple vendors and trade-offs such as price, delivery, reliability, and product quality. The major limitations of this approach are it requires the knowledge of advanced statistical technique.

Wei et al. (1997), discuss in their paper about the neural network for the supplier selection. Comparing to conventional models for decision support system, neutral networks save a lot of time and money for system development. The supplier-selecting system includes two functions: one is the function measuring and evaluating performance of purchasing (quality, quantity, timing, price, and costs) and storing the evaluation in a database to provide data sources to neural network. The other is the function using the neural network method saves money and time of system development. The weakness of this method is that it demands software and requires a qualified personnel expert on this subject.

Dickson (1966), reports 23 different criteria for vendor’s evaluation. Of these criteria, he states that cost, quality and delivery times are among the most important performance measures in the selection of vendor’s. Since that time, numerous papers have cited his work approaching the vendor selection problem mainly from three perspective; conceptual, empirical, and mathematical (Talluri and Narasimhan 2003).

Chan (2003) reported seven performance measures as the key elements of vendor selection-cost, resource utilization, quality, flexibility, visibility, trust and innovativeness. For each measure, he identified factor commonly used for vendor selection.

Sarode et al. (2008) reported total twelve measures which includes qualitative and quantitative type-quality, visibility, flexibility and responsiveness, resource utilization, cost, asset, technological capability, service and time to market apart from these twelve measure total fifty eight items/ variables identified.

Noorul and Kannan (2006) identified seven performance measures- quality, delivery, production capability, service, engineering/ technical capabilities, business structure and price and their thirty two sub factors for the vendor selection. Weber et al. (1991), present a comprehensive review of the literature providing the most important criteria in the choice of suppliers. According to their investigation, they rank price as the most important factor in the selection process followed by lead time and quality factors.

Patton (1996) sampled 1500 buyers to identify the effects of human judgment models on vendor selection. His findings suggest that it is not as much the difference in attributes between vendors that affect the outcome, but it is the type of human model used that lead to the variance in the selection of vendors. Stanley and Wisner (2001), collect data from 118 executives to study the outcome of previous research concepts regarding this problem. One of the important results of their study suggests that greater emphasis should be given to strategic activities in the process of supplier's selection. Verma and Pullman (1998), propose the supplier selection process using the two methods namely Likert scale set of questions and a discrete choice analysis (DCA) experiment. According to them quality is an important factor to select the supplier.

Lambert et al. (1998), in their book, describe a method for evaluating and comparing several suppliers. A rating factor is assigned to each supplier followed by a weight to determine the importance of each factor. To make the comparison feasible, a weighted composite measure is developed by multiplying the rating factor by the weight. However, how to assign the weights has not been clearly described in their approach.

Weber et al. (1997), utilized data envelopment analysis (DEA) in the quest for vendor selection. Their approach is based on defining several attributes of vendor such as defects, price, and lateness in delivery. Based on this, a negotiation position is developed for those vendors that would like to be on the list of future supplier for the considered firm.

Sheu (2004), proposed a methodology in his research that would stimulate research in the related fields of global logistics, and may help address issues regarding the uncertainty and complexity of global logistics operations. Chan and Chung (2004), develop a multi-criterion genetic optimization for solving distribution network problems in supply chain management. In this work they combine analytic hierarchy processes with genetic algorithms to capture the capability of multi-criterion decision-making which will reduce the computation time. Vaidya and Kumar (2004), presents a literature review of the applications of the analytic hierarchy process (AHP) and also provided the various application area where the AHP is used as a multiple criteria decision-making tool. Handeld et al. (2002), integrate environment issues in their supplier assessment decisions with the help of AHP.

Tam and Tummala (2001) discussed the vendor selection for the telecommunication systems and based on the proposed model the time taken to select the vendor has been reduced. Based on the above literature, most of the previous researchers have considered only four to five main factors (quality, service, price and delivery) and about 8 to 32 sub factors for selection of vendors. This paper describes twelve main factors and 58 sub factors for the supplier/vendor selection.

Development of Decision framework for evaluating and selecting supplier Performance in supply chain:

The company chosen for this work plan to build a supply chain for its automobile production. Raw materials or components can be outsourced to vendors. The question arise which vendor are to be selected. The attributes and sub-attributes have to be most prevalent and important in the vendor selection process. Choosing the possible criteria for the vendor selection involves a decision making team which includes experts from the industry side (purchasing manager, purchasing director, sales manager, product manager, quality manager and production manager). The attributes and sub attributes involved in the vendor selection have been chosen by conducting a survey. A questionnaire consisting of these factors was designed for the survey. The respondents for the survey are selected randomly from different functional areas that are directly involved with the materials supplied by the vendors. Based on the survey conducted the major attributes and sub-attributes involved in the vendor selection are given in Table 1.

Development of analytical process for qualitative analysis

Analytical hierarchy process (AHP) was developed in 1972 as a practical approach in solving relatively complex problems (Saaty 1980). It is used for multicriteria problems in a number of application domains (Roger 1987, Saaty 2000 and Kodali and Chandra 2001, Kodali and Routroy 2006). The general approach of the AHP is to decompose the problem and make pair-wise comparison of all elements on a given level with related elements in the level just above it belong. A highly user friendly computer model is developed which assists the user in evaluating his/her choices. The schematic of AHP for selection of supplier in supply chain is shown in Fig 1.

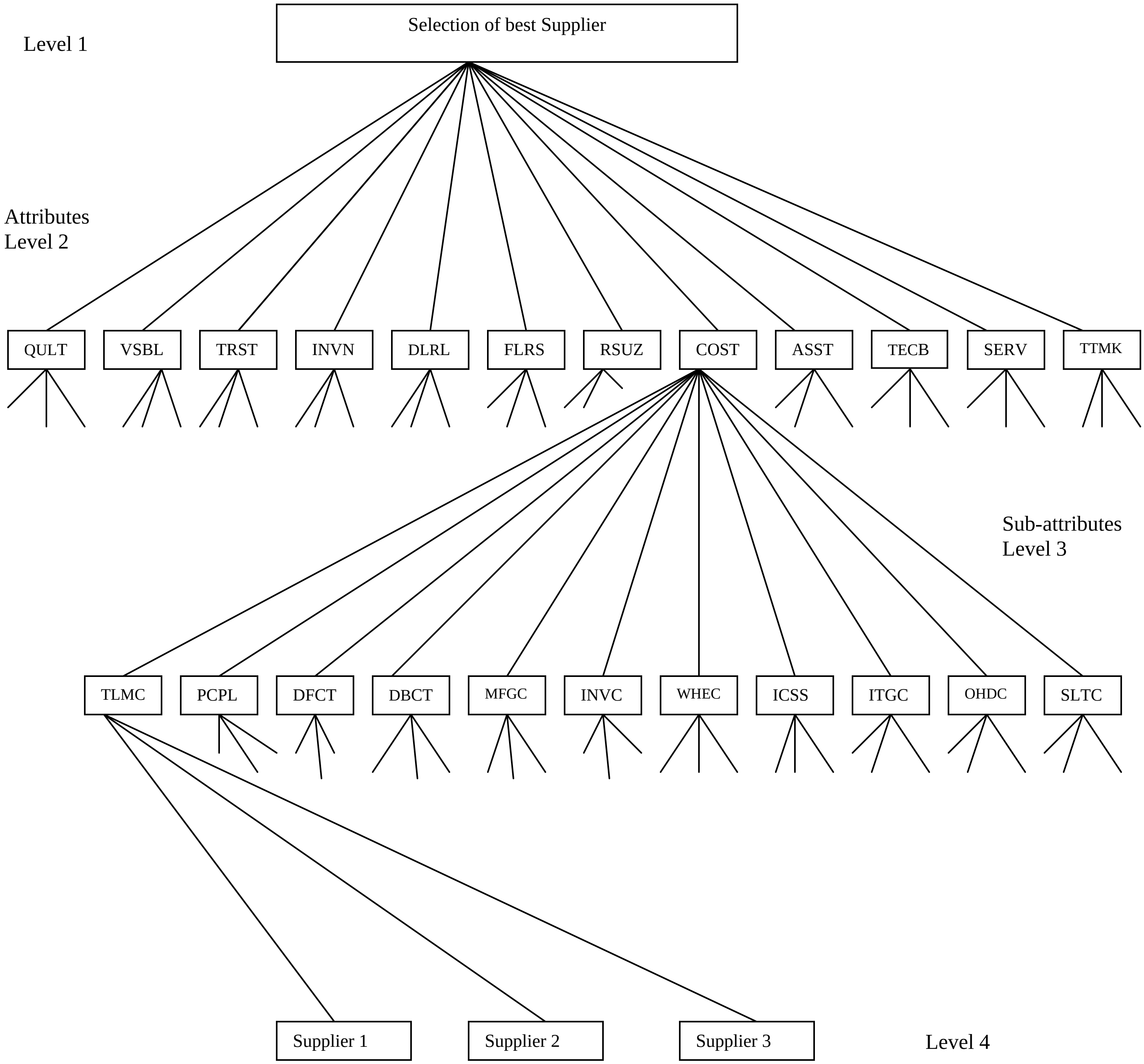

Fig.1. Schematic of AHP for selection of best supplier

Description of the model

A thorough analysis of the problem is required along with the identification of the important attributes/ criteria involved. Sarode et al (2008) presented a through analysis of identification of the important attributes/ criteria measures for performance measurement in supply chain. The attributes and sub-attributes used in the AHP for analysis for selection of supplier in supply chain are as follows.

Table-1 Performance measures (Sarode 2008)

1. Quality	**[QULT]**
• Customer satisfaction	[CUST]
• Customer response time	[CURT]
• Lead time	[LDTM]
• On-time delivery	[OTDL]
• Fill rate	[FLRA]
• Stock out probability	[STOP]
• Accuracy	[ACCY]
• Base of communication	[BACM]
• Process flexibility	[PRFL]
• Percentage rejections	[PGRJ]
• Inspection methods and plans	[INMP]
• Warranty claims	[WACL]
• Availability of test equipment	[AVTE]
• Adherence of total quality management concept	[ATQM]
2. Visibility	**[VSBL]**
• Time	[TIME]
• Accuracy	[ACCY]
3. Trust	**[TRST]**
• Consistency	[CNTY]
4. Innovativeness	**[INVN]**
• New launch of product	[NLPD]
• New use of technology	[NUTE]
5. Delivery reliability	**[DLRL]**
• Delivery performance	[DLPM]
• Fill rate	[FLRA]
• Order fulfillment lead time	[OFLT]
• Perfect order fulfillment	[POFM]
6. Flexibility and responsiveness	**[FLRS]**
• Supply chain response time	[SCRT]
• Production flexibility	[PDFB]
7. Resource utilization	**[RSUZ]**
• Manufacturing resources	[MFGR]
• Storage resources	[STRS]
• Logistics resources	[LGRS]
• Human resources	[HMRS]
• Financial resources	[FLRS]

8. Cost	**[COST]**
• Total logistics management cost	[TLMC]
• Process capability	[PCPL]
• Defects	[DFCT]
• Distribution cost	[DBCT]
• Manufacturing cost	[MFGC]
• Inventory cost	[INVC]
• Warehouse cost	[WHEC]
• Incentives cost and subsidies	[ICSS]
• Intangible cost	[ITGC]
• Overhead cost	[OHDC]
• Sensitivity to long term cost	[SLTC]
9. Assets	**[ASST]**
• Cash-to-cash cycle time	[CCCT]
• Inventory days of supply	[ITDS]
• Assets turns	[ASTT]
10. Technological capability	**[TECB]**
• Product and process facilities	[PDPE]
• Skill and manpower	[SKMD]
• Customised services	[CMSE]
• Cost evaluation	[CTEL]
11. Service	**[SERV]**
• On-time delivery	[OTDL]
• Base of communication	[BCMN]
• Response to changes	[PRCH]
• Process flexibility	[PRFL]
• Customer satisfaction	[CUSF]
12. Time to market	[**TTMK]**
• Delivery product to market quickly	[DPMQ]
• First in the market in introducing new product	[FMIP]
• Time to market lower than industry average	[TMIA]
• Fast development cell	[FDMC]

Analytical hierarchy process methodology

AHP (Saaty, 1982) was developed as a practical approach in solving relatively complex problems. AHP enables the decision maker to represent the simultaneous interaction of many factors in complex, unstructured situation. For the effectiveness of supply chain, the judgments based on observations are fed into AHP for each criterion and sub-criterion of all levels of hierarchy. Pair-wise comparisons of criterion at each level are done on a scale of relative importance, 1 reflecting equal weightages and 9 reflecting absolute importance (see appendix for detailed information).

The steps to be followed in the AHP are given below (Roger, 1987):

1) Define the problem and determine the objective.
2) Structure the hierarchy from the top through the intermediate levels to the lowest level. Refer to figure (Schematic of AHP).
3) Construct a set of pair-wise comparison matrices for each of the lower levels. An element in the higher level is said to be a governing element for those in the lower level, since it contributes to it or affects it. The elements in the lower level are then compared to each other based on their effect on the governing element above. This yields a square matrix of judgments. The pair-wise comparisons are done in terms of which an element dominates another. These judgments are then expressed as integers. If element A dominates over element B, then the whole number integer is entered in row A, column B and reciprocal is entered in row B, column A. If the elements being compared are equal, a one is assigned to both positions. Table 2 shows the pair-wise comparison matrix for level 2 criteria.

Table 2. Criteria pair-wise comparison matrix (level 2)

	QULT	VSBL	TRST	INVN	DLRL	FLRS	RSUZ	COST	ASST	TECB	SERV	TTMK
QULT	**1**	1/2	1	1/5	3	3	3	1	1	2	2	2
VSBL	2	**1**	1	2	3	2	4	1	2	1	2	2
TRST	1	1	**1**	1/2	1	3	2	2	1	1	1	2
INVN	5	1/2	2	**1**	5	3	6	3	2	2	3	3
DLRL	1/3	1/3	1	0.2	**1**	1	1	2	1/5	1/2	1/3	1
FLRS	1/3	1/2	1/3	1/3	1	**1**	2	1	1/3	1/2	1/4	3
RSUZ	1/3	1/4	1/2	1/6	1	1/2	**1**	1/2	1/5	1/9	1/2	1
COST	1	1	1/2	1/3	1/2	1	2	**1**	1/2	1/3	1/2	1
ASST	1	1/2	1	1/2	3	3	3	2	**1**	1/2	1	2
TECB	1/2	1	1	1/2	2	2	9	3	2	**1**	2	1
SERV	1/2	1/2	1	1/3	3	4	2	2	1	1/2	**1**	2
TTMK	1/2	1/2	1/2	1/3	1	1/3	1	1	1/2	1	1/2	**1**

4) There are n (n-1)/2 judgments required to develop the set of matrices in step 3 (reciprocals are automatically assigned in each pair-wise comparisons).
5) Having done all the pair-wise comparisons and entered the data, the consistency is determined using the eigenvalue. To do so, normalize the column of numbers by dividing each entry by the sum of all entries. The sum each row of the normalized values and take the average. This provides Principal Vector [PV]. Table 3 illustrates the normalized comparison matrix.

The check of the consistency of judgments is as follows:

- Let the pair-wise comparison matrix be denoted M_1 and principal vector be denoted M_2.
- Then define $M_3 = M_1 * M_2$; and $M_4 = M_3 / M_2$.
- Calculate λ_{max} = average of the elements of M_4.
- Calculate Consistency Index (CI) = $(\lambda_{max} - N) / N - 1$
- Consistency Ratio (CR) = CI/RCI corresponding to N
  where RCI : Random Consistency Index and
  N : Number of elements

Random index table

N	1	2	3	4	5	6	7	8	9	10
RCI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

  - If CR is less than 10%, judgments are considered consistent. And if CR is greater than 10%, the quality of judgments should be improved to have CR less than or equal to 10%.

6) Steps 3-5 are performed to have relative importance of each attribute for all levels and clusters in the hierarchy. Table 4 illustrates the sub-criterion analysis of criterion 'cost' (level III).

Table 3. Criteria pair-wise comparison matrix (level 2) normalized.

	QULT	VSBL	TRST	INVN	DLRL	FLRS	RSUZ	COST	ASST	TECB	SERV	TTMK	SUM	PV
QULT	0.074	0.066	0.092	0.031	0.122	0.126	0.083	0.051	0.085	0.191	0.142	0.095	1.160	0.097
VSBL	0.148	0.132	0.092	0.313	0.122	0.084	0.111	0.051	0.170	0.096	0.142	0.095	1.557	0.130
TRST	0.074	0.132	0.092	0.078	0.041	0.126	0.056	0.103	0.085	0.096	0.071	0.095	1.048	0.087
INVN	0.370	0.066	0.185	0.156	0.204	0.126	0.167	0.154	0.170	0.191	0.213	0.143	2.145	0.179
DLRL	0.025	0.044	0.092	0.031	0.041	0.042	0.028	0.103	0.017	0.048	0.024	0.048	0.541	0.045
FLRS	0.025	0.066	0.031	0.052	0.041	0.042	0.056	0.051	0.028	0.048	0.018	0.143	0.600	0.050
RSUZ	0.025	0.033	0.046	0.026	0.041	0.021	0.028	0.026	0.017	0.011	0.036	0.048	0.356	0.030
COST	0.074	0.132	0.046	0.052	0.020	0.042	0.056	0.051	0.043	0.032	0.036	0.048	0.631	0.053
ASST	0.074	0.066	0.092	0.078	0.122	0.126	0.083	0.103	0.085	0.048	0.071	0.095	1.044	0.087
TECB	0.037	0.132	0.092	0.078	0.082	0.084	0.250	0.154	0.170	0.096	0.142	0.048	1.365	0.114
SERV	0.037	0.066	0.092	0.052	0.123	0.168	0.056	0.103	0.085	0.048	0.071	0.095	0.995	0.083
TTMK	0.037	0.066	0.046	0.052	0.041	0.014	0.028	0.051	0.043	0.096	0.036	0.048	0.557	0.046

Table 4. Cost sub-criteria analysis (level 3)

	TLMC	PCPL	DFCT	DBCT	MFGC	INVC	WHEC	ICSS	ITGC	OHDC	SLTC
TLMC	**1**	1	1	1	1	3	4	2	1	1	3
PCPL	1	**1**	1	1	1	4	4	3	2	1	7
DFCT	1	1	**1**	1	1	3	4	2	8	2	8
DBCT	1	1	1	**1**	1	3	4	2	1	1	2
MFGC	1	1	1	1	**1**	3	3	2	1	1	5
INVC	1/3	1/4	1/3	1/3	1/3	**1**	1	1	1/2	1/4	1
WHEC	1/4	1/4	1/4	1/4	1/3	1	**1**	1/2	1/3	1/4	4
ICSS	1/2	1/3	1/2	1/2	1/2	1	2	**1**	1/2	1/3	1/3
ITGC	1	1/2	1/8	1	1	2	3	2	**1**	1/2	2
OHDC	1	1	1/2	1	1	4	4	3	2	**1**	3
SLTC	1/3	1/7	1/8	1/2	1/5	1	1/4	3	1/2	1/3	1
SUM	8.417	7.476	6.833	8.583	8.367	26	30.25	21.500	17.833	8.667	36.333

7) The alternative analysis for the lowest level of sub-criteria to be carried out in the similar manner as above. Table 5 illustrates the alternative analysis of Consistency. The remaining alternative analyses are to be carried out similarly.

Table 5. Alternative analysis for consistency (CNTY)

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	**1**	4	1
Supplier 2	1/4	**1**	1/7
Supplier 3	1	7	**1**
SUM	2.25	12.042	2.142

Table 6. Case Situation

Industry Type	Automotive production
Supply chain strategy	Somewhat responsive
Product type	standard
Product strategy	Moderate profit margin and supplier risk
Company vision	To be a world-class company and market leader

8) The desirability index for each alternative is calculated by multiplying each value in ‘weight of sub-criteria’ column by the respective value of ‘criteria weight’ column, then multiplying the obtained value, by the value for each respective alternative and summing the results.

Highly user-friendly software, the multiattribute decision model, i.e. AHP is developed in VC^{++} to aid the user for pair-wise comparison of the attributes as well as for the alternatives and for analysing the user inputs. The attributes are compared with other in a pair-wise comparison with respect to the case situation discussed in Table 6.

From the analysis, it is clear that Supplier 1 is the best under the circumstances of the developed case situation (see Tables 7-9). The reliability of the judgments supplied by the user can be estimated from graphs (Figs.2-4) that are generated for each alternative and its corresponding deciding criteria. Fig 5 would depict the composite overall scores for the alternative suppliers.

Table 7. Weightages of attributes for suppliers

Subcrit	L3-wt	L2-wt	Supplier 1	Supplier 2	Supplier 3
CUST	0.0940	0.0967	0.2970	0.5396	0.1634
CURT	0.0990	0.0967	0.3333	0.3333	0.3333
LDTM	0.1000	0.0967	0.2402	0.5499	0.2098
OTDL	0.1060	0.0967	0.1192	0.7238	0.1570
FLRA	0.0840	0.0967	0.1744	0.6337	0.1919
STOP	0.0470	0.0967	0.4444	0.1111	0.4444
ACCY	0.0380	0.0967	0.3333	0.3333	0.3333
BACM	0.0580	0.0967	0.2500	0.5000	0.2500
PRFL	0.0880	0.0967	0.5400	0.3000	0.1600
PGRJ	0.1070	0.0967	0.5470	0.2630	0.1890
INMP	0.0540	0.0967	0.5840	0.2310	0.1840
WACL	0.0630	0.0967	0.4830	0.3480	0.1670
AVTE	0.0307	0.0967	0.5270	0.3320	0.1390
ATQM	0.0260	0.0967	0.6300	0.2180	0.1510
TIME	0.7500	0.1230	0.4099	0.3504	0.2397
ACCY	0.2500	0.1230	0.3333	0.3333	0.3333
CNTY	1.0000	0.0870	0.4145	0.0860	0.4995
NLPD	0.6660	0.1780	0.4126	0.3275	0.2599
NUTE	0.3340	0.1780	0.4430	0.3870	0.1690
DLPM	0.5579	0.0450	0.1365	0.2385	0.6250
FLRA	0.2316	0.0450	0.2158	0.6817	0.1025
OFLT	0.1187	0.0450	0.5930	0.2490	0.1570
POFM	0.0915	0.0450	0.6480	0.2270	0.1220
SCRT	0.7500	0.0500	0.2500	0.5000	0.2500

PDFB	0.2500	0.0500	0.4286	0.1429	0.4286
MFGR	0.2560	0.0296	0.2000	0.6000	0.2000
STRS	0.1860	0.0296	0.2000	0.6000	0.2000
LGRS	0.2000	0.0296	0.5950	0.2760	0.1280
HMRS	0.2180	0.0296	0.6300	0.2610	0.1080
FLRS	0.1400	0.0296	0.3660	0.4970	0.1350
TLMC	0.1120	0.0525	0.1667	0.6667	0.1667
PCPL	0.1340	0.0525	0.2500	0.5000	0.2500
DFCT	0.1700	0.0525	0.1111	0.7778	0.1111
DBCT	0.1550	0.0525	0.5490	0.2400	0.2090
MFGC	0.1130	0.0525	0.2500	0.2500	0.5000
INVC	0.0360	0.0525	0.1700	0.4430	0.3870
WHEC	0.0380	0.0525	0.3333	0.3333	0.3333
ICSS	0.0470	0.0525	0.1670	0.3480	0.4830
ITGC	0.0790	0.0525	0.1700	0.4430	0.3870
OHDC	0.1180	0.0525	0.1420	0.4280	0.4280
SLTC	0.0400	0.0525	0.1690	0.3870	0.4430
CCCT	0.0700	0.0870	0.3400	0.3333	0.3333
ITDS	0.6040	0.0870	0.3400	0.3333	0.3333
ASTT	0.3250	0.0870	0.2210	0.3180	0.4900
PDPF	0.2800	0.1130	0.1700	0.6667	0.1667
SKMP	0.2840	0.1130	0.3400	0.3333	0.3333
CMSE	0.1550	0.1130	0.3400	0.3333	0.3333
CTEL	0.1800	0.1130	0.5500	0.2090	0.2400
NIDP	0.1100	0.1130	0.5840	0.1840	0.2310
OTDL	0.2700	0.0820	0.5840	0.1840	0.2310
BCMN	0.2850	0.0820	0.4120	0.3270	0.2590
RPCH	0.1550	0.0820	0.5490	0.2090	0.2400
DRFL	0.1800	0.0820	0.3270	0.4120	0.2590
CUSF	0.1090	0.0820	0.3100	0.4930	0.1950
DPMQ	0.3850	0.0463	0.6860	0.1860	0.1260
FMIP	0.2550	0.0463	0.3760	0.4740	0.1490
TMIA	0.1570	0.0463	0.3580	0.5170	0.1240
FDMC	0.2010	0.0463	0.1890	0.5470	0.2630

Table 8. Data Summary

Subcrit	Supplier 1	Supplier 2	Supplier 3
CUST	0.0027	0.0049	0.0015
CURT	0.0032	0.0032	0.0032
LDTM	0.0023	0.0053	0.0020
OTDL	0.0012	0.0074	0.0016
FLRA	0.0014	0.0051	0.0016
STOP	0.0020	0.0005	0.0020
ACCY	0.0012	0.0012	0.0012
BACM	0.0014	0.0028	0.0014
PRFL	0.0046	0.0026	0.0014
PGRJ	0.0057	0.0027	0.0020
INMP	0.0030	0.0012	0.0010
WACL	0.0029	0.0021	0.0010
AVTE	0.0016	0.0010	0.0004
ATQM	0.0016	0.0005	0.0004
TIME	0.0378	0.0323	0.0221
ACCY	0.0102	0.0102	0.0102
CNTY	0.0361	0.0075	0.0435
NLPD	0.0489	0.0388	0.0308
NUTE	0.0263	0.0230	0.0100
DLPM	0.0034	0.0060	0.0157
FLRA	0.0022	0.0071	0.0011
OFLT	0.0032	0.0013	0.0008
POFM	0.0027	0.0009	0.0005
SCRT	0.0094	0.0188	0.0094
PDFB	0.0054	0.0018	0.0054
MFGR	0.0015	0.0045	0.0015
STRS	0.0011	0.0033	0.0011
LGRS	0.0035	0.0016	0.0008
HMRS	0.0041	0.0017	0.0007
FLRS	0.0015	0.0021	0.0006
TLMC	0.0010	0.0039	0.0010
PCPL	0.0018	0.0035	0.0018
DFCT	0.0010	0.0069	0.0010
DBCT	0.0045	0.0020	0.0017
MFGC	0.0015	0.0015	0.0030
INVC	0.0003	0.0008	0.0007
WHEC	0.0007	0.0007	0.0007
ICSS	0.0004	0.0009	0.0012

ITGC	0.0007	0.0018	0.0016
OHDC	0.0009	0.0027	0.0027
SLTC	0.0004	0.0008	0.0009
CCCT	0.0021	0.0020	0.0020
ITDS	0.0179	0.0175	0.0175
ASTT	0.0062	0.0090	0.0139
PDPF	0.0054	0.0211	0.0053
SKMP	0.0109	0.0107	0.0107
CMSE	0.0060	0.0058	0.0058
CTEL	0.0112	0.0043	0.0049
NIDP	0.0073	0.0023	0.0029
OTDL	0.0129	0.0041	0.0051
BCMN	0.0096	0.0076	0.0061
RPCH	0.0070	0.0027	0.0031
DRFL	0.0048	0.0061	0.0038
CUSF	0.0028	0.0044	0.0017
DPMQ	0.0122	0.0033	0.0022
FMIP	0.0044	0.0056	0.0018
TMIA	0.0026	0.0038	0.0009
FDMC	0.0018	0.0051	0.0024

Table 9. Decision index for desirability of each supplier

Decision index for supplier 1	0.373
Decision index for supplier 2	0.344
Decision index for supplier 3	0.283

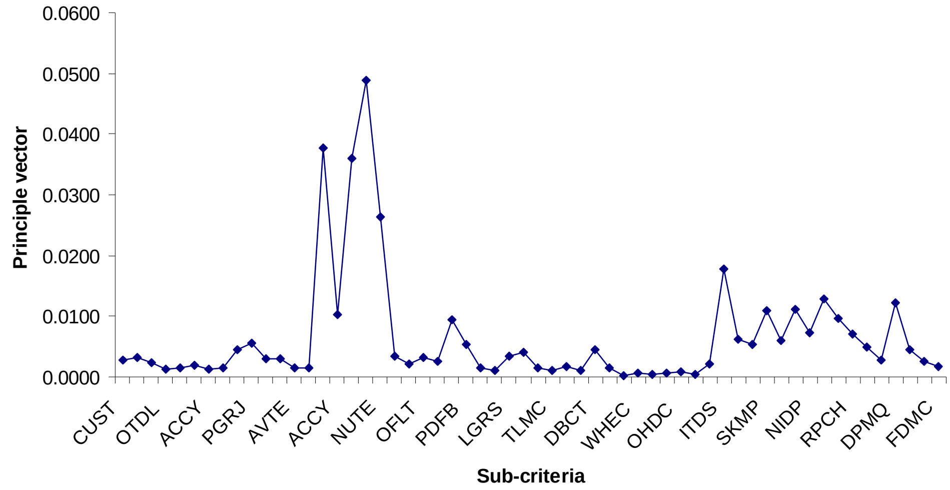

Fig 2. Data Summary graph for Supplier 1

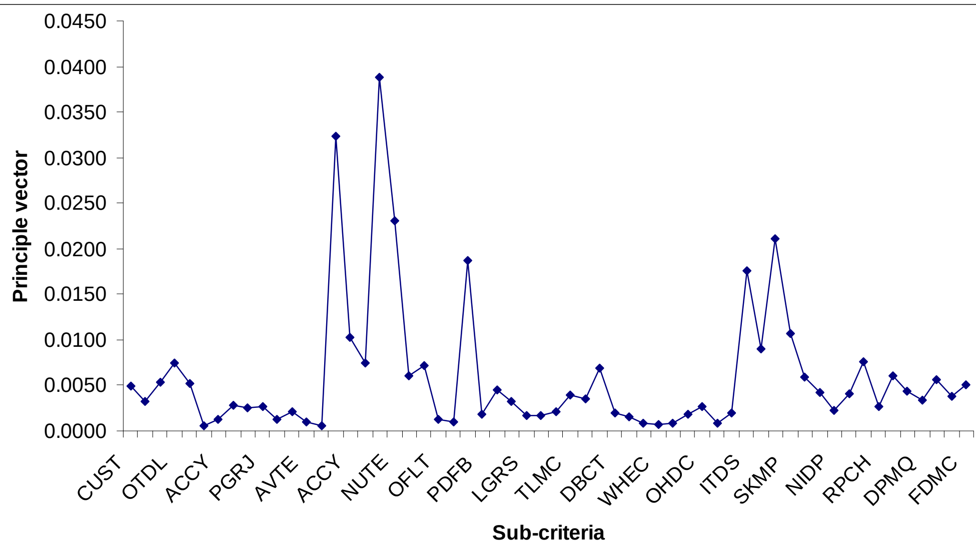

Fig. 3. Data Summary graph for Supplier 2.

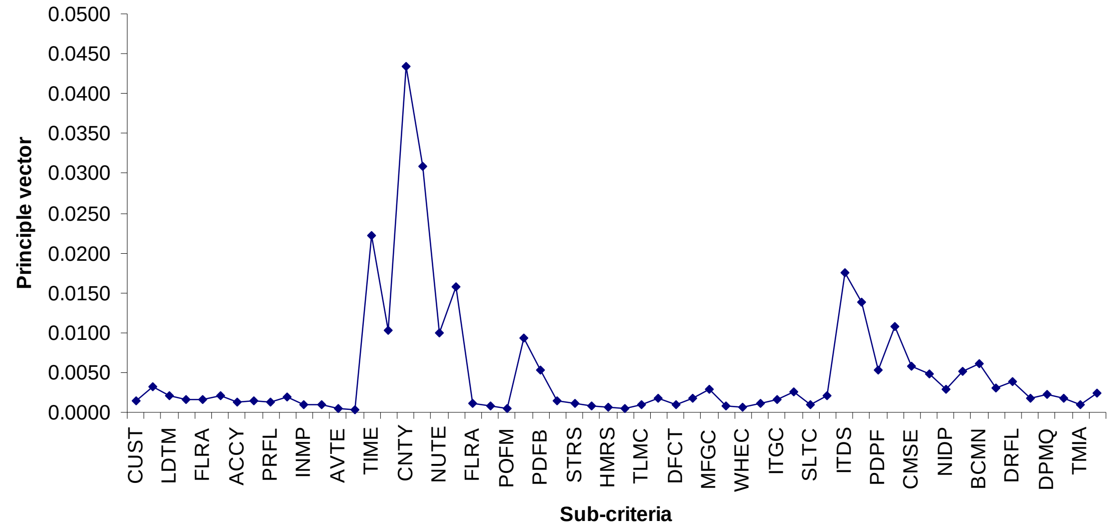

Fig.4. Data summary graph for Supplier 3.

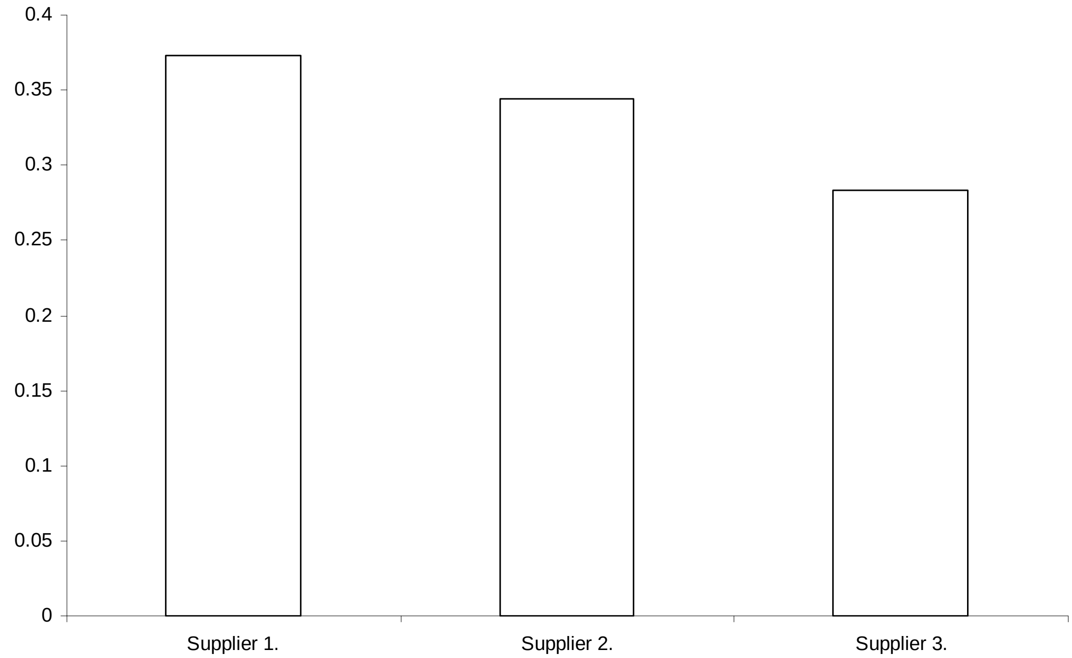

Fig.5. Composite overall scores for alternative Suppliers

Conclusion

The proposed approach forms a flexible and systematic decision framework for selection of supplier in competitive supply chain. The proposed decision framework for evaluating and selection of supplier enables decision makers to provide the base for the final choice from the overall potential suppliers. In this paper, the framework is evaluated by a case situation but the framework is applicable to different types of industries by allowing managers to structure their problems into priority weights, which can reflect their own priority considerations.

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Notes

Appendix
Scale of relative importance

Intensity	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Weak importance of one over the other	Experience and judgment slightly favor one another
5	Essential or strong	Experience and judgment slightly favor one another
7	Very strong	An activity is strongly importance favored and its dominance is demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest degree
2,4,6,8	Intermediate values	When compromise is needed

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