Building a Recommendation System for Supplier Splits Allocation in Hardware Networking Industries

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Abstract: *Globalization has made supply chain more complex, diverse and makes it possible to obtain any material from any location on the planet. It is the most difficult decision to make in outsourcing, yet it is crucial to a supply chain's success. The supplier selection process consumes a significant amount of a company's financial resources and is critical to its success. The primary goal of supplier management strategies is to decrease the purchasing risk, increase the total value for buyer and finally foster long term relationships between vendors and buyers. This study aims to build a multicriteria supplier recommendation system to select better suppliers in networking industries. There are two steps to the suggested model. Using analytical hierarchy process (AHP), the weights of the criteria are first determined. This study takes into consideration 5 criteria and 11 sub criteria. The results of the Pareto analysis were used to establish which criteria have the greatest impact on the organization's selection process. The output of the AHP model, that is the criteria weights are used as the input to determine the supplier ranking using TOPSIS process. The findings demonstrate that using a structured decision-making methodology is critical, particularly in complex situations with both qualitative and quantitative criteria.*

Index Terms **- Supplier Management, Analytical hierarchy process, Qualitative criteria, TOPSIS.**

I. INTRODUCTION

The process of supplier section is a strategic decision for organizations. Having a reliable supplier selection model brings considerable advantages to firms and improves the contentment of consumers. It's vital to note that selecting the correct providers is much more than scanning several pricing lists, and decisions will be made based on a variety of factors. The supplier selection's performance is evaluated based on both qualitative and quantitative factors. These factors include product cost, logistics cost, Product compliance, rejected product ratio, defects, on-time delivery, lead time, fulfilment of urgent orders, innovation capabilities, Development capabilities, manufacturing technology and new product introduction.

The process of supplier selection involves two main phases, firstly to determine the relevant and important criteria for supplier selection and then to pick the suppliers from the vast set of options available. Mastering the supplier selection process decrease's, the overall risk, increases the customer satisfaction and caters a relationship with the vendor and purchasers. Incorrectly implementing the supplier selection process can have a major impact on the economic conditions of the organization. In today's global economy, inefficient supplier selection can have ramifications across supply chains all over the world.

The strategies of supplier selections in terms of technology, product cost, fulfilment, quality are necessary to decrease the upstream uncertainty, like product rejects due to quality, not following the decided delivery lead-time; and downstream uncertainties because of demand changes and difference in product mixture, the cost and competitors strategy. The impact can be directly seen, or it can also be controlled by the supplier selection process, especially through the technology and quality aspect of supplier's performance.

Experts and researchers have used multi-criteria decision making (MCDM) methods to help managers to pick the supplier that aids the organization in achieving its goals and to evaluate and analyze the decisions made. MCDM is a technique that decides by simultaneously evaluating multiple conflicting criterions. It gives a structured approach to decision making.

II. LITERATURE REVIEW

Crucial business entities who embrace Data analytics techniques for their supplier selection, as a brand-new paradigm are seemingly offered endless promises of business transformation and operational efficiency improvements. In the area of Supply Chain Management (SCM) especially, some examples have captured the eye of both practitioners and researchers. Supplier selection has received more scrutiny by the supplier management departments in organizations. Normally the supplier selection process has multiple steps. First, it begins with identifying the requirements. Then the criteria's must be selected. Next the qualified suppliers must be identified by the manger. As the last step the evaluation and section are conducted.

Vendor selection has gained more importance during the recent years from academic personals and professional because of its importance and its ability to be structured in the form a mathematical model. Different research papers compare and contrast the techniques used for decision making, the criterions and alternatives when it comes to supplier selection. Nikhil Chandra Shil (2015) in his paper gives an understanding of what different criteria's have been used for supplier selection through the years and also gives a brief of supplier selection techniques being used in literature.

Youssef Mohamed A., Mohammed and Bidhu Mohanty in their paper provide a brief review of the supplier selection technique that exists in literature. Then in the context of advanced manufacturing technology, a paradigm for vendor evaluation and selection is presented as a cost dependent, deterministic and multiple attribute problem. The paper presents a model that takes into consideration quality and responsiveness in terms of cost. The steps to determine the optimized order levels such that it reduces the overall inventory cost is also mentioned. The model described in simple to interpret and execute by any business sector. The presented methodology gives the decision makes the choose from the various cases through which the best criteria's for supplier selection.

Ferhan C and Demet Bayraktars in their extensive study suggest a overall model for vendor allocation. In order to select the supplier, they use lexicographical goal programming and analytical hierarchy process. The presented model includes both quantitative and qualitative aspects of the process. In the paper the description of the model building phase, the results ad applications of the proposed model in different sectors are described. The criteria's for supplier selection used n this study include Fulfillment, the price and quality factors. These criteria's are used as the objective function of goal programming. A fourth objective is also added to the model which is utility function. In order to calculate vendor scores, which are the coefficients of the fourth objective function, an AHP model was created that included several critical criteria that influence supplier selection in addition to quality, delivery, and cost.

Lyès Benyoucef, Hongwei Ding, Xiaolan Xie in their report of supplier selection problems present the different selection criteria's for vendor selection and the methods that can be used to tackle this decision. The model presented in this report is of two phases. In the first phase the relevant suppliers are selected by the organizations and then these suppliers are subjected to liner integer programming to select the best vendors in the second phase. The constraints used for liner programming and are both with respect to the supplier and buyer. Few of the selection methods described in this paper include elimination, lexicographic, optimization and finally probability method.

Dickson conducted an interesting study based on a questionnaire which was sent to 273 organizations and managers who were responsible for supplier selection. These managers and organization were selected from the list of National association of purchasing managers. The list consisted of various managers and members from the US and Canada. The questionnaire was about the relative importance of 23 criteria's. 62.3 % of Dickson's research showed that the criteria of most significance is "quality" at the time of research being conducted that is in the sixties. Few of the criteria's of extreme importance according to Dickson's survey are fulfillment, performance history, warranty and the production facilities. The reciprocal arrangement was given the least importance when the criteria's were ranked by the agents and manger's.

Srinivas Talluri, Shawnee, Vickery Sriram in their paper highlight the process of choosing the best supplier from a list of options. The criteria were set in accordance with the firm's needs, and a multiple linear regression analysis was utilized as a statistical method to select the best supplier. Criteria have been translated into three separate indices from various angles, and supplier selection is based on the indices given to them based on the inter relationships. This study provides a considerable amount of contribution by representing a model with multiple factors for ensuring efficient negotiations between the vendor and the organization. The paper also applies the model to a real-life data of buyer and vendor situation. In evaluating and ranking suppliers, the presented models allow for effective accounting of many attributes. The model does not require the buyer to assign prior weights or relevance levels to different aspects, therefore the evaluation can be done with any supplier dataset in the presence of a set of input and output factors, resulting in effective strategies.

III. RESEARCH METHODOLOGY

Choosing an organization's suppliers is a critical decision. The majority of a company's financial resources are spent on obtaining components from vendors. As a result, selecting the correct provider is critical. Suppliers must be chosen based on a combination of qualitative criteria like quality, manufacturing capabilities etc. The recommendation system is built using python and mainly two multi criteria decision making techniques which are analytical hierarchy process and Technique for order of preference by similarity to ideal solution are used. The objective of this recommendation system is to combine both qualitative and quantitative data while selecting a supplier.

3.1 Data collected from repositories

Data collection is a vital phase in any of the analyses that has been done. Here too, data collection will play an important role because this will form the basis, or we can say the fundamental core of the analysis.There are three main repositories from where the required data for the supplier can be extracted:

- A local data source in the form of snowflake tables has the data regarding the supplier costs, this table consists of the cost quoted by the supplier for that quarter and the previous quarter. The weighted average of the supplier quotes gives the quote for that component. Both levels of cost is available in this data sources.

- The second data source is in the form of an excel sheet table including information on fright costs. This data source contains information on the cost of transporting a component from a supplier's location to a contract manufacturer's location. The information is available on a component-by-component basis. Aside from that, the table includes the component's country of origin and destination, the respective cities and the supplier quote before fright cost is added and the supplier quote once the fright cost is added.

- The third data source is a supplier rating repository in the form of an excel sheet table. This data source has been created by integrating the different supplier rating criteria's which were in the form of individual excel sheets. The supplier ratings are given by supply chain mangers for very suppliers. The suppliers are rated on various criteria's and on a 10-pointer scale ranging from 0 to 100. This data base consisted of 5 criteria's and 11 sub criteria's

3.2 Tools and Techniques used for analysis

The tools and techniques used to build the recommendation system are MS excel, SQL, python, AHP and TOPSIS. MS excel was used for data handling and data integration. Since the data source was able in different platforms like snowflake SQL was used for database management and retrieval. Python was used to build the recommendation system with the help of libraries like Nympy and Pandas. AHP technique was used to calculate the weights of criteria and sub-criteria's and TOPSIS is used to rank the suppliers according to various criterions.

3.3 Steps to build the recommendation system

In this section the methodology of building a recommendation system for supplier splits allocation is described. The figure below shows methodology used to build the recommendation system using multi criteria decision making techniques. The entire methodology of the project is divided into five steps and shown in figure 1– Criteria selection, Calculation weights, Consistency check, TOPSIS, Recommendation system.

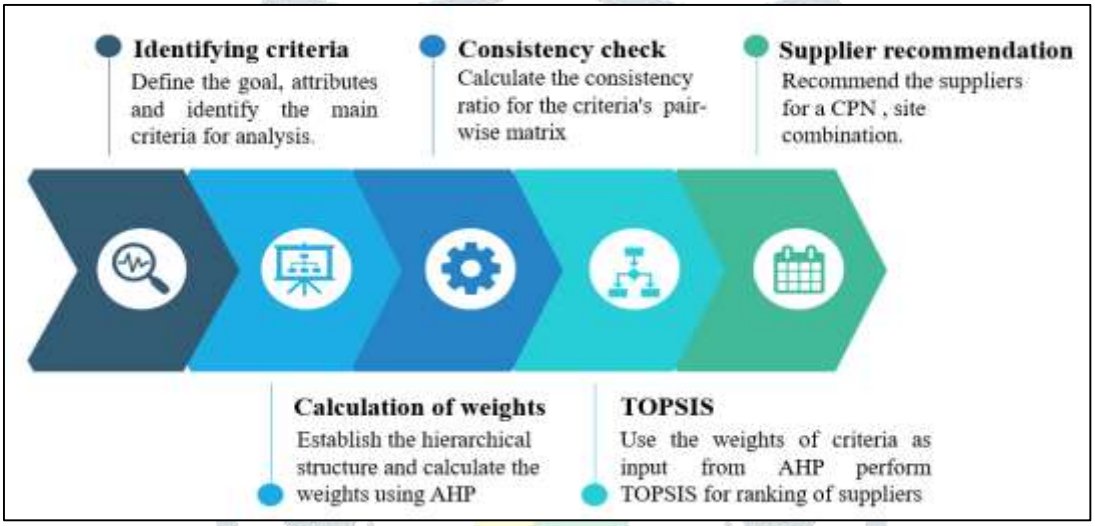

Fig 1: Methodology used for building recommendation system

Step 1- Criteria selection phase:

The first step in building any recommendation system is to define the goal of this system. In this case the goal is to select the best supplier. The multiple attributes that influence this decision must be taken into consideration. These attributes must include quantitative and qualitative criterions. In this case 5 main criterions were taken into consideration namely cost of the component, the quality of the product supplier, the fulfilment capabilities of the supplier, the technological capability of the supplier and finally the ability to handle a new product introduction. In this study the number of alternatives that is the suppliers are chosen to be 60. The raw data selected is for 31 components and they have 60 suppliers. Analytical hierarchy process is used to calculate the weightage given for each criterion, and a hierarchy is made as shown in the figure 2.

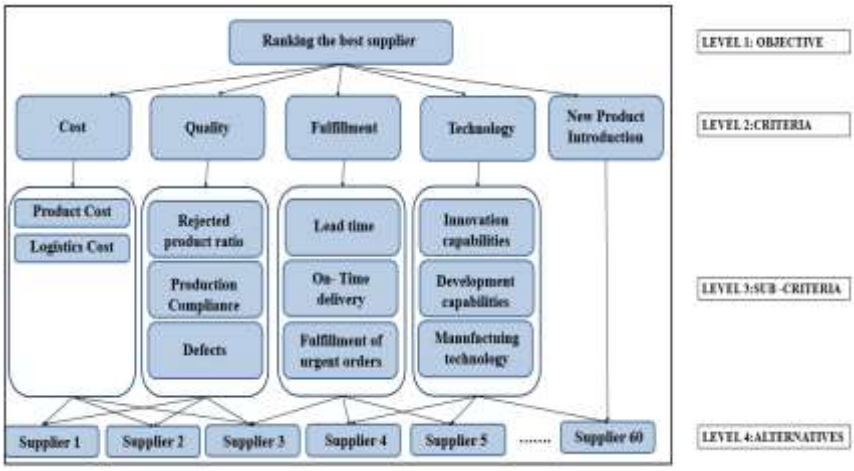

Fig 2: Supplier selection hierarchy

Step 2- Calculation of weights phase:

Once the hierarchy is determined in the previous step. The weights of the criteria's and sub criteria's need to be calculated using AHP analysis. The weights of these criteria's will be used as the input to TOPSIS process and used to rank the supplier. The pair wise criteria matrix is made as shown in table 1 for this study.

Table 1: Pair-wise comparison matrix for criteria

	Cost	Quality	Fullfilmen	NPI	Technology
Cost	1.00	3.00	2.00	5.00	3.00
Quality	0.33	1.00	2.00	4.00	2.00
Fullfilment	0.50	0.50	1.00	5.00	5.00
NPI	0.20	0.25	0.20	1.00	0.25
Technology	0.33	0.50	0.20	4.00	1.00

The pair wise comparison matrix is made is made by giving the relative importance of different attributes with respect to the goal. The relative importance is given based on the Saaty scale of relative importance. Once the pair-wise matrix is made then it needs to be normalized. Each value in the pair wise comparison matrix is divided by the sum of the columns to get the normalized value. Finally, the criteria weights are calculated as an average of the rows in the normalized matrix.

Step 3- Consistency check phase:

To check the validity of the pair-wise comparison matrix in the previous phase the consistency ratio of every matrix is calculated if the ratio is more than 0.1 then the user can procced to the next step. The consistency matrix is first calculated by multiplying the non-normalized pair wise comparison matrix with the criteria weights obtained. The sum of these weighted values is calculated along the row of the matrix to give the weighted sum as shown in table 2.

Table 2: Checking the consistency for pair-wise comparison matrix

	Cost	Quality	Fullfilmen	NPI	Technology	Weighted	Criteria weights	Ratio
Cost	0.38	0.65	0.48	0.15	0.36	2.02	0.38	5.34
Quality	0.13	0.22	0.48	0.12	0.24	1.18	0.22	5.43
fullfilment	0.19	0.11	0.24	0.15	0.60	1.29	0.24	5.37
NPI	0.08	0.05	0.05	0.03	0.03	0.24	0.05	4.88
Technology	0.13	0.11	0.05	0.12	0.12	0.52	0.11	4.57

Then the ratio is found for every criterion by dividing the weighted sum with the weights of the criteria. Finally, the average of all the ratios is found to calculate the lambda max. The consistency ratio is calculated as per the equation1 and equation 2.

$$\text{Consistency Index : } CI = \frac{\lambda_{max} - n}{n-1} = 0.03 \quad (1)$$

$$\text{Consistency Ratio (CR)} = \text{CI/RI} = 0.026 \quad (2)$$

Step 4- TOPSIS phase:

In this step the weights from AHP are taken as input and the ranking for suppliers is determined as a part number and site combination. The ranking of suppliers is obtained in this phase. The AHP method is used to determine the weights, which are then employed in the TOPSIS process to rank the suppliers. Because the evaluation is done on a product cost level, and product costs can vary vastly between components, the ranking of suppliers is given for each component. TOPSIS reasoning is straightforward and easy to comprehend. It analyses a group of possibilities by defining weights to every criterion, normalising the scores for each set of criteria, and calculating the mathematical length between every option and the ideal choice in order to offer the optimum score for each. Normalization is done using equation 3.

$$\overline{X}_{ij} = \frac{X_{ij}}{\sqrt{\sum_{j=1}^{n} X_{ij}^2}} \quad (3)$$

The vector normalized matrix is multiplied with the global weights of criteria's obtained by AHP and the ideal best and the ideal worst solution for every criterion is identified. The criteria's are first identified as beneficial or non-beneficial. For example, the product cost is a non-beneficial criterion that means the ideal best value will be the smallest values and the ideal worst value will be the largest value. In case of the beneficiary criteria like innovation capabilities the ideal best value is the highest value, and the ideal worst value is the least value. The ideal best and worst values are identified and represented. Finally, the Euclidian distance from the Ideal best and the ideal worst is calculated and the performance index is calculated for every supplier using equation 6. The Euclidian distance from the best and worst solution is calculated using equation 4 and equation 5.

$$S_i^- = \left[\sum_{j=1}^{n} (v_{ij} - v_j^-)^2\right]^{0.5} \quad (4)$$

$$S_i^- = \left[\sum_{j=1}^{n} (v_{ij} - v_j^-)^2\right]^{0.5} \quad (5)$$

$$P_i = \frac{S_i^-}{S_i^- + S_i^-} \quad (6)$$

Step 5- Recommendation system Phase:

As the last step of the model, all the components will undergo the similar TOPSIS process as described in step 4. The suppliers will be ranked on a component site combination. Since the same component can go multiple sites. The ranking of supplier is provided and not just the best supplier since sometimes there are possibilities where there is contract with the supplier that would make it necessary to allocate some splits to the supplier even with a lower ranking. The final output of is obtained in the form of an excel sheet with components and supplier rankings. This will be discussed in detail in the result section.

IV. RESULTS AND DISCUSSIONS

Results are an important part of any project. Here, results in a quantitative manner show us the significance of numbers and how they are directly and indirectly affecting the project. Results throw in more light into the project. Supplier selection is a critical decision that all firms must make. Procurement of components undergoes strategic planning because the efficiency of this process will provide a competitive edge. Because in a real-world setting, all elements will influence decision-making, the supplier selection problem must be tackled using both quantitative and qualitative data. Using a mathematical model to pick suppliers standardizes the process and decreases the amount of expertise required of management before each decision.

The overall outlook of the recommendation project depends on the input variable ultimately. And these variables need to be fed with utmost concern and care. The variables in this project were the individual product cost, logistics cost, the product compliance capability of a supplier, rejected product ratio, defects, lead-time, on time delivery, fulfillment of urgent orders, innovative capabilities, Manufacturing technology used by suppliers. These data were combined onto on excel sheet by using python to produce the raw ratings of supplier criteria's.

The required raw data was combined on python and analysis was conducted to build the recommendation system. The AHP and TOPSIS techniques were extensively used to calculate the weights for criteria's and the ranking of suppliers was done using TOPSIS for every part number and site combination. To build the recommendation system for supplier selection the weights of criteria, local weights of sub-criteria and global weights of sub criteria was calculated and tabulated as shown in figure 3. These global weights are used as input to perform TOPSIS for ranking the suppliers. The TOPSIS process gives a performance index for every supplier and these are ranked to determine the best supplier. The TOPSIS process happens for every part number, site combination and determines the best supplier.

Table 3: Global weights and ranking of sub-criteria's

Criteria	Weights of criteria	Sub-Criteria	Local weights of criteria	Global weights of criteria
Cost	0.38	Product cost	0.83	0.32
		Landed cost	0.17	0.06
Quality	0.22	Rejected product ratio	0.21	0.05
		Product complaince	0.66	0.15
		Defects	0.13	0.03
Fullfilment	0.24	Lead-time	0.25	0.06
		On time delivery	0.58	0.14
		Fullfilment of urgent orders	0.17	0.04
Technology	0.11	Innovation	0.10	0.01
		Development	0.23	0.03
		Manufacturing	0.67	0.07
NPI	0.05			0.05

Pareto analysis was used to prioritize the important criteria for selecting suppliers as shown in figure 4. The results show that 12 criteria of supplier selection were reduced to 6 criteria, including the criteria in the following dimensions: 'Product Cost,' 'Product compliance,' 'On-time delivery,' 'Manufacturing,' and 'Landed cost' .In particular, 'Product cost' obtained the top priority for selecting suppliers, followed by 'product compliance,' 'on-time delivery' 'Logistics cost,' and 'manufacturing ', which were identified as the top five criteria for supplier selection. However, the criteria under 'New product introduction' dimension was not defined as important in the supplier selection phase.

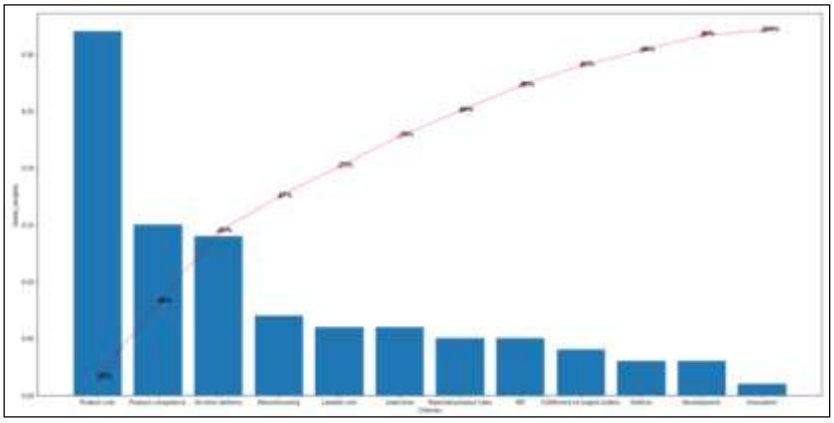

Figure 4. Pareto chat showing weightage given to sub-criteria's

The supplier ranking for every part number and site combination is obtained in the form of an excel sheet. This sheet can be used by supply chain managers while deciding the supplier splits. This will help the managers in taking a decision with both qualitative and quantitative data. The supply chain managers will not have to spend much time on analyzing and using their expertise to draw inferences from different qualitative data sources. This recommendation system will also reduce the overall errors that could possibly be made during profit and loss calculations.

V. CONCLUSION

Strategic sourcing is a multi - attribute challenge that necessitates the consideration of both subjective and analytical factors. One of the variables mentioned in this study is quality, which may be measured by failure rate. Similarly, the AHP scale accurately captures metrics such as technology used for manufacturing, On-time delivery, fulfillment of orders, product compliance, Development capabilities and innovation capabilities. Similar metrics might be grouped together in a cluster for future research. The TOPSIS process uses Euclidian distance to calculate the performance index of suppliers and hence determining the best supplier.

TOPSIS and AHP offer clear advantages as decision-making aids, such as pragmatism, conciseness, and systematism. As a result, the TOPSIS and AHP methods can be used to solve situations involving multi-objective decision-making. The proposed decision system can be used for quantitative sorting and rational selection of different models based on the two techniques, which is beneficial to the scientification and standardization of the decision-making. Supplier selection is a multicriteria problem that requires both qualitative and quantitative measures to be considered. The generated recommendation system aids the supply chain managers in deciding the better supplier in a standardized manner. The supply chain managers do not only have to rely on their expertise to decide the better supplier while supplier splits allocation.

As a future scope this project can be extended to increase the focus on supplier ratings and how the rating process is conducted. Machine leaning and data visualization tools like tableau can be used to present the recommendation system in the form a dashboard. This analysis can be extended to a greater number of parts and suppliers across quarters. These data points once extended to the historical data will play a key role in strategic decisions of the company.

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