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Development of Decision Support System for Vendor Selection Using Ahp-Vikor Based Hybrid Approach

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ABSTRACT: *Supply chain management (SCM) has emerged as an increasingly important approach to improve the performance of logistics systems. SCM is an integrated approach to increase the effectiveness of the logistics chain by improving cooperation between the stack holders in the supply chain. Supplier selection is one of the most crucial activities performed by organizations because of its strategic importance. This project is done in an automobile industry of North India. The supply chain of the company is analyzed and major problems areas are identified by using SWOT analysis and Fishbone diagrams. Stress is being laid on development of a performance measurement framework and vendor evaluation and selection in supply chain management. In the present work, AHP model and an integrated model of AHP-VIKOR for Vendor selection has been developed and demonstrated the methodology through a case study conducted in XYZ automotive manufacturing company. The major advantages of this research are that it can be used for both qualitative and quantitative criteria. The results show that the model has the capability to be flexible and can be applied in different types of industries to help choose vendors.*

Keywords*: Supply Chain Management, MCDM, VIKOR, AHP.*

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I. INTRODUCTION

Supply chain management (SCM) has emerged as an increasingly important approach to improving the performance of logistics systems. SCM is an integrated approach to increase the effectiveness of the logistics chain by improving cooperation between the players in the chain. Supplier selection is one of the most crucial activities performed by organizations because of its strategic importance. The need for high-quality suppliers has always been an important issue for many manufacturing organization's supply chains in the turbulent business environment. The purchase price is also a highlighted consideration for the purchasing organization due to its impact on the product cost, but the purchase price is not all of the cost associated with the material receipt. Additional costs are required by the purchasing organization to correct the deficiencies when a supplier fails to meet quality and delivery requirements. Hence, the purchasing department must consider the full-part cost instead of a unit-price-oriented cost. A key and perhaps the most important process of the purchasing function is the efficient selection of vendors, because it brings significant savings for the organization. The objective of the vendor selection process is to reduce risk and maximize the total value for the buyer, and it involves considering a series of strategic variables. Among these variables is the time frame of the relationship with vendors, the choice between domestic and international vendors, and the number of vendors, that is, choosing between single or multiple sourcing and the type of product. Some authors have identified several criteria for vendor selection, such as the net price, quality, delivery, historical supplier performance, capacity, communication systems, service and geographic location [1-2]. These criteria are key issues in the supplier assessment process since it measures the performance of the suppliers.

This paper presents a structured model for evaluating the vendor selection for an automotive components industry located at the northern part of India using the analytical hierarchy process (AHP). This paper is organized as follows after this introduction in Sect. 2 the literature review is given. Section 3 describes the problem and SCM model. Section 4 presents an overview of AHP. Section 5 presents the proposed model using AHP. In Sect. 6, the application model (case study) is discussed. Sections 7 and 8 present the results and conclusion of the paper.

II. LITERATURE REVIEW

At present, there is intense competition is going on among the supply chains of the companies in the Indian business environment. A large amount of publications have appeared on the subject matter, particularly in the vendor selection problem. The following paragraphs summarize some of the contributions that are important to this paper.

Chen et al., (2006) adopted a fuzzy decision making approach to solve the supplier selection problem in the SCM using some criteria such as profitability of supplier, relationship closeness, technological capability, conformance quality and conflict resolution. Liao & Kao (2011) confined the TOPSIS approach is based on the idea that a chosen alternative should be shortest distance from the positive ideal solution and farthest distance from the negative ideal solution. Onut et al., (2009) developed a supplier evaluation approach based on the ANP and TOPSIS method to help a telecommunication company in a vendor selection. Alihadi & Awaluddin (2011) they propose integrated model that evaluates supplier and allocates order to them. In the first step, they evaluates supplier by qualitative criteria such as financial structure, service and loyalty by FUZZY AHP process. Tam and Tummala (2001) have used AHP in vendor selection of a telecommunication system, which is a complex, multi-person, multi-criteria decision problem. The authors have found AHP to be very useful in involving several decision makers with different conflicting objectives to arrive at a consensus decision. The decision process, as a result, is systematic and reduces time to select the vendor. Weber et al. (1991) previous studies had been surveyed to find out the most important criteria for vendor selection. They have indicated that vendor selection is of great importance for both the private and public sectors and should not be done without complete evaluation of those criteria influencing the selection process. Garfamy et al, (2005) in the domain of vendor selection problem, a lot of criteria have been discussed. The relative importance placed on evaluative criteria varies largely in accordance with the nature of the selection situation and is complicated further by the fact that some criteria are quantitative (price, quality, capacity, etc.), while others are qualitative (service, flexibility, brand image, etc.).

III. PROBLEM DESCRIPTION

XYZ enterprises are the manufacture of various types of automobile product like a piston, gear, helical spring etc. As a part of its strategy, Division Outsources the noncore mechanical jobs to Private Vendors due to capacity constraints and facility constraints. The Outsourcing department of XYZ Enterprises is responsible for the techno-commercial function of registering new vendors, selecting the appropriate vendors for the job from the vendor list, finalization, sending enquiries, tendering, making comparative statement, negotiations, purchase proposal, placing purchase order, quality inspections, receipt of goods and final payment to vendors.

Few Of The Problems Described Below:

a) Default by vendors in supplying quality goods and meeting delivery schedules is a major concern for management.
b) Lots of cases of Re tendering are reported where the vendors are sent the inquiries but they don’t respond. Increasing Administrative cost per order is a concern for management.
c) Quality of products is being compromised by many vendors and there is nothing much that can be done after placement of Purchase Order.
d) Cases are observed where inquiries were also sent to vendors who don't manufacturer the parts mentioned in the inquiry.
e) Increasing dependency on very few vendors is obstructing in-house production schedules. Delays are causing cost escalations in many products.
f) Some vendors are taking the order just to get associated with XYZ Enterprises and with no intention to fulfill its terms.
g) Some vendors are taking orders in excess of their capacities whereas some are having lots of spare capacities.
h) The lack of classification of vendors according to a class of components is resulting in an unfair competition between high-quality vendor and low-quality vendor.
i) Presently Vendors are not given reasons for not qualifying in the preliminary shortlisting.

All these above points indicate that there is no consistent approach to select the vendors. The evaluators are performing the vendor selection procedures without full consideration of all the factors. There are general restrictions imposed on the selection procedure based on the lowest price, which may not completely fulfill what is required in terms of quality, delivery, service etc. Therefore, this research takes into consideration the whole criteria and sub-criteria that control the vendor selection No method for selecting vendors by bringing consensus within the department. Process. This research will try to develop a model for selecting the best vendors who are capable of satisfying certain criteria. As a case, this research, in particular, will deal with vendor selection process for Highly Critical mechanical jobs Outsourced in XYZ Enterprises. It is an attempt to improve the selection process in general and develop a model that can be used regularly to restrict these issues and problems at the early stage of vendor selection and achieve fair competition among vendors. Vendor selection of any manufacturing firm is done on selected criteria and its sub-criteria. Criteria are selected for vendor selection: quality, price, service, business overall performance, technical ability and on time delivery. Each Criterion has various sub-criteria e.g. Reliability and durability are sub-criteria of quality.

IV. EVALUATION OF VENDORS USING AHP METHOD

The Analytic Hierarchy Process (AHP) is a powerful and flexible decision making process to help people set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. By reducing complex decisions to a series of one-on-one comparisons, then synthesis the results, many researchers have concluded that AHP is a useful, practical and systematic method for vendor rating and has been applied successfully[1]. But one of the AHP's limits is decision model should structure the complete hierarchy which reflects all frameworks of goal. The Analytic Hierarchy Process (AHP) is a structured technique for helping people deal with complex decisions. Rather than prescribing a "correct" decision, the AHP helps people to determine one. Based on mathematics and human psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. The AHP provides a comprehensive and rational framework for structuring a problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. It is used throughout the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education. The AHP is a multi-attribute evaluation method that involves three phases: decomposition, comparative judgments, and synthesis of priorities (Saaty, 1980). In the decomposition phase, the project team can explicitly develop the AHP hierarchy model from the fundamental-objective hierarchy as mentioned above. In the second phase, each decision maker utilizes paired comparisons for the attributes and alternatives to extract judgment matrices with a nine-point scale at each level. In the third phase, the paired comparison process is repeated for each attribute in the alternative prioritization problem based on the largest eigen-value method. Finally, the relative importance of attributes and the global priority of alternatives can be obtained by aggregating the weights over the hierarchy. Hence, AHP can accelerate the development of a consensus amongst multiple decision makers in vendor management and selection process. A schematic representation of the AHP methodology is shown in Figure 1.

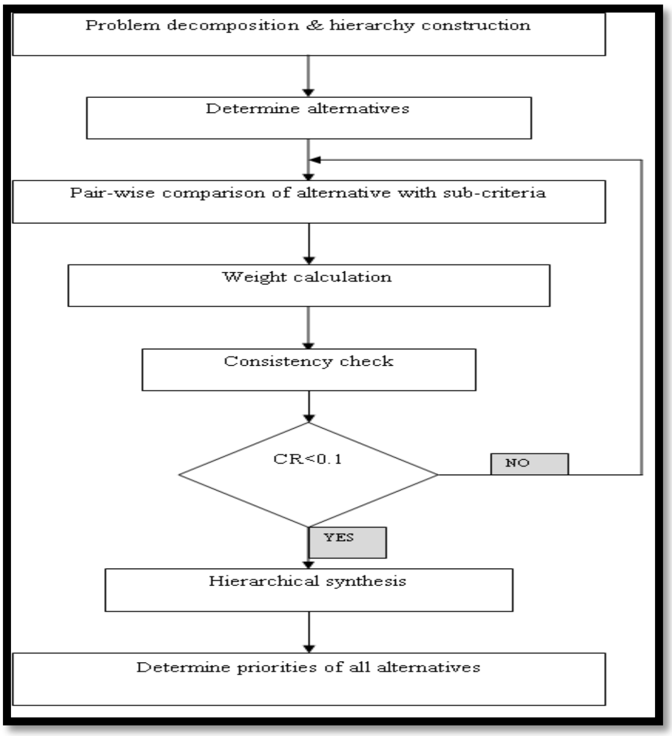

Figure 1 A schematic representation of the AHP methodology (Adopted Satty, 1980)

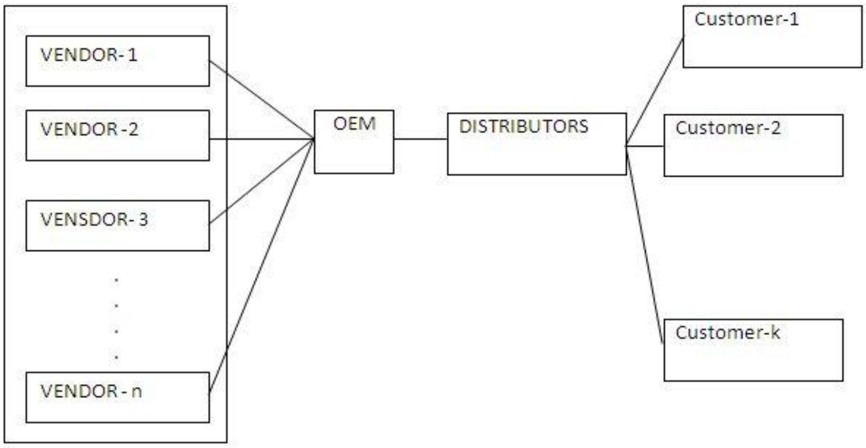

Figure 2: Best Vendor Selection Model

4.1 Establishment of a structural hierarchy

This step allows a complex decision to be structured into a hierarchy descending from an overall objective to various 'criteria', 'sub-criteria', and so on until the lowest level. The objective or the overall goal of the decision is represented at the top level of the hierarchy. The criteria and sub-criteria contributing to the decision are represented at the intermediate levels. Finally, the decision alternatives or selection choices are laid down at the last level of the hierarchy. According to Saaty [31], a hierarchy can be constructed by creative thinking, recollection, and using people's perspectives. He further notes that there is no set of procedures for generating the levels to be included in the hierarchy. Zahedi [33] comments that the structure of the hierarchy depends upon the nature or type of managerial decision. Also, the number of the levels in a hierarchy depends on the complexity of the problem being analyzed and the degree of detail of the problem that an analyst requires to solve [33]. As such, the hierarchical representation of a system may vary from one person to another.

4.2 Establishment of comparative judgments

Once the hierarchy has been structured, the next step is to determine the priorities of elements at each level ('element' here means every member of the hierarchy). A set of comparison matrices of all elements in a level of the hierarchy with respect to an element of the immediately higher level are constructed so as to prioritize and convert individual comparative judgments into ratio scale measurements. The preferences are quantified by using a ninepoint scale. The meaning of each scale measurement is explained in Table 1. The pair-wise comparisons are given in terms of how much more element A is important than element B. As the AHP approach is a subjective methodology [34], information and the priority weights of elements may be obtained from a decision maker of the company using direct questioning or a questionnaire method.

Preference Weights / Level Of Importance	**Definition**	**Explanation**
1	EQUALLY PREFERRED	Two vendors are equal in this criteria
3	MODERATELY	Experience and judgment slightly favors' vendor a over vendor b
5	STRONGLY	Experience and judgement strongly and essentially favors vendor a over vendor b
7	VERY STRONGLY	Vendor a is strongly favored over b and its dominance is well demonstrated
2,4,6,8	INTERMEDIATE VALUES	Used to represent compromise between the preferences listed above

Table 1: Thomas Saaty's nine-point scale (source: Saaty, 1994)

Value of aij Interpretation 1 3 5 7 9 2, 4, 6, 8 Objectives i and j are equal of importance Objective i is weakly more important than objective j Experience and judgment indicate that objective i is strongly more important than objective j Objective is very strongly or demonstrably more important objective j Objective i is absolutely more important than objective j Intermediate values-for example, a value of 8 means that objective i is midway between strongly and absolutely more important than objective j

4.3 Synthesis of priorities and the measurement of consistency

The pair-wise comparisons generate a matrix of relative rankings for each level of the hierarchy. The number of matrices depends on the number elements at each level. The order of the matrix at each level depends on the number of elements at the lower level that it links to [1]. After all matrices are developed and all pair-wise comparisons are obtained, eigenvectors or the relative weights (the degree of relative importance amongst the elements), global weights, and the maximum eigenvalue (λmax) for each matrix are then calculated. The λmax value is an important validating parameter in AHP. It is used as a reference index to screen information by calculating the consistency ratio CR [31] of the estimated vector in order to validate whether the pair-wise comparison matrix provides a completely consistent evaluation. The consistency ratio is calculated as per the following steps:

1. Calculate the eigenvector or the relative weights and λmax for each matrix of order n
2. Compute the consistency index for each matrix of order n by the formulae:

$CI = (\lambda max - n) / (n - 1)$ …………………………………………………………………………………… (1)

3. The consistency ratio is then calculated using the formulae:

$CR = CI/RI$…………………………………………………………………………………………. (2)

Where RI is a known random consistency index obtained from a large number of simulations runs and varies depending upon the order of matrix. Table 3 shows the value of the random consistency Index (RI) for matrices of order 1 to 10 obtained by approximating random indices using a sample size of 500 [31]. The acceptable CR range varies according to the size of matrix, i.e., 0.05 for a 3 by 3 matrix, 0.08 for a 4 by 4 matrix and 0.1 for all larger matrices, $n \geq 5$ [31, 34]. If the value of CR is equal to, or less than that value, it implies that the evaluation within the matrix is acceptable or indicates a good level of consistency in the comparative judgments represented in that matrix. In contrast, if CR is more than the acceptable value, inconsistency of judgments within that matrix has occurred and the evaluation process should therefore be reviewed, reconsidered, and improved. The comparative judgments should be reconsidered with respect to the issues raised in the section of establishment of Comparative judgments. The problem may also have to be more carefully restructured, i.e., grouping related elements together under a more general topic [35]. An acceptable consistency property helps to ensure decision-maker reliability in determining the priorities of a set of criteria.

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 2 Average random index (RI) based on matrix size (adopted from Saaty [31])

III. THE PROPOSED MODEL USING AHP

In this section a conceptual approach for structuring the selection of the best vendor using the AHP is introduced and the AHP decision steps are designed. A four level hierarchy decision process displayed in Fig. 2 is described below. Level I: Initially, the objective or the overall goal of the decision is presented at the top level of hierarchy. Specifically, the overall goal of this application is to 'select the best Vendor for the original equipment manufacturer plant'. Level II: The second level represents the category of a vendor to supply a component/sub-assembly for the manufacturing plant, which are identified to achieve the overall goal. The performance capabilities are derived from a number of sources. According to [30], the performance capabilities can be classified into five aspects: cost, quality, speed, flexibility, and dependability. Krajewski and Ritzman [41] define manufacturing's objectives as cost, quality, time, and flexibility. However, in this study only three issues have been considered and are used to constitute the second level to achieve the overall goal. Level III and IV: The third level of the hierarchy contains the sub-factors of each major factor. Three major factors and sub-factors (as shown in table 3) were identified from an extensive literature survey. The fourth level of the hierarchy represents the alternative vendors. The AHP model shown in figure 2 may be regarded as a feasible way for visualizing any vendor selection decision problem systematically. The decision-maker can apply this framework to structure their particular problem in selecting the best vendor for their choices in many circumstances.

6. Proposed AHP model to the case study

The objective of this section is to illustrate how vendor selection decisions are made using this model. The models have been applied to an automobile company in the northern part of India.

Vendor Selection Criteria

After reviewing the literature, the list of 32 criteria applicable for Outsourcing of Critical Mechanical jobs for XYZ enterprise in the present scenario was listed below.

Table 3 List of criteria and Sub-criteria

Serial no	Criteria	Sub-criteria
1	Quality	Product durability (lifespan of job work is as per design)
2		Product reliability (consistency over a range of past job works)
3		Quality management systems (control on procedures)
4		Percent rejections
5		Adherence to quality tools
6		Reputation and position in the market
7	Price	Competitive pricing
8		Understanding and willingness to follow financial security clause
9		Payment terms
10		Payment procedure understanding
11	Service	Attitude towards handling of complaints
12		Ability to maintain after sales service
13		Ability and willingness to provide technical support and training if req.
14		Flexibility (order volumes, mix of products, payments, freight, price reduction, order frequency and amount)
15	Business Overall Performance	Financial stability (sustainability)
16		Quality performance (ISO /as9100 accreditation)
17		Knowledge of the market
18		Use of information systems (communication)
19		Management capability (includes management commitment)
20		Performance history (vendors reputation for performance)
21	Technical Capability	Offering technical support when required
22		Technical know-how (vendor has the required skill set and possess good understanding of technology)
23		Vendor experience in related class of jobs
24		Responsiveness to change in quantity and due dates
25		Use of current technologies
26		Personnel technical abilities
27	On Time Delivery	Delivery lead time (speed)
28		Spare capacity to meet the requirements
29		Upcoming delivery commitments
30		Ability and willingness to expedite an order (continuation of cooperation)
31		Safety and security components
32		Suitable geographical location

Table 4 Pair-wise comparison of criteria

Criteria	Quality	Price	Service	Business overall performance	Technical capability	On time delivery
Quality	1.00	9.00	7.00	7.00	1.00	3.00
Price	0.11	1.00	0.33	0.33	0.14	0.14
Service	0.14	3.00	1.00	3.00	0.20	0.20
Business overall performance	0.14	3.00	0.33	1.00	0.20	0.20
Technical capability	1.00	7.00	5.00	5.00	1.00	1.00
On time delivery	0.33	7.00	5.00	5.00	1.00	1.00
TOTAL	2.73	30.00	18.67	21.33	3.54	5.54

Table 5 Normalized matrix of criteria

Criteria	Quality	Price	Service	Business overall performance	Technical capability	On time delivery	criteria local weights
Quality	0.37	0.30	0.38	0.33	0.28	0.54	0.37
Price	0.04	0.03	0.02	0.02	0.04	0.03	0.03
Service	0.05	0.10	0.05	0.14	0.06	0.04	0.07
Business overall performance	0.05	0.10	0.02	0.05	0.06	0.04	0.05
Technical capability	0.37	0.23	0.27	0.23	0.28	0.18	0.26
On time delivery	0.12	0.23	0.27	0.23	0.28	0.18	0.22

Table 7 Pair-wise comparison of vendors on quality sub-criteria 1

Criteria	Quality	Price	Service	Business overall performance	Technical capability	On time delivery	λ Value
Quality	0.37	0.26	0.51	0.36	0.26	0.66	6.62
Price	0.04	0.03	0.02	0.02	0.04	0.03	6.21
Service	0.05	0.09	0.07	0.15	0.05	0.04	6.33
Business overall performance	0.05	0.09	0.02	0.05	0.05	0.04	6.03
Technical capability	0.37	0.20	0.37	0.26	0.26	0.22	6.41
On time delivery	0.12	0.20	0.37	0.26	0.26	0.22	6.49
						λ_{max}	6.35
				CI = 0.07	RI = 1.24	CR =0.05	

CI= $(\lambda_{max}-N)/(N-1) = (6.35-6)/5 = 0.07$
For 6*6 matrix value for RI=1.24 so, CR=CI/RI =0.07/1.24 =0.05
Value of CR is less than 0.1 so judgments are acceptable.
In quality, there are four sub-criteria first is product durability, second is product reliability, third is quality management and fourth is percent rejection.

Product durability	Vendor1	Vendor2	Vendor3	Vendor4	Vendor5	Vendor6	Vendor7	Vendor8	Vendor9	Vendor10	local weights
Vendor 1	1.00	3.00	1.00	3.00	1.00	3.00	0.33	0.33	0.33	3.00	0.091
Vendor 2	0.33	1.00	0.20	1.00	0.20	0.33	0.33	0.20	0.20	0.20	0.028
Vendor 3	1.00	5.00	1.00	3.00	0.33	0.33	0.33	0.20	0.33	3.00	0.071
Vendor 4	0.33	1.00	0.33	1.00	0.33	0.33	0.33	0.20	0.33	0.33	0.032
Vendor 5	1.00	5.00	3.00	3.00	1.00	1.00	1.00	1.00	1.00	3.00	0.130
Vendor 6	0.33	3.00	3.00	3.00	1.00	1.00	0.20	0.20	0.33	3.00	0.080
Vendor 7	3.00	3.00	3.00	3.00	1.00	5.00	1.00	1.00	3.00	3.00	0.180
Vendor 8	3.00	5.00	5.00	5.00	1.00	5.00	1.00	1.00	3.00	3.00	0.203
Vendor 9	3.00	5.00	3.00	3.00	1.00	3.00	0.33	0.33	1.00	3.00	0.128
Vendor 10	0.33	5.00	0.33	3.00	0.33	0.33	0.33	0.33	0.33	1.00	0.056
total	13.33	36.00	19.87	28.00	7.20	19.33	5.20	4.80	9.87	22.53	

Table 8 (A) Global weight of vendor

s no.	Criteria	LW	Sub-criteria	GW	GW sub criteria	V1 LW	V1 GW	V2 LW	V2 GW	V3 LW	V3 GW
1	Quality	0.37	1	0.54	0.2	0.09	0.0179	0.03	0.0055	0.07	0.0139
2			2	0.28	0.1	0.04	0.0045	0.08	0.0081	0.03	0.0027
3			3	0.09	0.03	0.08	0.0025	0.06	0.0019	0.04	0.0012
4			4	0.09	0.03	0.13	0.0043	0.05	0.0016	0.11	0.0037
5	Price	0.03	1	0.17	0	0.04	0.0002	0.02	0.0001	0.07	0.0003
6			2	0.83	0.02	0.07	0.0017	0.15	0.0036	0.03	0.0007
7	Service	0.07	1	0.83	0.06	0.02	0.0015	0.25	0.0154	0.02	0.0011
8			2	0.17	0.01	0.03	0.0003	0.13	0.0016	0.02	0.0003
9	Business	0.05	2	0.05	0	0.03	0.0001	0.15	0.0004	0.02	0.0001
10			3	0.36	0.02	0.03	0.0005	0.09	0.0017	0.03	0.0005
11			4	0.44	0.02	0.02	0.0005	0.09	0.0021	0.03	0.0007
12	Technical		1	0.88	0.23	0.07	0.0159	0.03	0.0071	0.09	0.0213
13		0.26	2	0.13	0.03	0.02	0.0008	0.07	0.0023	0.05	0.0017
14	On Time Delivery	0.22	1	0.29	0.06	0.02	0.0015	0.23	0.0143	0.02	0.0014
15			2	0.07	0.01	0.04	0.0006	0.25	0.0037	0.02	0.0004
16			3	0.49	0.11	0.04	0.0038	0.17	0.0186	0.02	0.0024
17			4	0.03	0.01	0.13	0.001	0.13	0.001	0.13	0.001

Table 8(B) Global weight of vendor

s no.	Criteria	LW	Sub-criteria	GW	GW sub criteria	V4 LW	V4 GW	V5 LW	V5 GW	V6 LW	V6 GW
1	Quality	0.37	1	0.54	0.20	0.03	0.0064	0.13	0.0256	0.08	0.0158
2			2	0.28	0.10	0.09	0.0091	0.04	0.0045	0.18	0.0181
3			3	0.09	0.03	0.06	0.0017	0.07	0.0023	0.17	0.0054
4			4	0.09	0.03	0.06	0.0020	0.10	0.0033	0.04	0.0013
5	Price	0.03	1	0.17	0.00	0.03	0.0001	0.14	0.0007	0.04	0.0002
6			2	0.83	0.02	0.16	0.0038	0.08	0.0020	0.15	0.0037
7	Service	0.07	1	0.83	0.06	0.15	0.0091	0.02	0.0012	0.15	0.0093
8			2	0.17	0.01	0.12	0.0015	0.04	0.0004	0.15	0.0018
9	Busines s	0.05	0.05	0.00	0.16	0.0005	0.05	0.0001	0.17	0.0005	0.05
10			0.36	0.02	0.13	0.0023	0.11	0.0020	0.19	0.0035	0.36
11			0.44	0.02	0.12	0.0028	0.10	0.0022	0.18	0.0041	0.44
12	Technic al Ability	0.26	0.88	0.23	0.03	0.0062	0.22	0.0495	0.08	0.0188	0.88
13			0.13	0.03	0.04	0.0014	0.20	0.0064	0.06	0.0020	0.13
14	On Time Deliver y	0.22	0.07	0.01	0.14	0.0020	0.02	0.0003	0.14	0.0020	0.07
15			0.49	0.11	0.11	0.0120	0.02	0.0021	0.15	0.0159	0.49
16			0.03	0.01	0.03	0.0002	0.13	0.0010	0.13	0.0010	0.03
17			0.03	0.01	0.03	0.0002	0.13	0.0010	0.13	0.0010	0.03

Table 9 Ranking of vendor on overall all six criteria

VENDOR NAME	GROSS WEIGHT FROM AHP	RANK
VENDOR7	0.175218	1
VENDOR8	0.171681	2
VENDOR6	0.113674	3
VENDOR5	0.105245	4
VENDOR2	0.088963	5
VENDOR9	0.085487	6
VENDOR4	0.069785	7
VENDOR1	0.057615	8
VENDOR3	0.053376	9
VENDOR10	0.043628	10

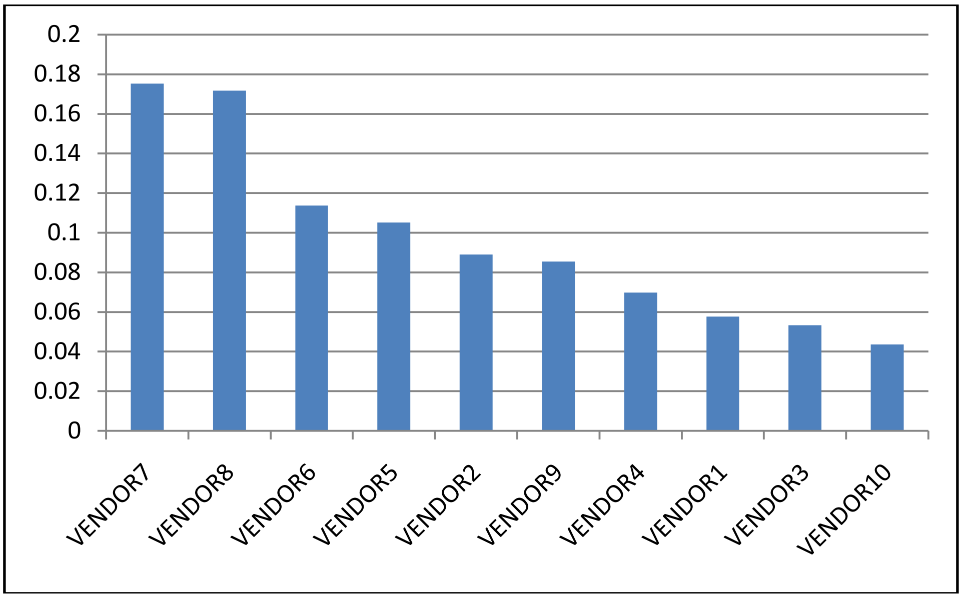

Figure 3 Analysis of global weight of vendor

V. VENDOR RANKING THROUGH VIKOR METHOD

The VIKOR (the Serbian name is "VIšekriterijumsko KOmpromisno Rangiranje" which means multi-criteria optimization and compromise solution) method was mainly established by Zeleny and later advocated by Opricovic and Tzeng. This method helps to solve multi-criteria decision making problems with conflicting and non-commensurable criteria, assuming that a compromise can be acceptable for conflict resolution, when the decision maker wants a solution that is the closest to the ideal solution and farthest from the negative-ideal solution, and the alternatives can be evaluated with respect to all the established criteria. It focuses on ranking and selecting the best alternative from a set of alternatives with conflicting criteria, and on proposing the compromise solution (one or more).

The compromise solution is a feasible solution, which is the closest to the ideal solution, and a compromise means an agreement established by mutual concessions made between the alternatives (Rao, 2007). In VIKOR method, the best alternative is preferred by maximizing utility group and minimizing regret group. This method calculates ratio of positive and negative ideal solution In order to take wise decision on Vendor selection, a methodology is proposed by combining Analytic Hierarchy Process (AHP) and VIKOR.
The outline of the proposed methodology is shown below:

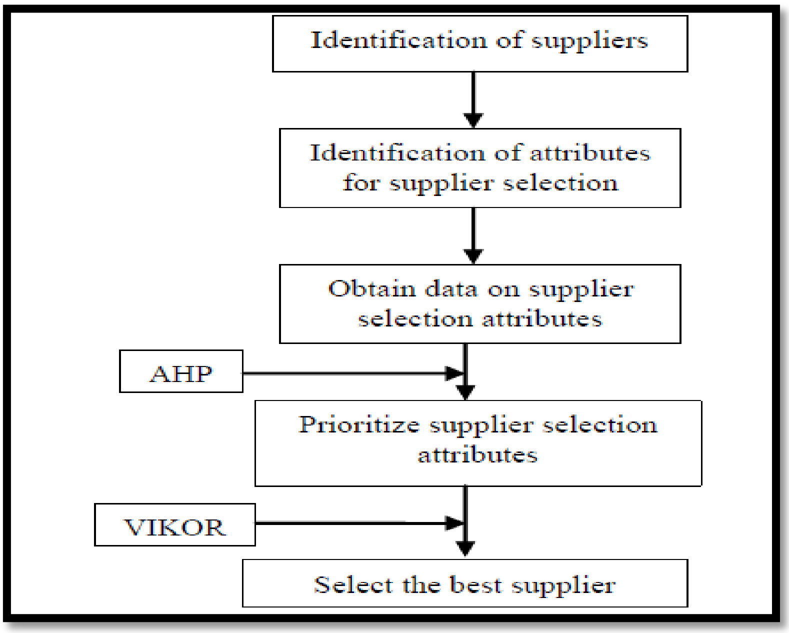

Figure 4 Vendor selection using VIKOR

In this methodology the priority structure of Vendor selection attributes is obtained by using AHP. The weights of the Vendor selection attributes will be reflected in determining the VIKOR index for each Vendor. On the basis of VIKOR indices it is easier for a decision maker to identify the best Vendor.

The step by step methodology is discussed below:
Step 1: Identification of Vendor selection attributes the process of selection of a Vendor for any firm is started with the identification Vendor selection attributes. The attributes for Vendor selection are usually depends on the type of firm, product, purchasing capability etc.
The top level executives are generally involved in the identification of Vendor selection attributes. There are a number of Vendors selection attributes. But the most common attributes are quality, price, service, Business overall performance, technical ability, on time delivery.
Step 2: Obtain data on Vendor selection attributes.
The data pertaining to Vendor attributes may be obtained through questionnaire survey. A questionnaire is developed by the management of the company to obtain the response data on Vendor selection attributes by purchase group.
Step 3: Determination of the priority structure of Vendor selection attributes using AHP
Step 4: Formulation of MCDM decision matrix:
The MCDM decision matrix has to be formed as shown below
Where A_i= the i^{th} alternative (i = 1,2,3,…….m)
Cx_j = the jth criterion (j = 1,2,3,……..n)
X_{ij} = individual performance of the alternatives (Vendors)

	Cx_1	Cx_2	Cx_3	.	.	Cx_n
A_1	x_{11}	x_{12}	x_{13}	.	.	x_{1n}
A_2	x_{21}	x_{22}	x_{23}	.	.	x_{2n}
A_3	x_{31}	x_{32}	x_{33}	.	.	x_{3n}
.	.	.	.	.	.	.
.	.	.	.	.	.	.
A_m	x_{m1}	x_{m2}	x_{m3}	.	.	x_{mn}

Step 5: Representation of normalized decision matrix.

The normalized decision matrix can be expressed as follows:
$F = [f_{ij}]_{m\times n}$ (1)
Where, $f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$, i = 1,2,…,m; j = 1,2,….,n
x_{ij} is the performance of alternative A_i with respect to the jth criterion
Step 6: Determination of positive-ideal solution and negative-ideal solution
Determination of positive-ideal solution and negative-ideal solution
The positive ideal solution A* and the negative ideal solution A- determined as follows:
$A^* = max\, f_{ij} \mid j \in J \text{ or } min\, f_{ij} \mid j \in J \mid i = 1,2,\ldots,m$
$= f_1^*, f_1^*, \ldots f_j^*, \ldots f_n^*$
$\bar{A} = min\, f_{ij} \mid j \in J \text{ or } max\, f_{ij} \mid j \in J \mid i=1,2,\ldots mm$
$= f_1^-, f_1^-, \ldots f_j^-, \ldots f_n^-$
Step 7: Calculation of Utility measure and Regret measure.

The Utility measure Si and Regret measure Ri for each alternative are computed using the following expressions:
$S_i = \sum_{j=1}^{n} w_j \times \left[\frac{f_j^* - f_{ij}}{f_j^* - f_j}\right]$ (2)
$R_i = max_j \left[w_j \times \frac{f_j^* - f_{ij}}{f_j^* - f_j}\right]$ (3)

Where w_j =weight of the jth criterion.
Step 8**:** Computation of VIKOR index
The VIKOR index is calculated by using the following expression

$$Q_i = v\left[\frac{S_i - S^*}{\bar{S} - S^*}\right] + 1 - \boldsymbol{v}\left[\frac{R_i - R^*}{\bar{R} - R^*}\right] \quad (4)$$

Where Q_i represent VIKOR value, S^* represent maximum utility factor , S^- represent minimum utility value, R^* maximum regret value, R^- represent minimum utility value S_i represent utility value of alternative (Vendor) R_i represent regret value and v represent weight of maximum group utility and its value usually set 0.5.

Step 9: Rank the order of preference
The alternative which is having smallest VIKOR index value is the best solution.
Step 1: identification of Vendors and step2: identification of attributes of Vendors is already done at the initial phase of AHP.
Step 3: Prioritizing of Vendor's attribute has been done from Table2

Table 10 Weight of criteria

	Quality	Price	Service	Business	Tech	Delivery
weight from table 2	0.37	0.03	0.07	0.05	0.26	0.22

Step4: Formulation of MCDM Matrix has been summarized from table 49A, 49B and 49C.

Table 11 Weight of criteria for Vendors

	Quality	Price	Service	Business	Tech	Delivery
Vendor1	0.34	0.11	0.05	0.08	0.09	0.23
Vendor2	0.22	0.17	0.39	0.34	0.10	0.78
Vendor3	0.24	0.10	0.27	0.08	0.15	0.20
Vendor4	0.23	0.18	0.06	0.41	0.07	0.42
Vendor5	0.34	0.22		0.26	0.41	0.20
Vendor6	0.47	0.19	0.30	0.54	0.14	0.58
Vendor7	0.87	0.19	0.10	0.36	0.49	0.48
Vendor8	0.71	0.46	0.53	0.55	0.24	0.69
Vendor9	0.40	0.24	0.13	0.18	0.21	0.29
Vendor10	0.17	0.15	0.13	0.20	0.10	0.12

Step5: Normalized decision matrix has been made as per formula

$F = [f_{ij}]_{m \times n}$

Where, $f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$, i = 1,2,…,m; j = 1,2,….,n

x_{ij} is the performance of alternative A_i with respect to the jth criteria

Table 12 Normalized matrix of criteria

	Quality	Price	Service	Business	Tech	Delivery
Vendor1	0.24	0.15	0.06	0.08	0.12	0.16
Vendor2	0.15	0.25	0.48	0.31	0.13	0.54
Vendor3	0.17	0.14	0.05	0.08	0.19	0.14
Vendor4	0.16	0.26	0.34	0.38	0.09	0.29
Vendor5	0.24	0.31	0.07	0.24	0.54	0.14
Vendor6	0.33	0.27	0.38	0.50	0.19	0.40
Vendor7	0.61	0.27	0.13	0.34	0.64	0.33
Vendor8	0.50	0.65	0.66	0.51	0.31	0.48
Vendor9	0.28	0.34	0.16	0.16	0.27	0.20
Vendor10	0.12	0.21	0.16	0.19	0.13	0.09

Step6: positive-ideal solution and negative-ideal solution as per formula mentioned in above step6

Table 13 Most positive-ideal solution and negative-ideal solution

	Quality	Price	Service	Business	Tech	Delivery
f+	0.61	0.14	0.66	0.51	0.64	0.09
f-	0.12	0.65	0.05	0.08	0.09	0.54

Step 7: Calculation of Utility measure and Regret measure has been calculated as per formula mentioned in above step7 and shown below:

Table 14 Utility measure and regret measure of vendor

	Quality	Price	Service	Business	Tech	Delivery	Utility measure si	Regret measure ri
Vendor1	0.28	0.00	0.07	0.05	0.25	0.04	0.68	0.28
Vendor2	0.35	0.01	0.02	0.02	0.24	0.22	0.86	0.35
Vendor3	0.33	0.00	0.07	0.05	0.21	0.03	0.69	0.33
Vendor4	0.34	0.01	0.04	0.02	0.26	0.10	0.76	0.34
Vendor5	0.28	0.01	0.07	0.03	0.05	0.02	0.46	0.28
Vendor6	0.21	0.01	0.03	0.00	0.21	0.15	0.62	0.21
Vendor7	0.00	0.01	0.06	0.02	0.00	0.12	0.21	0.12
Vendor8	0.08	0.03	0.00	0.00	0.15	0.19	0.46	0.19
Vendor9	0.25	0.01	0.06	0.04	0.17	0.06	0.59	0.25
Vendor10	0.37	0.00	0.06	0.04	0.24	0.00	0.71	0.37

Step 8**:** Computation of VIKOR index has been measure has been calculated as per formula mentioned in above step8 and shown below:

Table 15: Value of Q_i of vendors

Vendors	Utility measure S_i	Regret mea sure R_i	Q_i
Vendor1	0.68	0.28	0.69198
Vendor2	0.86	0.35	0.95615
Vendor3	0.69	0.33	0.79896
Vendor4	0.76	0.34	0.85825
Vendor5	0.46	0.28	0.51433
Vendor6	0.62	0.21	0.51148
Vendor7	0.21	0.12	0
Vendor8	0.46	0.19	0.33872
Vendor9	0.59	0.25	0.55949
Vendor10	0.71	0.37	0.88827
Maximum	0.86	0.37	
Minimum	0.21	0.12	

Step 9: Rank the order of preference:

Lower the Qi value, Better will be ranking so ranking of all 10 vendors has been mentioned below:

$$Q_i = \nu \left[\frac{S_i - S^*}{\bar{S} - S^*}\right] + 1 - \boldsymbol{\nu} \left[\frac{R_i - R^*}{\bar{R} - R^*}\right]$$

Table 16: Ranking of vendors according to VIKOR method

Company name	Qi	Rank
Vendor7	0	1
Vendor8	0.338721	2
Vendor6	0.511476	3
Vendor5	0.514334	4
Vendor9	0.559494	5
Vendor1	0.691983	6
Vendor3	0.798959	7
Vendor4	0.858246	8
Vendor10	0.888272	9
Vendor2	0.956151	10

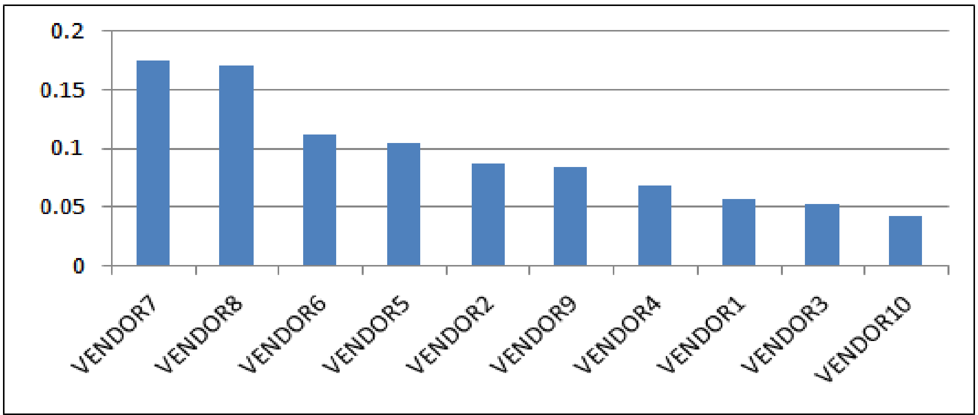

Figure 5 Value of Q_i of vendor

VI. RESULTS AND DISCUSSIONS

The ultimate objective of dealing with the Vendor selection problem is to obtain a solution for prioritizing of Vendors. The best Vendor may provide faster delivery, reduced cost, good service, better business overall performance along with the improved quality in order to increase competitive advantage in the market. In the present work, AHP model and an integrated model of AHP-VIKOR for Vendor selection has been developed and demonstrated the methodology through a case study conducted in XYZ manufacturing company. Both models are well suited to deal with multi-criteria decisions that involve both qualitative and quantitative factors. Our study and analysis considered 6 criteria and 32 sub criteria to prioritize the Vendors of critical mechanical jobs. Based on survey, we considered 6 criteria and 19 sub criteria for further analysis and remaining sub criteria have been not considered since its weights were less than 0.7. Consistency ratio for 6 criteria and 19 sub criteria were evaluated and found that all are less than 0.1. So every criteria and sub criteria are meeting the AHP's philosophy.

Further for every sub criteria, Consistency ratio for all ten vendors are evaluated and found that two sub criteria 1. Financial stability (sustainability) and 2. Spare capacity to meet the requirements are not meeting consistency ratio limitation(< 0.1), so both sub criteria has been eliminated further. So finally based on 6 criteria and 17 sub criteria, prioritizing of ten Vendors has been done by both methods AHP and AHP- VIKOR for critical mechanical jobs. We also completed the comparison analysis among AHP and VIKOR methods. Even though the ranking outcomes were the same for best 04 Vendors by AHP and AHP-VIKOR Methods and majority of ranking results of remaining Vendors are nearby as shown below:

Table 17: Ranking of vendor by AHP and VIKOR method

Vendor Name	Vikor Rank	Ahp Rank
Vendor7	1	1
Vendor8	2	2
Vendor6	3	3
Vendor5	4	4
Vendor9	5	6
Vendor1	6	8
Vendor3	7	9
Vendor4	8	7
Vendor10	9	10
Vendor2	10	5

The proposed methodology can be applied for Vendor selection in any manufacturing/ service sector Company.

VII. MANAGERIAL IMPLICATION & CONCLUSIONS

In the present research AHP-VIKOR technique is effective for selection of Vendor in the supply chain. Models developed attempts to suggest how the AHP-VIKOR technique is useful for selection of Vendor. The objective of this research was to develop criteria or its sub-criteria that would help to selection of Vendor in the supply chain of industry. This technique is very useful for material selection and chosen of service. Vendor play important role to boost upstream supply chain. Vendor helps to make good market reputation of the organization. Vendor selections depend on quantitative and qualitative criteria. In Vendor selection AHP-VIKOR technique has been used. Both techniques are multi decision criteria method. There are six criteria and seventeen sub-criteria have been implemented in the Vendor selection model. Vendor 7 and Vendor 8 got first and second position in Vendor selection priority.

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