

Effective Supplier Selection Using ANP

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Abstract

A supplier provides monetary benefits as well as non-monetary benefits for the organization, especially to maintain company reputation and customer satisfaction. Therefore, an effective supplier network is an important key success factor of the organization. There are many common drawbacks in the existing supplier selection processes which hinder the selection of effective supplier/suppliers. Therefore, the objective of this research is to develop a model and a mechanism to overcome these common drawbacks while predicting the validity of the model across a few industries. With the scope of this paper, supplier selection was considered as a multi-criteria decision making problem (MCDM) because supplier selection is the evaluation of trade-offs between multiple criteria. Analytic Network Process (ANP) which is a technique to solve MCDM problems in which the criteria affect each other and have nonlinear correlation, is used here to prioritize criteria and alternatives. Therefore, this model is flexible for selecting suppliers for any product/service across any organization, sector, and industry. The significance of the proposed model is its Flexibility across any industry with limitations and supports multiple criteria with any number of alternatives.

Keywords: General supplier selection model, Supplier selection process, ANP

1. Introduction

At present, with globalization, intensive competition is developed within the market. If any organization needs to survive in this competitive market, they should possess a competitive advantage over other companies. Effective supplier selection process/ effective suppliers are a major determinant of the degree of competitive advantage within an organization. Because at the basic level, enterprise competitiveness is characterized by the high quality and the low cost of the product/service provided by that organization and it depends on the quality and cost of products/services provided by suppliers. An effective supplier can be stated as an asset for the organization that provides monetary benefits as well as non-monetary benefits for the organization, especially to maintain company reputation and customer satisfaction. Therefore, an effective supplier network is an important key success factor of the organization.

There are several common drawbacks can be identified in the existing supplier selection processes which hinder the selection of effective supplier/suppliers. Not having a well-established systematic procedure for supplier selection process across any industry can be stated as the major drawback of the existing supplier selection process. Therefore, issues like subjective decisions, difficulties in quantifying qualitative criteria, and conflicts in group decision-making can arise. It is also a disadvantage from suppliers' perspective as a supplier cannot systematically align their processes because requirements and expectations differ from organization to organization. Not having a standardized set of criteria and sub-criteria and a systematic way to prioritize them can be stated as another significant drawback of the existing supplier selection processes.

In the past literature, most of the proposed models for supplier selection environmental, social & quality system factors are lesser considered. The scope of the selection criteria is limited to commercial and technical criteria and focuses on a case study of a particular organization and industry. There is no significant general supplier selection model across any organization, industry, or cooperate sector which can be subjected to continuous development with knowledge of industry experts and academia.

With the scope of this paper, supplier selection was considered as a multi-criteria decision-making problem (MCDM) because supplier selection is the evaluation of tradeoffs between inconsistent, contradictory, and competing criteria with each other. Analytic network process (ANP) is a technique to solve MCDM problems in which the criteria affect each other and have a nonlinear correlation. In this study, the goal is to use ANP to rank suppliers because it has the

capability of handling both quantitative and qualitative criteria, defining interdependencies among criteria, sub-criteria, and alternatives, and modeling the decision-making problems as a network, not as hierarchies.

1.1. Objectives

The objectives of this research are to study and identify the drawbacks of existing supplier selection processes, identify the most appropriate set of criteria and sub-criteria for a general supplier selection model, develop a general model to prioritize criteria, sub-criteria, and alternative suppliers which is flexible across any industry while predicting the validity of the model across few industries. The main objective of this research is to propose a general mechanism to minimize the inefficiencies of existing supplier selection process. The whole supplier selection process should be focused and studied identify the inefficiencies of existing supplier selection process of different organization.

2. Literature Review

The literature review carried out basically under seven related key aspects and they are the Supply Chain Management, Importance of effective supplier management, Different Methods used in the supplier selection process of an organization, Supplier selection process as a multi-criteria decision-making problem, Multi-Criteria Decision-Making process, Different criteria used for supplier selection and Analytic Network Process (ANP).

The integration of all activities from purchasing raw materials to deliver the final products to the customers can be termed as supply chain management of an organization (Digalwar, et. al., 2014). There are three decision levels in supply chain management, which are strategic, tactical, and operational. Supplier selection which is a long-term planning decision belongs to the strategic decision level of supply chain management of an organization (Onder and Kabadayi, 2015). Out of these, supplier selection can be stated as the most critical decision for an organization to achieve its competitive advantage. This strategic decision-making process involves the evaluation of tangible and intangible criteria to select the right suppliers with multiple objectives. The selection and evaluation process of suppliers of an organization is formed based on the organizational strategies (Onder and Kabadayi, 2015).

Most of the research publications related to supplier evaluation and selection emphasize the importance of a proper supplier selection mechanism for an organization. These factors can be listed as follows.

1. Cost, technology, market share, and quality will the competing factors for any globally competing company which is determined by selecting the most effective suppliers for that company. (Yilmaz et. al., 2011).
2. The suppliers can be considered as one of the most valuable intangible assets for an organization because the strategic relationship with suppliers will directly affect the supply chain performance of an organization (Onder and Kabadayi, 2015).
3. As the supplier selection process of an organization is a critical factor for its competitive advantage, its suppliers must align with the internal core competencies and capabilities of that organization (Jajimoggala and Rao, 2011).
4. The modern-day supplier relationship extends to strategic partnering, strategic alliances, outsourcing and relationship marketing. Therefore, the supplier selection process of an organization is comparatively complex (Galankashi et. al., 2015).

All the above factors pave the way to emphasize the necessity of a proper supplier evaluation mechanism for an organization.

Some of the research highlighted the common drawbacks of the existing supplier selection processes. Some of them are industry-specific while some of them are company-specific. But some of the issues are commonly visible in the whole supplier selection process. These common issues can be listed as follows.

1. Though there are many departments in an organization that should involve in the supplier selection process, most of the time it is contributed only by the procurement department(Su and Zhan, 2019).
2. On many occasions, procurement department personnel make decisions based on their subjective experience, intuition, and emotions without attending to a logical and scientific way of supplier selection(Su and Zhan, 2019).

The most common method used in most of the companies for its supplier selection is the categorical approach with the opinion of all related departments to the supplier selection process. The categorical method relies heavily on the experience and ability of the individual buyer. This method is quite simple, it is not supported by objective criteria, and rarely leads to performance improvements. The main drawback of this method is that the identified attributes are weighted equally, and the decisions made using this system tend to be fairly subjective (Digalwar, et. al., 2014).

Supplier selection decisions must be extended from considering strategic and operational factors as well as tangible and intangible factors in the analysis (Digalwar, et. al., 2014). Supplier selection is a process of tradeoffs between many contradictory and conflicting criteria between each other. It means that optimizing one criterion may cause some other ones to go far from optimization (SADEGHI et. al., 2012). Therefore, supplier selection of an organization can be considered as a Multi-criteria decision-making problem (MCDM) problem (Kaur et. al., 2015).

Steps of an MCDM problem can be summarized as criteria selection, determine available alternative options, selection of aggregation method, and finally ranking of alternatives while giving weights to the selection criteria. Among many MCDM problem-solving techniques, ANP is the most suitable technique that can be used for supplier selection as ANP allows us to model the problem in a network manner instead of hierarchy. (SADEGHI et. al., 2012). Also, ANP supports incorporating both qualitative and quantitative criteria while facilitating the quantification of qualitative criteria (Bayazit, 2006). The advantage of ANP is the capability of solving the problems in which alternatives and criteria have such interactions that cannot be shown in a hierarchy (Yilmaz et. al., 2011). That makes ANP more suitable to use as a technique in the supplier selection process.

The above chapter summarizes the findings from past literature to the current study. It highlights the importance of supply chain management to an organization to achieve a competitive advantage, how effective supplier selection contributes to effective supply chain management, different tools and techniques for supplier selection, why supplier selection can be considered as an MCDM problem, features and different techniques available to Solve MCDM problems and ANP as an effective technique to solve supplier selection as an MCDM problem, effectively.

3. Methods

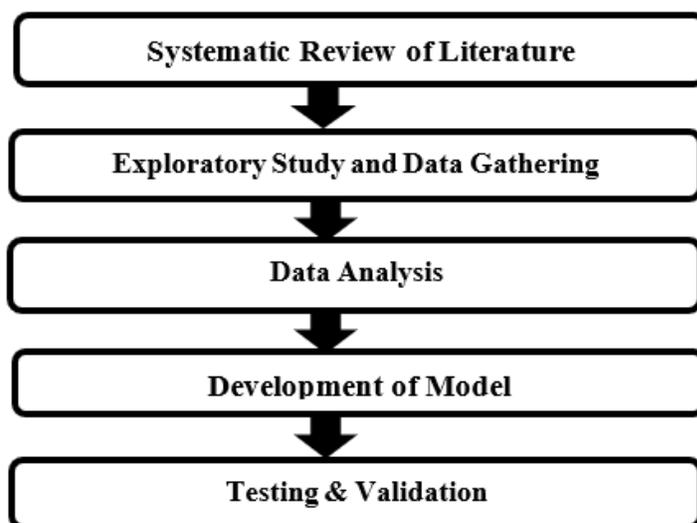


Figure 1 - The Methodology

The main objective study of this study is to determine a more efficient and accurate method to rank supplier selection criteria and rank available options/alternative suppliers based on these criteria integrating opinions from different decision-makers who are directly contributed/responsible for the supplier selection process of any organization. The traditional criteria for supplier selection include cost, quality, delivery, etc. but as this study focus on a broader scope

of criteria and sub-criteria, the Supplier selection process as a MCDM problem has been the main focus of this research.

The research design of this comprises of a methodology with well-organized five steps which are interconnected with each other.

The first step of the methodology was the systematic review of the literature. From that the different research approaches, limitations and gaps between the studies up-to-date vs the area of interest were identified. Then the criteria, sub-criteria, tools and techniques used for supplier selection in each study were analyzed systematically and identified the most appropriate criteria and sub-criteria for a general supplier selection model. Here supplier selection was decided to consider as MCDM problem because supplier relationship does not depend merely on financial aspects or price factor but many other important strategic and operational factors and final decision depends on the trade-offs among the conflicting multiple criteria which comprises both qualitative and quantitative factors. Here ANP was selected as the technique to proceed with the research because it has capabilities like handling both quantitative and qualitative criteria, defining interdependencies among criteria, sub-criteria and alternatives modeling the decision-making problems as a network not as hierarchies. So, interdependencies among criteria and sub-criteria in the supplier selection process can be modeled easily.

The second step was the exploratory study and data gathering. Here the existing supplier selection processes of diverse organizations were studied to identify drawbacks of the existing supplier selection process. Then Expert opinions on the supplier selection process and its criteria were gathered by conducting preliminary interviews with industry experts in each company. The tentative criteria list and tentative models were developed based on the expert opinions and literature review. Then an online survey and some structured interviews were conducted to finalize the most appropriate criteria and sub-criteria used for the ANP model. The questions of the online survey and structured interviews were prepared to identify priorities of criteria and sub-criteria to select supplier/s for a particular product in this company. Here they were asked to place each criterion and sub-criteria in a Likert Scale according to their opinion regarding the suppliers for a particular product.

The third phase of methodology was data analysis. Then data gathered from the survey and interviews were organized and analyzed systematically. Then those data converted into another format making them compatible to feed into the ANP model developed in Super Decision software.

The fourth phase of the methodology was the development of the model. Here the tentative model developed in the second phase was modified and finalized according to the results obtained in the third phase of the methodology.

In the fifth phase, the above-finalized model was tested with the past supplier selection cases of this company. Here data obtained through past supplier selection records were fed to the finalized ANP model and tested. Then those results were computed and compared with the actual results. With that comparison, the model was modified and validated to compatible it with a general supplier selection process of any company.

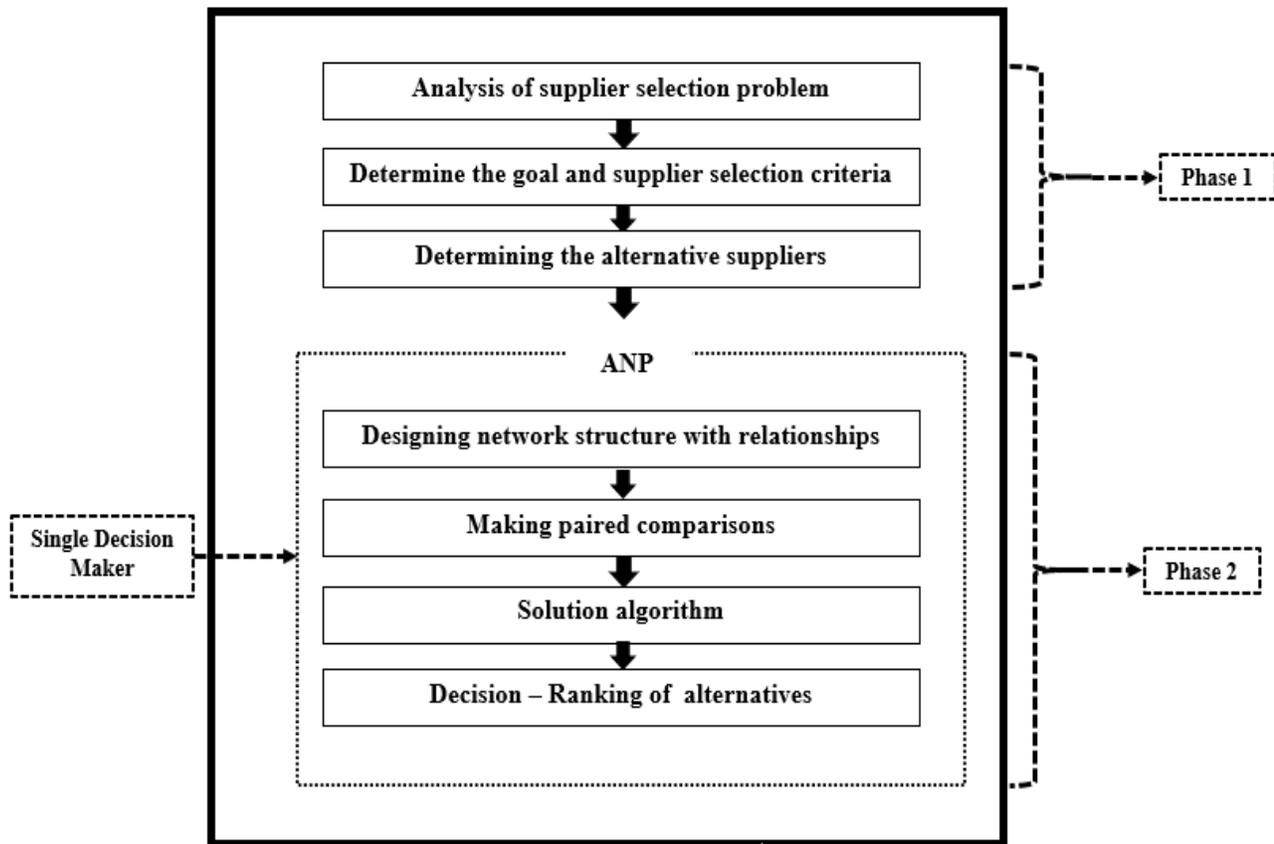


Figure 2. The proposed ANP model for supplier selection

4. Data Collection

Any profit-oriented company or non-profit oriented company which may be a Small scale, medium scale, or large scale can be taken for sampling frame as supplier selection is a mandatory process in any organization. But here in this, profit-oriented large-scale companies with diverse business processes are taken as the sampling frame because the supplier selection process is carried out more systematically in these companies. Also, it is convenient to obtain the most updated data and industry expert knowledge. Therefore, convenience sampling, which is a non-probability sampling method is used as the sampling technique in this study. The tentative criteria list with the sub-criteria for each criterion is identified from the literature review. Then it is further improved through experts' opinions from the industry so as to compatible it with the practical aspects of the supplier selection process. These were used as secondary data sources. One to one interview, an online survey, and a study on past records of the supplier selection process of selected organizations are carried out to finalize criteria and sub-criteria and to validate the proposed models. These were used as the sources of primary data

At the initial stage, criteria and sub-criteria used in each study were analyzed to identify the most appropriate criteria and sub-criteria for a supplier selection process. Then after a systematic filtering process, a tentative criteria list including sub-criteria for each criterion was prepared. The concept of triple bottom line i.e. Economical criteria, Environmental criteria, and social criteria was used as the basis for this criteria list. At the initial stage, there were eight criteria and 28 sub-criteria under that. Then preliminary interviews were conducted with industry experts to gain their opinion and modified the criteria list. Then based on that tentative criteria list, an online survey was conducted among the 3-resource people in a selected company. Here a chemical manufacturing company was selected as the sample company. This company was selected on the basis of convenient sampling and it was a company that can be

easily reachable and accessible to the authors of this research. This company is a quite large-scale manufacturing company where supplier selection process is intensively carried out. Also, some structured interviews were conducted to identify the criteria and sub-criteria priorities. These structured interviews are conducted with the same resource people in the same company selected to conduct the online survey. Then those data were organized and analyzed systematically. Here gathered data were converted into a compatible format to feed into the ANP model build in Super Decision software as shown in table 1. Then based on the results obtained through the ANP model, the finalized criteria list with sub-criteria was prepared. It consists of 7 main criteria and 18 sub-criteria as shown in figure 3

Table 1- Data sample obtained through an online survey

Criteria	Delivery Capability	Environmental Factors	Financial Factors	General Conditions	Production Capacity	Quality System Factors	Social Factors
Delivery Capability		6	1/3	5	2	4	7
Environmental Factors			1/8	1/3	1/5	1/3	2
Financial Factors				5	4	7	8
General Conditions					1/3	1/4	2
Production Capacity						4	6
Quality System Factors							2
Social Factors							

Here in the table 1, it shows one sample of data collection through structured interviews to determine the priority weightages for each criterion for the supplier selection process of the selected company

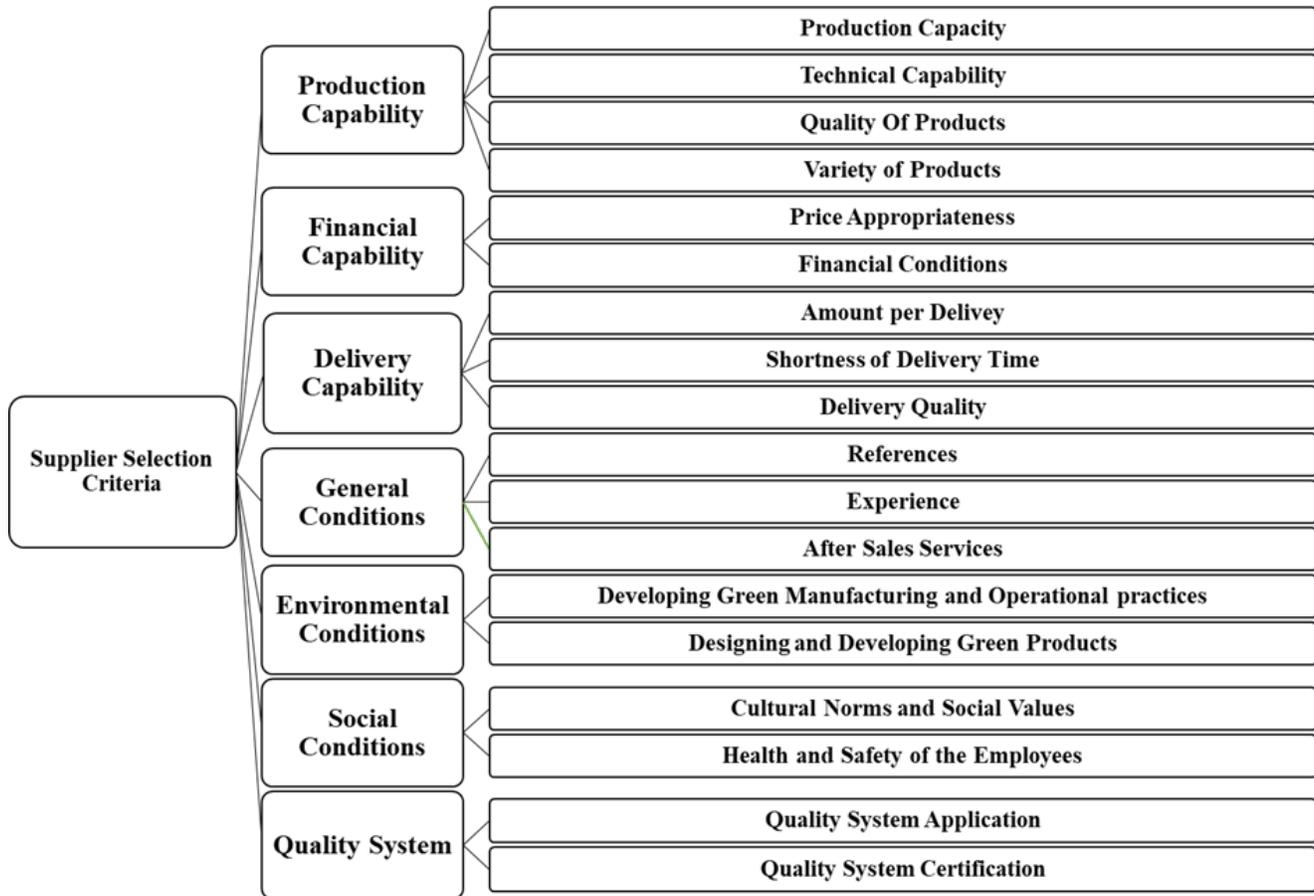


Figure 3 - The Finalized set of criteria and sub-criteria

5. Results and Discussion

5.1 Numerical Results

The following tables represent the final results of the survey data processed and simulated through the proposed ANP model.

Table 2- The prioritization weightages for criteria

Criteria	Priority
Financial Capability	0.410
Delivery Capability	0.225

Production Capability	0.162
Quality System Factors	0.086
General Condition	0.055
Environmental Factors	0.034
Social Factors	0.028

Table 3 - The prioritization weightages for sub-criteria within each criterion

Criteria	Criteria Weight	Sub-Criteria	Sub-Criteria Weight	Final Weight	Rank
Delivery Capability	0.225	Delivery Quality	0.637	0.143	2
		Shortness of Delivery Time	0.258	0.058	6
		Amount per Delivery	0.105	0.024	9
Environmental Factors	0.034	Designing and Development	0.667	0.023	10
		Adopting to Green Man.	0.333	0.011	15
Financial Capability	0.41	Price Appropriateness	0.8	0.328	1
		Financial Conditions	0.2	0.082	4
General Condition	0.055	After Sales Services	0.4	0.022	11
		References	0.4	0.022	11
		Experience	0.2	0.011	16
Production Capability	0.162	Quality of Products	0.549	0.089	3
		Production Capacity	0.239	0.039	7
		Technical Capability	0.147	0.024	8
		Variety of Products	0.065	0.011	17
Quality System Factors	0.086	Quality System Certification	0.8	0.069	5
		Quality System Application	0.2	0.017	14
Social Factors	0.028	Health and Safety of the Employees	0.667	0.019	13
		Cultural Norms and Social Values	0.333	0.009	18

Table 4 – Final selection of suppliers

Criteria	Sub-Criteria	Final Weight	Pairwise Comparisons			Final Value		
			Supplier 1	Supplier 2	Supplier 3	Supplier 1	Supplier 2	Supplier 3
Delivery Capability	Delivery Quality	0.143	0.297	0.540	0.163	0.043	0.077	0.023
	Shortness of Delivery Time	0.058	0.280	0.627	0.094	0.016	0.036	0.005
	Amount per Delivery	0.024	0.208	0.661	0.131	0.005	0.016	0.003

Environmental Factors	Designing and Development	0.023	0.163	0.540	0.297	0.004	0.012	0.007
	Adopting to Green Man.	0.011	0.122	0.558	0.320	0.001	0.006	0.004
Financial Capability	Price Appropriateness	0.328	0.163	0.540	0.297	0.054	0.177	0.097
	Financial Conditions	0.082	0.117	0.614	0.268	0.010	0.050	0.022
General Conditions	After Sales Services	0.022	0.263	0.190	0.547	0.006	0.004	0.012
	References	0.022	0.230	0.122	0.648	0.005	0.003	0.014
	Experience	0.011	0.540	0.297	0.163	0.006	0.003	0.002
Production Capability	Quality of Products	0.089	0.540	0.297	0.163	0.048	0.026	0.015
	Production Capacity	0.039	0.163	0.297	0.540	0.006	0.011	0.021
	Technical Capability	0.024	0.163	0.297	0.540	0.004	0.007	0.013
	Variety of Products	0.011	0.122	0.558	0.320	0.001	0.006	0.003
Quality System	Quality System Certification	0.069	0.540	0.163	0.297	0.037	0.011	0.020
	Quality System Application	0.017	0.637	0.105	0.258	0.011	0.002	0.004
Social Factors	Health and Safety of the Employees	0.019	0.625	0.136	0.238	0.012	0.003	0.004
	Cultural Norms and Social Values	0.009	0.637	0.105	0.258	0.006	0.001	0.002
						0.274	0.453	0.273

The final results of the survey show that the most important criteria that should consider when selecting suppliers for the selected product in this chemical manufacturing company are financial capability, delivery capability and production capability of the suppliers which gained priority weightages of 0.41, 0.225 and 0.162 respectively through ANP model. As this is a large-scale chemical manufacturing company, these three capabilities can be considered as the most important factors that should be considered when it comes to the supplier selection process of this organization. According to the results, it can be concluded that Quality system factors, general conditions, environmental factors, and social factors of the supplier gained relatively low priority weightages. When analyzing the priority weightages for sub-criteria price appropriateness of the supplier is the most important criteria for them. Delivery quality, product quality are some of the other important factors in this company. In the current supplier selection process in this company, they consider only factors like the quality and price of the product and the punctuality of suppliers. But this limited set of criteria lead to choosing ineffective suppliers. This result of this study shows the scope and the importance of criteria and sub-criteria that should be used for supplier selection in this company. Also, if using the same ANP model to prioritize important factors for another organization, it may be different priority values according to their requirements. Also, these priority values may change with the external factors which can influence the company operations like, government rules and regulations and environmental and social factors that are influencing the company according to the demographic factors of that company.

The table 4 shows the results for a one supplier selection case of the selected company where this model is tested with. In here the second supplier who has obtained the highest final value (0.453) is the most suitable supplier for this particular supplier selection case.

5.2 Validation

As the first step of validating the model, few past records of supplier selection processes from each company were taken and studied. Then the same cases have proceeded through proposed models. Here the ANP model is built in

Super Decision software. Then the results obtained through the model were compared and contrasted with the results of the past records of each case. Then the proposed model was validated and verified using obtained results along with the guidance of a few resource persons from the company.

5. Conclusion

As an effective supplier pool is a key success factor of an organization that can highly contribute to gain competitive advantage, the supplier selection process should be systematically considered. For this reason, supplier selection is evaluated by researchers for many years in a large framework consisting of various techniques from the experimental to the analytical ones, and its successful applications were performed in numerous sectors. The main intention of this study was to propose a systematic procedure along with a general supplier selection model that is capable of addressing existing problems in the current supplier selection process like the subjectivity of decisions, difficulty in quantifying qualitative criteria. The proposed model is tested and validated through a case in a chemical manufacturing company.

In this paper, supplier selection was considered as a multi-criteria decision problem and a model is proposed by using ANP. Therefore, this model is flexible for selecting suppliers for any product/service across any organization, sector, and industry. The significance of the proposed model is its Flexibility across any industry with limitations and supports multiple criteria with any number of alternatives. But this model will be more appropriate for large-scale manufacturing companies who are mainly focusing on exports, procuring products than services, procuring products use as the raw materials in the manufacturing process. Also, a general model with the same set of prioritized criteria cannot be applied across all industries. Also, industry-wise prioritizations not exactly similar but can relate to the general model with a few modifications and assumptions. Also, the data gathered from experts' opinions show that this model also can be used in post supplier evaluation processes of the same organizations.

Though there are many researches carried out using ANP for supplier selection, all of those are restricted to particular company, industry or a certain demographic area. But this research suggests a general mechanism that can be used for any supplier selection process of an organization in despite of the size, profit orientation or type of the organization (manufacturing or service).

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