Supplier Selection Model in Canadian Automotive Aftermarket Business

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ABSTRACT

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Supplier selection is one of the strategic issues that companies face, and it has a significant impact on their financials, reputation, and performance. This decision is such big that its influence may remain for years. It is not easy for big companies with vast product lines to frequently switch from one supplier to another. The contracts are such detailed and have different aspects that make changing a supplier rapidly impossible. In addition, the process of changing a supplier is cumbersome and costly. All these, make this decision vital and unbelievably sensitive, and essential for the vast companies.

The automotive industry's supply chains are considered as one the most complicated chains among different sectors. Although there are common aspects in automotive industries and other businesses, the nature of this industry and its associated businesses can be distinct in many ways, making this industry an exciting topic of research. These characteristics could show the importance of the automotive industry in general and spare parts aftermarket in particular—these characteristics of the automotive industry vary in different regions and under different circumstances. Therefore, we face unalike situations and conditions in different countries. The market behavior and features are different. Thus, the managers' needs and attitudes would be different as well.

Therefore, I decided to conduct this research on the Canadian automotive aftermarket business to understand the needs and attitudes of the executives and customers of a considerable proportion of this market. I create three different supplier selection models based on the requirements of this market. The applied methods are AHP, fuzzy-AHP, and TOPSIS to select the final supplier out of three alternatives. Eventually, I compared the results and provided suggestions for the executives.

To gather data on the weights of criteria, I executed two surveys with two different targeted participants. Also, a group of experts formed the decision-making committee for alternatives pairwise comparison. Service was determined as the most critical criterion following by the product criterion. The selected alternative has highly qualified products, very competitive pricing, and more flexibility than its competitors. Analyzing the model's results, I provided suggestions for the selected alternative to increase the score difference with other alternatives and become a more suitable selected supplier.

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1 Introduction

Nowadays, business is complex and competitive worldwide. Hundreds of thousands of companies are actively competing to increase their market share. Supply chain management plays a crucial role in this competition. A sound supply chain management can contribute significantly to the efficiency and competitiveness of any organization. Supply chain management is not only limited to manufacturers, but many distributors and service providers can benefit from it (Stank et al., 2016). However, there are significant problems embedded in managing a supply chain, especially in large networks.

Supply chain management needs cross-functional integration. Different departments within an organization are involved. Marketing, product, and/or customer service departments should be integrated within a firm's supply chain (Armistead and Mapes, 1993). According to Lambert and Cooper (2000), the information flow in a functionally sound supply chain operating network is crucial, convoluted, and gigantic. Customer relationships, service, demand, orders, and other practices are involved in a supply chain. As shown in figure 1-1, all aforementioned practices have a supplier or service provider for themselves. For instance, a CRM software company is needed for the customer service department, or an ERP software provider should be hired for monitoring demand, sales, and inventory. An advertisement company can help the marketing team or product development section, and last but not least, the principal supplier(s), which is pivotal for the company's primary operation, should be selected from various alternatives. All these stakeholders have various key roles which they should execute flawlessly. Any bottleneck in any stage shown in figure 1-1 can cause significant disruptions, evidencing all members' importance within a supply network. Thus, we can conclude that selecting an external supplier and service provider is crucial for any organization.

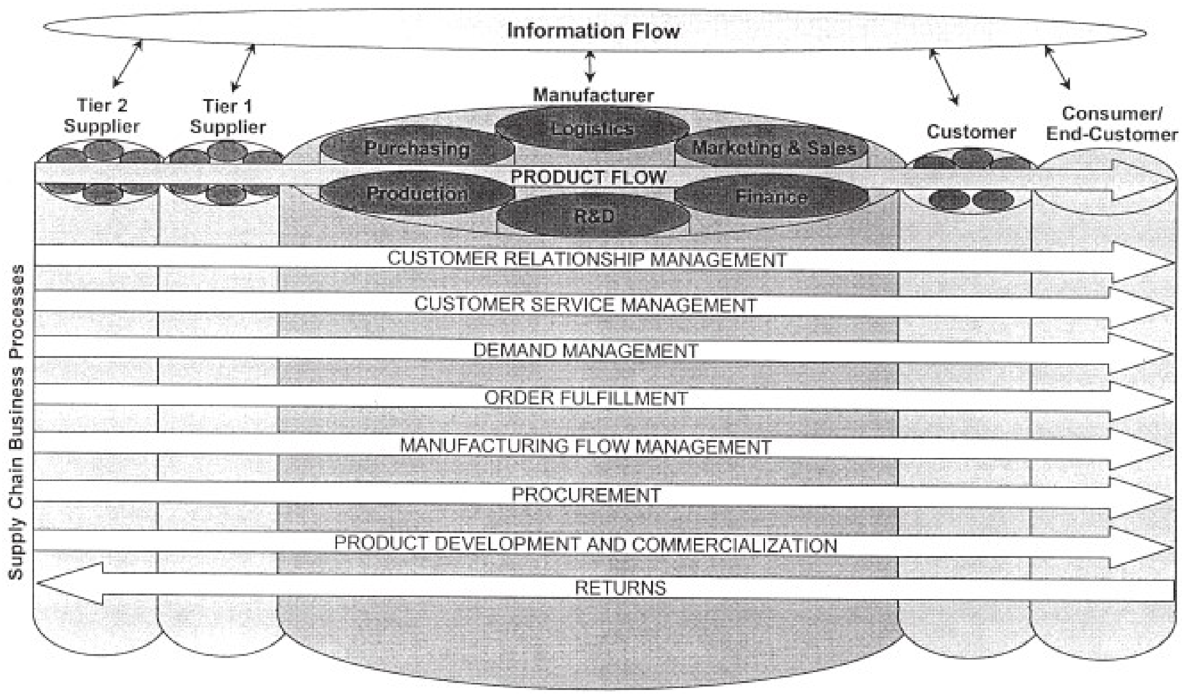


Figure 1-1 Information and operation flow (Lambert and Cooper,2000)

Among different measures in managing a supply chain, supplier selection is considered one of the strategic ones that companies face as it has a significant impact on their financials, reputation, and performance (Dweiri et al., 2016). Making this decision is so crucial that its influence will last for years. Monitoring and supervising current suppliers' performance is a complex task requiring cross-sectoral involvement of different departments within a company. This is even more complicated for large corporations with extensive product lines with thousands or millions of items and products. Let alone changing a supplier that is operationally and bureaucratically a nuisance (Gosling et al., 2010).

On the one hand, contracts have many details and different aspects, making it almost impossible to switch from one supplier to another quickly. On the other hand, the process of changing a supplier is taxing and costly. These factors show us that selecting a new supplier can be unbelievably sensitive and vital, especially for companies with a large supply chain.

Not only business figures but also academic researchers put this topic under the spotlight. According to Siguaw and Simpson (2004), various factors exist based on which a supplier should be evaluated and eventually selected. They suggest that researchers can consider up to 84 criteria to evaluate suppliers. They also mention that these criteria carry varying weights in different industries. Their findings show the complexity and importance of this topic in supply chain management, which can differ from industry to industry.

Supplier selection is a topic in the broad spectrum of a multi-criterion decision-making process (MCDM). MCDM is a sought-after topic in management science, and many pieces of research have focused on this topic. Various methods have been evolved and shaped for best practices in this domain. The analytical hierarchy process (AHP), created and evolved by Thomas Saaty in the late 1980s, is among the most popular and utilized ones. Since then, many other methods were created by combining different methods or extending AHP, such as Fuzzy-AHP, Analytic Network Process (ANP), ELECTRE, and TOPSIS, to name a few. Aruldoss et al. (2013) researched which methods are more popular among both business and academic entities in MCDM. The top three in their ranking are AHP, Fuzzy-AHP, and TOPSIS. Their finding is aligned with that of many other studies, such as that of Jain et al. (2018). Therefore, I decided to use three methods in this project to evaluate suppliers: AHP, Fuzzy-AHP, and TOPSIS. Using these three methods and comparing the result in the automotive industry is not an issue that has been addressed before in the literature.

A comprehensive description of each method will be provided in the literature review and methodology sections.

In this project, I confine the supplier selection process to supplier selection in the aftermarket automotive parts industry. Much research has been conducted in the automotive industry's supply chains. According to Dyer and Chu (2003), the automotive industry's supply chains are considered one of the most complicated networks among different industries. Although there are common issues in the automotive industry and other businesses, the nature of this industry and its associated businesses can be distinct in many aspects, making it an exciting point of research.

A car has about a million parts supplied to car manufacturers and parts distributors to satisfy the consumers' demands. According to the IBISWorld 2021 report, the automotive aftermarket and spare parts business is the sixth-biggest business worldwide, let alone the car industry, the fourth-biggest industry worldwide. The global auto parts and accessories manufacturing and distribution represent more than $384 billion in the world business (IBISWorld, 2021). Many of the suppliers in this industry have business ties with both the large car manufacturers and aftermarket distributors. Interestingly in many cases, automotive spare parts aftermarket is a more money-making business and has more potentials than the new car market, which shows the importance of the automotive industry in general and spare parts aftermarket in particular (Depner and Bathelt, 2005).

The automotive industry is one of the points of interest for researchers and academia, and supplier selection plays a significant role in this business. On the one hand, the supply network of the automotive industry is one of the most complex chains among different businesses (Dyer and Chu, 2003). On the other hand, the supply chain in this industry is incredibly vast. For example, Toyota has the largest distribution network worldwide, and the most extensive section of this network is related to automotive spare parts either for the original use in the production line or for the aftermarket business (Depner and Bethalt, 2005).

Considering the importance and attractiveness of the automotive spare parts industry, I decided to research this industry. The targeted market of this project is the North American automotive aftermarket business. There is some other research conducted in different countries such as India or Turkey. Nevertheless, the North American automotive aftermarket business is relatively overlooked. This large industry is constantly growing as more cars are ready to go to the market. As the average age of on-road vehicles is increasing, requiring regular maintenance. The market size only in the U.S. was more than $75 billion in 2018 and is forecasted to reach more than $86 billion by 2025 (Grand View Research, 2019). I asked a leading retailer and wholesaler in automotive replacement parts in this market to engage in this project. We will call this leading retailer "The Company."

Fortunately, when I asked the company to participate in this project, they dealt with a challenging decision-making process for selecting a supplier out of three for a specific product line. It was an exciting process as one of these suppliers was already the current supplier of this category, and two others were competitors. The company wanted to re-evaluate the current supplier and make a comparison among these three firms.

We decided to make a supplier selection model using the methods mentioned above. By using these methods and comparing the results, the company will be able to make a sound judgment about the performance of these suppliers and make the final decision.

This project was done using real-world business data. Although there is much research on supplier selection for the automotive industry, we have not seen any study conducted in North America, in general, and in the Canadian market, in particular. In this project, we have three alternatives, one of which should be selected as the ultimate supplier. We created three decision-making models and conducted two surveys with different groups of participants. A group of leaders and experts in the Canadian automotive aftermarket business contributed to this project by participating as members of the decision-making committee. More than twenty criteria and sub-criteria were identified and defined, and extensive analyses were conducted. Service was determined as the most critical criterion following by the product criterion. The selected alternative, among three alternatives, has highly qualified products with competitive pricing and flexibility.

This project has the following sections to address the issue in the best possible way and elaborate on the taken measures:

- Chapter 2: Literature review and methodology
- Chapter 3: The Model
- Chapter 4: Data Collection and analysis
- Chapter 5: Conclusion
- APPENDIX: Calculations and survey questionnaire

2 Literature Review

2.1 The Importance of the Supplier Selection

Evolving and progressing global trade and business has made supply chain management (SCM) one of the key concepts in management and business. The business growth leads to numerous companies, and many must compete for gaining more market share. One of the results of this severe competition is the necessity of cutting expenses and enhancing companies' operations. Firms from first-tier manufacturers to distributors are taking more interest in enhancing their supply chain. For these reasons, SCM is considered a combination of tools to reduce supply chain risks and reduce production and distribution costs. Also, SCM helps firms improve their revenue, customer service, and inventory planning. The basis of all practices mentioned above for an enhanced supply chain is a practical purchasing function (Boran et al., 2009).

As a result of globalization and increasing competition, purchasing function is of primary importance in SCM. According to Ayhan (2013), purchasing function is essential for any organization, including manufacturers and distributors. He claims that manufacturers spend more than 60% of their total turnover on purchasing. Also, costs of purchasing goods and services consist 70% of the product cost. The vital step for having a sound purchasing function is selecting an appropriate supplier (Haq and Kannan, 2006). The supplier selection itself includes many steps. Reinecke et al. (2007) describe supplier selection as a process consisting of identifying the alternatives, evaluating each of them based on suitability to the firm's supply chain, and eventually preparing and signing the contracts and taking the legal measures. As can be seen, these activities make the supplier selection topic very complex and exciting for both academics and practitioners. Many academics see the supplier selection process as a multi-criteria decision-making process. Dickson (1966) and Weber et al. (1991) were pioneers who brought up this topic and categorized it into decision-making science. Weber et al. (1991) maintained that 60% of the supplier selection models reviewed by them had more than one criterion, which gives enough reason to categorize supplier selection as a multi-criteria decision-making problem (MCDM).

2.2 Multi-Criteria Decision Making Problem

Multiple-criterion decision-making (MCDM) is a branch of operations research getting constant attention from academia and practitioners. MCDM methods use mathematical and computational tools to evaluate the available decision alternatives under several defined performance criteria. Although these methods work more accurately with numerous decision-makers, even an individual decision-maker still can benefit from utilizing these models (Lootsma, 2007).

In the spectrum of sciences and knowledge that MCDM uses, many fields exist. Mathematics, psychology, economics, finance, management, coding and software development, and information systems. Although it has been many decades since this topic received more attention, there are still significant opportunities for more research (Roy, 2005).

Many methods and approaches have been developed for the MCDM problem, and many scholars focused explicitly on it. Saaty (1980, 1985) argues that we live in a very complex world, and our problems are as complex as the environment in which we live. Therefore, decision-makers at any level face various factors and criteria, and it is imperative to understand which elements we should emphasize and what their relative importance is. Aruldoss et al. (2013) conducted interesting research about different methods used for the MCDM problem and their popularity. They concluded that three methods are more popular among researchers and practitioners AHP, Fuzzy-AHP, and TOPSIS. Many scholars worked on MCDM, and they managed to develop different analytical methods in this field.

2.2.1 AHP

Saaty, an academician, focused on MCDM problem-solving methods. In his researches, Saaty initiated and developed one of the most popular methods for decision-making with complex and various criteria. His method, Analytical Hierarchy Process (AHP), has been used in various fields. From politics to project management, we can find academia and practitioners using this method for making better decisions in a complex environment. Saaty (1985) named some complex and significant decisions whose decision-makers used AHP in practice for making and finalizing their decision. For instance, in his book, he made a model to address the Northern Ireland conflict using AHP.

After Saaty, many scholars and practitioners used this method in different fields. Kamal and Al-Harbi (2001) used AHP to select the appropriate contractor for a project in the oil industry. They had six criteria and five alternatives, making it an exact MCDM problem. Ahmad and LaPlante (2006) created a selection model based on AHP for selecting the software for their project. In their paper, they defined twelve criteria for selecting the ultimate candidate out of five alternatives. Gaudenzi and Borghesi (2006) used AHP to help supply chain managers prioritize risks within their supply network. They defined four risks in a supply chain at five different levels: procurement, warehousing, order cycle, manufacturing, and distribution. By using AHP, they managed to prioritize the risks in each level of the supply chain. Al-Khalil (2002) used AHP to identify the appropriate project delivery method. He constructed a complex AHP model with three main criteria and twenty-four sub-criteria with three alternatives.

2.2.2 Fuzzy-AHP

Saaty was not the only researcher who worked on and developed AHP. During that time, many other people worked on it and combined it with other problem-solving methods. One of the most popular combinations is the combination of the AHP and Fuzzy problem-solving method. Kacprzyk (1983) maintains that environments in which human beings try to make decisions are full of uncertainties and lack of information. Hence, we should use non-absolute methods to focus on a range rather than an absolute result in our decision-making processes. In this matter, the fuzzy method allows us to solve problems with a range of numbers and data, which is very beneficial for decision-making problems.

Van Laarhoven and Perdrycg (1983) were the first academics who combined fuzzy triangular numbers with Saaty's AHP ranking method. This initiation captured the attention of many other researchers to work on this concept. Ayağ and Özdemir (2006) believed that AHP alone is insufficient for a sound decision-making judgment. Furthermore, we need a more rational method combined with AHP to help decision-makers have their best judgment. Their research suggested that fuzzy number logic is the best method for AHP to obtain accurate results. Aruldoss et al. (2013) maintain that fuzziness occurs in many studies and decision-making processes while various available alternatives exist. Multiple quantitative and qualitative factors must be considered for any MCDM problem under very unclear and uncertain situations. Therefore, a combination of AHP and fuzzy problem-solving methods can be beneficial to mitigate the risks embedded in a decision-making process.

After Van Laarhoven and Perdrycg (1983), Ruoning and Xiaoyan (1992) used a different formulation for "fuzzification" of the AHP method. Although their method was slightly different from Van Laarhoven and Perdrycg (1983), the results were aligned. These newly designed methods were rather complex in mathematical calculations. Chang (1996) developed another fuzzy-AHP method which interestingly became very popular among other researchers. His paper has been cited more than 4700 times since its publication. He incorporated AHP comparison principles into fuzzy numbers such that the calculations are less complicated.

Fuzzy-AHP became very popular among academics and experts, and they used it in various fields of MCDM. Pan (2008) used the fuzzy-AHP approach for selecting the suitable construction method in a bridge construction project. In his research, he defined five criteria, namely, quality, cost, safety, duration, and shape. The author also defined eleven sub-criteria affecting the final score. In the end, he managed to choose the best construction method out of three alternatives. He maintained that using the fuzzy-AHP method for this MCDM problem led to significant savings in time and expenses.

Mangla et al. (2015) used fuzzy-AHP to analyze the risks associated with a green supply chain. Having reviewed the literature and interviews experts, they defined six potential risks within a green supply chain: operational risks, supply risks, product recovery risks, financial risks, demand risks, and governmental-related risks. Eventually, using fuzzy-AHP, the authors suggested that operational and financial risks are the most critical ones that should be addressed in a green supply chain.

In their exciting research, which was also used in practice, Lien and Chan (2007) created a model to select the best ERP system by applying the fuzzy-AHP method. They defined 32 criteria in product and managerial aspects. They used their model in semiconductor industry and education industry. Interestingly, the experts of each mentioned industry had different attitudes towards the importance of the criteria, and consequently, the results were different. Fuzzy-AHP was able to address the problems efficiently, and eventually, the results were promising and valuable.

Shaverdi et al. (2014) used fuzzy-AHP for assigning the importance of five criteria to evaluate the financial performance of the companies in the petrochemical sector. Their criteria include liquidity ratios, financial leverage ratios, activity ratios, profitability ratios, and growth ratios. They further defined 17 sub-criteria. Eventually, they used their model for ranking seven different petrochemical companies regarding their financial performance. The purpose of their study was to identify the best alternative for investing among those companies.

2.2.3 TOPSIS

AHP and fuzzy-AHP have been used in a comprehensive spectrum of sectors, industries, and businesses. However, these are not the only methods to solve MCDM problems. Aruldoss et al. (2013) identified nine different approaches and methods to solve an MCDM problem. In addition to AHP and fuzzy-AHP, Analytic Network Process (ANP), Data envelopment analysis (DAE), Aggregated Indices Randomization method (AIRM), Weighted Product model (WPM), weighted Sum Model (WSM), Goal Programming, ELECTRE, and Grey analysis. Goal programming also consists of different approaches, among which the most popular is TOPSIS.

Aruldoss et al. (2013) conducted an extensive study on different MCDM methods in different fields. They concluded that fuzzy-AHP and TOPSIS are the most used and popular methods in different researches and projects. Unlike AHP and fuzzy-AHP, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is not based on the pairwise comparison. In TOPSIS, we assume that each criterion intends to increase or decrease its associated utility in a monotone way. This assumption lets us define the positive and negative ideal solution (Nikoomaram et al., 2009). TOPSIS has also been used for various studies, researches, and projects for the MCDM problem. Hwang and Yoon (1981) designed TOPSIS for the first time. They proposed this method to select the best alternative among a finite number of criteria. Since then, this method has always been one of the points of interest among researchers working on MCDM problems.

Real-world projects and research in academia applied TOPSIS, just like AHP and Fuzzy-AHP, to solve MCDM problems. Behzadian et al. (2012) identified those fields in which TOPSIS was widely used to solve any MCDM problems as supply chain management and logistics, manufacturing systems, business and marketing management, human resources management, energy management, chemical engineering, and water resources management.

As noted earlier, various studies have used TOPSIS. Also, some researchers developed the initial method proposed by Hwang and Yoon (1981). Some extensions of TOPSIS like Fuzzy-TOPSIS or Intuitionistic-TOPSIS were also developed based on the initial model. Torlak et al. (2011) used Fuzzy-TOPSIS to rank the domestic airlines in Turkey. They defined nine criteria: advertising, quality, competitiveness, customer loyalty, market share, customer service, e-commerce, management, and branding. Their model analyzed four airlines, and eventually, Turkish Airlines became the best airline in Turkey.

TOPSIS is also an appropriate method for solving today's problems and decision-making processes. Tzeng and Huang (2011) used TOPSIS to identify the most efficient urban bus engine in urban public transportation. Their model is sought-after these days. The proposed criteria for their model were energy supply, energy efficiency, air pollution, noise pollution, industrial relationship, employment cost, maintenance cost, vehicle capability, road facility, speed of traffic flow, and sense of comfort. They also had various alternatives: Diesel bus, CNG bus, LPG bus, Hydrogen engine, Methanol engine, Electrical with direct charging, Electrical with battery, Hybrid-Gas, Hybrid-Diesel, Hybrid-CNG, and Hybrid-LPG. According to their model created base on TOPSIS, the best alternative is an electric bus with an exchangeable battery, and the better alternative is an electric bus with direct charging.

Alimoradi et al. (2011) used a hybrid method using TOPSIS and AHP to find the appropriate location for a remanufacturing facility. They defined four criteria for the designated location: proximity to manufacturers, equipment and tools availability, closeness to customers for returned cores, and proper logistics infrastructure. In their problem, they had four alternatives for the location of the remanufacturing facility. Using TOPSIS, they selected the alternative with the highest score in logistics infrastructure and closeness to the manufacturer's criteria. In a similar problem, Yong (2006) used Fuzzy-TOPSIS to select the best plant location based on such criteria as available skilled workers, expansion possibility, availability of acquirement material, and investment cost. He had three alternatives, and the final selection was the location with the lowest-needed investment.

Yang et al. (2011) used TOPSIS to select the appropriate vessel for a particular cargo transfer in voyage chartering. Their model is dynamic and practical for different cargos and routes. They identified twenty-four specialized and specific criteria for vessel industry, such as a breath of vessel or double bottom plating. Moreover, they incorporated other financial and environmental criteria such as water-polluting, staff and salaries need, maintenance cost, and engine reliability. In their problem, they have five different vessels as alternatives. The selected alternative was the vessel with less pollution and maintenance cost than other alternatives.

2.3 Supplier Selection; an MCDM Problem

Supplier selection is one of the most critical practices for managing any supply chain. It has a significant impact on organizations in various aspects. New supplier selection or deciding to continue the business with the current supplier has long-lasting financial effects. This decision will also influence the reputation of the companies. MCDM methods were among the most frequently used approaches in evaluating and selecting the suppliers (Memari et al., 2019).

Nowadays, executives and decision-makers in firms and companies should address multiple problems and satisfy various requirements while selecting a new supplier or contractor. This challenging process requires a systematic approach that aims to reduce expenses, decrease lead time, and shortens the required time for the whole operation. On the other hand, companies must mitigate the risks, improve their products or services, and other related issues. These challenges define a company's criteria. Additionally, the resources are always limited, and we need to make the most out of the available resources. Once we look at all these challenges, criteria, and restrictions to select and evaluate a supplier or contractor, we can conclude that supplier selection is indeed a multi-criteria decision-making problem (Stevic et al., 2016).

Researchers and academics who worked on supplier selection modeling used AHP, Fuzzy-AHP, and TOPSIS methods the most as other studies on MCDM do in different fields. Kilincci and Onal (2011) used the fuzzy-AHP approach to select suppliers in a washing machine company. Their model was relatively complex. They defined three main criteria and fourteen sub-criteria to select one supplier out of three alternatives. The main criteria represent the supplier's capability and include financial status, management, technical ability, quality systems, geographical location, production capacity, and working with desired IT systems. The second main criterion was product performance and consisted of three sub-criteria: price, handling, and quality. The third main criterion was service performance and included easiness in follow-ups, lead time, technical support, and professionalism as sub-criteria. They asked the executives of this washing machine company to put weights on the criteria using the pairwise comparison method in AHP. The main essential criterion was the product performance followed by supplier characteristics and service performance, respectively. The selected supplier had the best price and quality even though its lead time and geographical location were not the best compared to other alternatives.

Kumar et al. (2018) applied the TOPSIS method to select suppliers for steel manufacturing companies. Their model defined only one level of main criteria: cost, delivery time, quality, performance, and reputation. There were four alternatives, and interestingly, the ultimately selected supplier did not weigh highest on every single criterion. Although the selected supplier neither had the best price nor the best quality, it was selected by the model as it was the best alternative once the decision-makers consider all the criteria. The beauty of creating a supplier selection model is that it helps mitigate the risks and take the best measures in very complicated and uncertain environments.

Kahraman et al. (2003) used fuzzy-AHP to select a supplier for a European white goods company for their new model of aspirators. They also categorized the criteria as supplier, product, and service. They also defined eleven sub-criteria that targeted a wide range of characteristics and capabilities of the suppliers, from the financial capability to product handling and quality. This model was different from several similar models because the researchers excluded the cost from their model and primarily focused on the supplier qualifications, product quality, and service performance. They assigned weights to the criteria using fuzzy-AHP, and the most important category was supplier performance, followed by product performance and service. The most critical sub-criterion was financial capability. Although the selected supplier did not have the best score in financial capability, it earned the best score in management, product quality, and service performance. Thus, the model selected this supplier and gave it the best score compared to the other two alternatives. Once again, this model shows that we cannot rely on only one criterion, which we consider the most important one to select and evaluate suppliers.

Not all the researchers categorized the criteria as Kahraman et al. (2003) or Kilincci and Onal (2011) did. Lee et al. (2009) created a supplier selection model for an LCD manufacturer. Their point of focus was environmental sustainability and green supply network. They defined six main criteria and twenty-three sub-criteria to select the ultimate supplier out of three alternatives. The main criteria were quality, technology capability, pollution control, environmental management, green product, and green competencies. The sub-criteria focused mainly on environmental and technical aspects associated with the LCD manufacturing industry. They used AHP and fuzzy-AHP to prioritize the criteria and compared the alternatives. Quality was the most important criterion, followed by technology capability and green products.

Stevic et al. (2016) used fuzzy-AHP and TOPSIS to identify the least preferred supplier for a manufacturer. In the supply network of this company, five active suppliers were supplying the pipes needed in the production line. The company intended to decrease the number of suppliers to four. Therefore, unlike other research identifying the best alternative, the researchers needed to identify the weakest supplier in this study. Stevic and his colleagues defined six criteria: price, pipe length, delivery time, payment method, mode of delivery, and quality. The most important criteria were delivery time and quality. The selected supplier for exclusion from the supply network was identified. The difference between this supplier and the other alternatives was significant, helping the decision-makers decide more safely.

2.3.1 Supplier Selection in Automotive Industry

The automotive industry has always been an impressive field for researchers working on supplier selection models. The complexity and uncertainty in this business, on the one hand, and the different criteria in different regions and countries as well as different levels in the supply chain on the other, make the supplier selection a sought-after topic in the automotive business.

Dweiri et al. (2016) used AHP to create a supplier evaluation model for an automotive company in Pakistan. The authors defined four main criteria with twelve sub-criteria. The four main criteria were price, quality, delivery, and service. Price consists of unit price, free transportation, and discounts. Quality had quality management system (QMS), compatibility, and rejection rate as the sub-criteria. Lead time, error, and on-time delivery are the sub-criteria under the main criterion of delivery. Service also consisted of orders update, warranty, and geographical location.

Having asked the company executives to compare the criteria, the researchers managed to rank the criteria using the AHP method. Price turned out as the essential criterion followed by quality, delivery, and service, respectively. Although the selected supplier did not have the best quality and lead time, it offered the best price and service.

Ayhan (2013) created a supplier selection model for an automotive company in Turkey using fuzzy-AHP. He had three alternatives and defined five criteria. The criteria were quality, location, cost, delivery, and after-sales services. In his model, the location or origin of products was identified as the essential criterion followed by quality, after-sales services, cost, and delivery. Interestingly, the selected supplier has the lowest score on the most critical criterion. However, its score for quality was so high that it compensated for its low score for location. To verify the reliability of the results, the researcher ran the model with the fuzzy-TOPSIS method to compare the result with those of fuzzy-AHP. The outcome was identical, and the selected supplier in the latter method was the same as that in the former.

Jain et al. (2018) worked on a supplier selection model for an Indian automotive company. They used AHP and TOPSIS to create their model. They defined eight criteria: quality, price, relationship, manufacturing capability, warranty, on-time delivery, environmental performance, and brand name. Also, there were three alternatives. To rank the criteria, they used the pairwise comparison method in AHP. Quality became the most important criterion followed by price and on-time delivery.

Interestingly, in this case, the result of AHP and TOPSIS differed. That is, the selected supplier using AHP is different from the selected supplier determined by TOPSIS. The researchers conducted the consistency test and sensitivity analysis and concluded that the sensitivity analysis of the TOPSIS method is the opposite of the TOPSIS results. Thus, they concluded that the result attained by AHP is more robust and reliable. Obviously, it is always better to not rely on only one method, particularly in the cases with alternatives with very close and similar attributes.

Boran et al. (2009) used the TOPSIS method to create a supplier selection model for an automotive manufacturing company. In their model, they had four criteria for five suppliers. The criteria with the sequence of their importance were quality, relationship closeness, delivery, and price. The selected supplier was the one with the best quality and shortest lead time. The researchers used a method to rank decision-makers and assign different importance weights to their opinion in their study. This flexibility to rank the decision-makers is one of the advantages that TOPSIS has over other MCDM methods. That is, if the decision-makers are different regarding the experiences, expertise, and other factors, the TOPSIS method can assign different weights to the decision-makers such that those with more experience or education have a higher impact on the final result.

2.4 Methodology

In this project, we use three methods mentioned above: AHP, Fuzzy-AHP, and TOPSIS. As explained earlier, these methods are among the most popular methods researchers use in the decision-making domain.

2.4.1 Analytical hierarchy process (AHP)

The AHP lets decision-makers find the most appropriate alternative regarding their target and considering the defined criteria. Using this method, the experts can create a logical framework that comprehensively represents all the criteria and essential aspects of the decision problem. By quantifying the judgment of the decision-makers, AHP can construct a model which interprets qualitative concepts to the numbers and scores.

The decision problem is first broken down into a hierarchy. This hierarchy illustrates the problem's broader image and lets the decision-makers have a better and comprehensive understanding of it. The hierarchy consists of the target or the decision goal, the criteria with different levels, and the alternatives. As explained earlier, this method has been developed by Saaty (1980,1985,1987). Table 1 illustrates the Saaty scale, which is the foundation of AHP modeling.

Table 1 Saaty scale used in AHP (Saaty, 1987)

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favor one over the other
5	Much more important	Experience and judgment strongly favor one over the other
7	Very much more important	Experience and judgment very strongly favor one over the other
9	Extremely more important	The evidence favoring one over the other is of the highest possible affirmation
2, 4, 6, 8	Intermediate scores	

The AHP methodology is based on mathematical calculations, which are shown and explained in the following equations. Equation 1 shows the pairwise comparison matrix. The matrix A is a $m \times m$ matrix. m is the number of the defined criteria.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mm} \end{bmatrix} \qquad (1)$$

Each entry a_{jk} of the decision matrix, shows the relative importance of the criterion j compared to the criterion k. If $a_{jk} > 1$, then the j criterion is more important than k, and obviously if $a_{jk} < 1$, then it means that the criterion k is more important than j. Finally, if $a_{jk} = 1$ it means that both criteria are identical or equally important. In mathematical modeling, we can define a constraint to avoid any confusion for the future user or the machine:

$$a_{jk}.a_{kj} = 1$$

Another equation that will be used for constructing the model in AHP is illustrated in equation 2. This equation is the normalizing matrix equation.

$$w = \sum_{j=m}^{j=1} a_{ij} = [w_1, \dots, w_m] \qquad (2)$$

Once the pairwise comparison matrices are created and formed by the decision-maker(s), subsequently, we need to normalize the decision matrix by using equation 2. The result can be seen in equation 3.

$$\frac{A}{w} = \sum_{j=m}^{j=1} a_{ij}.w_j^{-1} = \begin{bmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mm} \end{bmatrix}.\left[{}^{1}/_{w_1} \dots {}^{1}/_{w_m}\right] = \begin{bmatrix} {}^{a_{11}}/_{w_1} & \cdots & {}^{a_{1m}}/_{w_m} \\ \vdots & \ddots & \vdots \\ {}^{a_{m1}}/_{w_1} & \cdots & {}^{a_{mm}}/_{w_m} \end{bmatrix} \qquad (3)$$

After constructing the final matrix in equation 3, we need to identify the normalized eigenvector using equation 4.

$$W_j = \frac{1}{m} \sum_{j=m}^{j=1} {}^{a_{ij}}/_{w_j} = \begin{bmatrix} {}^{a_{11}}/_{w_1} & \cdots & {}^{a_{1m}}/_{w_m} \\ \vdots & \ddots & \vdots \\ {}^{a_{m1}}/_{w_1} & \cdots & {}^{a_{mm}}/_{w_m} \end{bmatrix}.\begin{bmatrix} 1 \\ \vdots \\ 1 \end{bmatrix}.m^{-1} = \begin{bmatrix} \frac{1}{m}\sum_{j=m}^{j=1} {}^{a_{1j}}/_{w_1} \\ \vdots \\ \frac{1}{m}\sum_{j=m}^{j=1} {}^{a_{mj}}/_{w_m} \end{bmatrix} \qquad (4)$$

The calculated matrix represents the weight of the criteria.

$$W = \begin{bmatrix} W_1 \\ \vdots \\ W_m \end{bmatrix} \qquad (5)$$

After calculating the final matrix, we need to run the consistency test to ensure that the responses to the survey or the decision-makers assigned importance to each criterion are consistent. This step is very crucial and must be applied thoroughly. Imagine we have three criteria, A, B, and C. The decision-makers believe that A is more important than B and B is equally important compared with C. Therefore, A must be more important than C. However, if the DMs indicates otherwise, it will cause inconsistency in the responses, and this is something that AHP can measure and let the DMs know if their opinions are consistent. For doing so, the inconsistency factor or consistency ratio (CR) should be calculated.

Calculating the inconsistency factor:

$$CR = \frac{CI}{RI} \quad (6)$$

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (7)$$

$$\lambda_{max} = \frac{\sum_{j=1}^{n} a_{ij} w_j}{w_i} \quad (8)$$

Where CI is the inconsistency index, and RI is the stability factor.

If CR<0.1, then the consistency is acceptable, and the model is consistent.

2.4.2 Fuzzy-AHP

In the basic AHP, a 1-9 scale is used to distinguish the priority of one criterion over another. However, in fuzzy-AHP fuzzy numbers or their linguistic equivalent will be applied. As mentioned earlier, there are some limitations while applying AHP. One of the most significant disadvantages is no absolute certainty for decision-makers. So, they need to use a scale that has more than nine points of comparison. This is the reason that researchers decided to incorporate fuzzy numbers in MCDM AHP problems. The result is an extension of AHP, which is called fuzzy-AHP.

This method can address the uncertainties better. Thus, the result of fuzzy-AHP sometimes, and, of course, not always, differs from basic AHP. Various extensions of fuzzy-AHP are different in several aspects, from different fuzzy numbers, triangular or trapezoidal, to different methods of calculations. Chang (1992) is the most common approach, which is also our choice.

Zadeh developed the fuzzy logic. He put a name on the ambiguous and unclear situations: "fuzziness." Therefore, he evolved the fuzzy method such that it can be used for making decisions and conduct conclusions with incomplete and vague given or attained information.

In order to explain the fuzziness mathematically, Zadeh defined a function that is constructed by fuzzy sets. These sets are assigned to each goal as a grade or score. The domain of this score is between zero and one. Usually, this sign "~" shows that a symbol represents a triangular fuzzy number (TFN). A TFN is shown in figure 2-1.

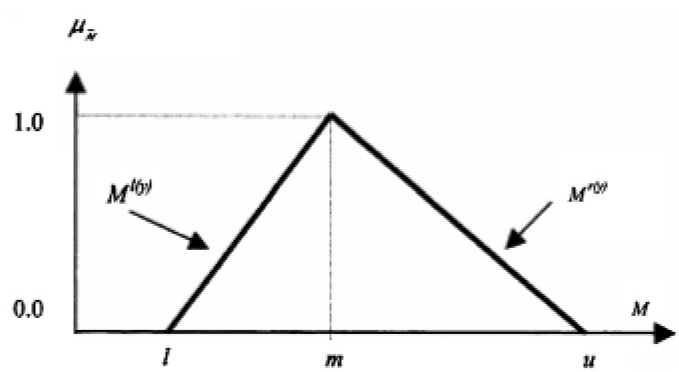


Figure 2-1 A triangular fuzzy number (Kahraman et al, 2004)

A three-parameter set describes any TFN. Here we call them (l, m, u). These parameters designate the least possible preferred value, the medium possible preferred value, and the most significant possible preferred value (Kahraman et al., 2004.) As mentioned before, each TFN can be shown by its membership function. This function is depicted in equation 9.

$$\mu_{\tilde{M}} = \begin{cases} 0, x < l, \\ (x-l)/(m-l), l \leqslant x \leqslant m, \\ (u-x)/(u-m), m \leqslant x \leqslant u, \\ 0, x > u. \end{cases} \quad (9)$$

In a supplier selection problem which is supposed to be addressed by fuzzy-AHP, let $A = (a_{ij})_{n \times m}$ be a fuzzy pairwise comparison matrix and $X = \{x_1, \dots, x_n\}$ be considered of an object set which represents the set of alternatives and let $U = \{u_1, \dots, u_m\}$ be a goal set of the defined criteria. Based on Chang (1992) analysis, each object is taken and g_i represents the goal for each object. Subsequently, m extent analysis values for each object can be attained from goals with the following symbols:

$$M_{g_i}^1, M_{g_i}^2, \dots, M_{g_i}^m, \quad i = 1, 2, \dots, n \quad (10)$$

According to Chang's method, the following steps are the steps for fuzzy-AHP calculations:

(1) once we defined M values, we can construct S_i , which is the fuzzy synthetic extent value concerning the ith object:

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} \quad (11)$$

(2) Now, we will calculate $\sum_{j=1}^{m} M_{g_i}^j$ and $\sum_{j=1}^{n} M_{g_i}^j$

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \quad (12)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right) \tag{13}$$

So:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{14}$$

(3) Chang defined a concept as a degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ which can mathematically be depicted as:

$$V(M_2 \geqslant M_1) = \sup_{y \geqslant x} \lfloor \min(\mu_{M_1}(x), \mu_{M_2}(y)) \rfloor \tag{15}$$

$$V(M_2 \geqslant M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1, & \text{if } m_2 \geqslant m_1, \\ 0, & \text{if } l_1 \geqslant u_2, \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise,} \end{cases} \tag{16}$$

Where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} which are shown in figure 2-2. To compare M_1 and M_2 we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$

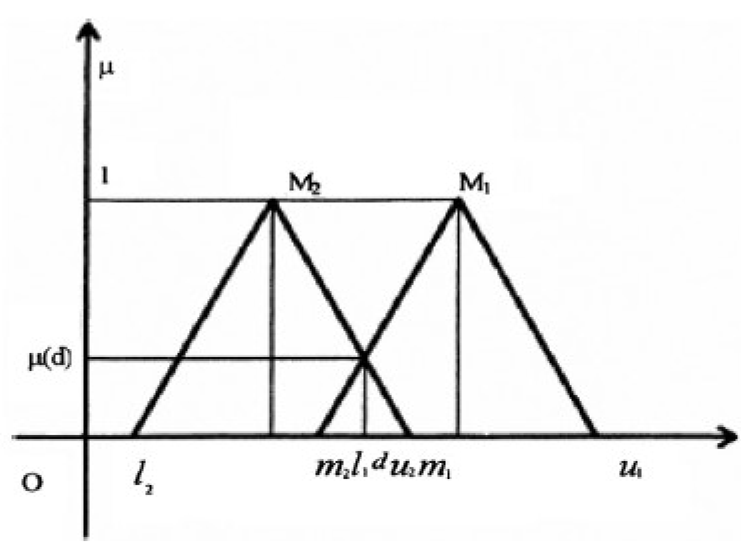


Figure 2-2 the intersection between M1 and M2 (Zhu et al, 1999)

(4) The next step is to define the degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i (i = 1,2, \dots, k)$.

$$V(M \geq M_1, M_2, \dots, M_k) = V(M \geq M_1) \; and \; (M \geq M_2) \; and \; \dots and (M \geq M_k) = \min V((M \geq M_i), i = 1,2,3, \dots, k. \tag{17}$$

(5) Finally, we can calculate the weight of the criteria and alternatives:

Assume $\acute{d}(A_i) = \min V(S_i \geq S_k)$ for k=1, 2, …, n for any k≠i. Then the weight vector is given by

$$\acute{W} = \acute{d}(A_1), \acute{d}(A_2), \dots, \acute{d}(A_n))^T \tag{18}$$

Where $A_i \; (i = 1,2, \dots, n)$ are n elements.

Next, we will normalize the vector weight. The normalized vector weight is:

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T$$

Where W is a non-fuzzy number and shows the priority weights of one alternative over another.

2.4.3 TOPSIS

For the first time, Hwang and Yoon (1981) proposed the technique for order preference by similarity to the ideal solution (TOPSIS). This method is based on selecting the ideal alternative, the closest to the most positive ideal situation, and avoiding the alternative, which is the closest to the most negative situation. Like many other maximizing and minimizing problems, here as well, the positive ideal solution is the one with maximizing the benefit and minimizing the cost. The negative solution is the one with the maximum cost and minimum benefit.

Like other methods, the first measure one should take is selecting and identifying the criteria and alternatives. Subsequently, a group of decision-makers should be formed, and they will evaluate the criteria. A decision matrix will be constructed like equation 19.

$$DM = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{19}$$

Then, DM should be normalized as follows:

$$\text{R} = r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{20}$$

weighting the normalized matrix is shown in equation 21:

$$V = v_{ij} = w_j \times r_{ij} \tag{21}$$

The positive and negative ideal solutions are calculated by equations 22 and 23:

$$IS^+ = MAX_i(V_{ij}) \tag{22}$$

$$IS^- = MIN_i(V_{ij}) \tag{23}$$

IS^+ has the best features regarding the given criteria and IS^- has the worst features associated with the criteria.

The next step calculates the geometric distance of each alternative from positive and negative ideal solutions, also known as Euclidean distance. The calculations can be done by equations 24 and 25:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (V_j^+ - V_{ij})^2} \tag{24}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (V_j^- - V_{ij})^2} \tag{25}$$

Finally, the relative closeness of an alternative is calculated by equation 26:

$$C_i = \frac{S_i^-}{S_i^- + S_i^+} \tag{26}$$

The alternative with the highest C_i is the chosen or the best alternative.

3 The Model

Having described and selected the MCDM methods for this project, we discuss how the criteria were picked and selected in this chapter. Then, we explain all the measures we took to collect the data and construct the model. All steps are shown in figure 3-1. More explanation will be provided in the creating the model section.

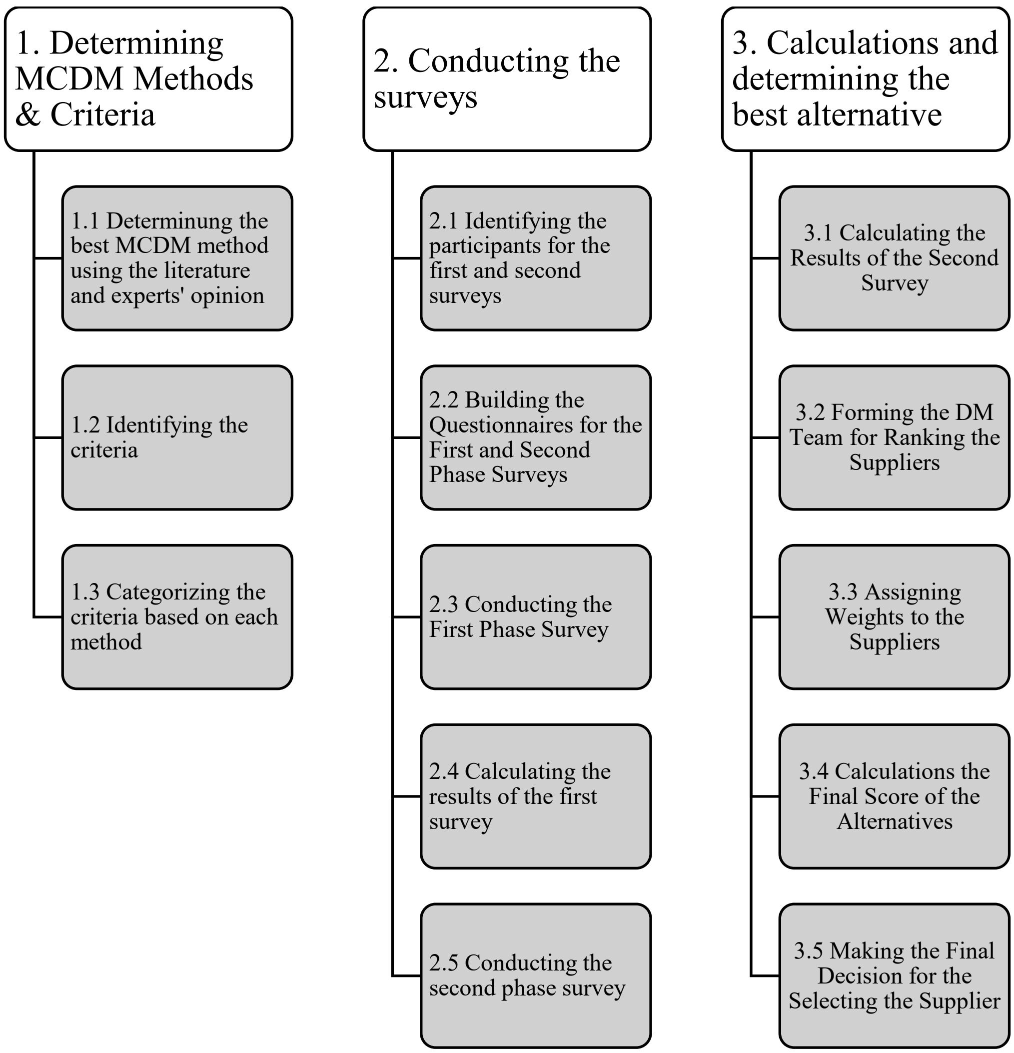


Figure 3-1 The steps towards creating the model

3.1 Determining the Criteria

In any supplier selection model, the very first and primary step is to determine the criteria. Based on the industry and business and the level of the operation in the supply chain, various criteria have different importance. This difference is because of the significant diversity which exists in purchasing context. Determining the criteria needs cooperation between the researchers and academia with practitioners and executives. In this project, we first create a list of the essential criteria in the literature. Subsequently, we shared the list with the company executives, and the final criteria were chosen based on the proven importance of academic research and the relevance to the company's operation in the aftermarket spare parts business. The steps for determining the criteria are shown in figure 3-2.

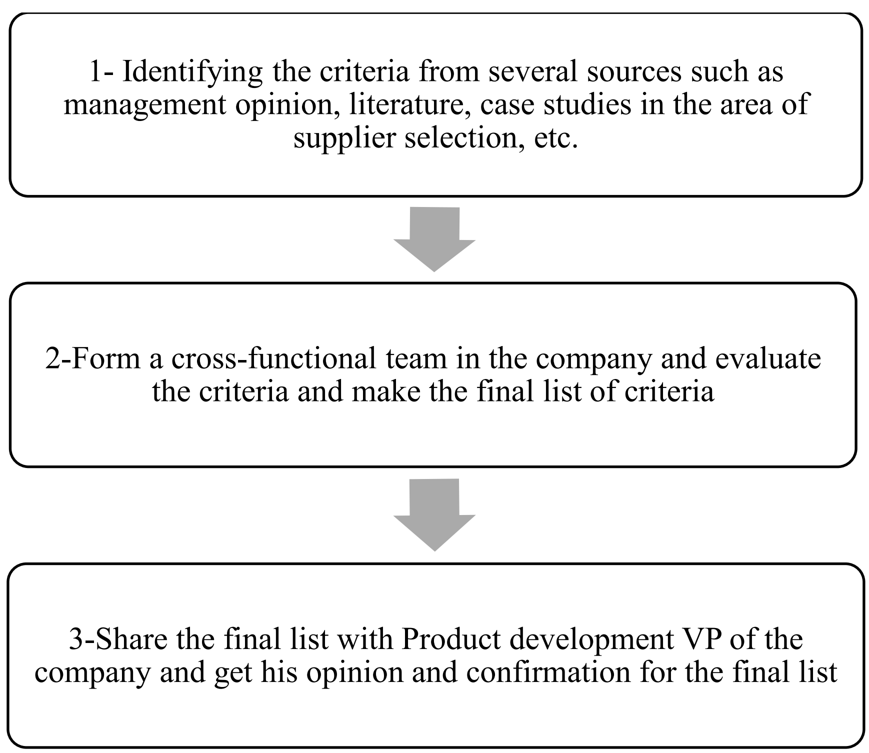


Figure 3-2 Steps towards determining the criteria

3.1.1 Supplier Selection Criteria

The field of procurement and selecting a third-party supplier or service provider is so crucial that many pieces of research have focused on different phases of the whole process of the selection. As mentioned earlier, any model is based on the criteria, and the chosen criteria play a significant role in the model functionality. In particular, in two selected methods in this project, AHP and Fuzzy-AHP, the model is based on the pairwise comparison. Thus, we should be vigilant in selecting the criteria as irrelevant criteria could lead to baseless results.

One of the first and eye-catching pieces of research about the critical criteria in supplier selection is Dickson's (1966) study. The author identified 23 criteria that purchasing managers identified as the most critical criteria. All the participants were executives in American and Canadian companies. The fall of the Soviet Union, the commencement of globalization, an industrialized China, and technology enhancements in the late '80s and early '90s motivated many researchers to conduct new studies on the new era of global business. Weber et al. (1991) executed their sought-after research, which was cited more than 3000 times so far. They focused on vendor selection and the associated criteria in this new era. The results show that net price, delivery, and quality are the most important criteria from the executives' perspective.

In another research, Swift (1995) compared five criteria: Product, Availability, Dependability, Experience, and Price. She also defined various sub-criteria for the mentioned main criteria. In her research, she conducted a survey and asked the purchasing managers to express their preferences regarding the given criteria. The results show that the purchasing managers are more interested in the total life cost of the product and less interested in the initial price. They prefer a better and more qualified relationship with the suppliers rather than just focusing on the price. The enhanced and qualified relationship will lead to better technical and financial support and mutual interests, which will lead to a better product.

Kar and Pani (2014) conducted extensive research to explore the importance of different supplier selection criteria. They studied tens of papers and articles published in this domain and create a list of the most commonly used supplier evaluation criteria. The list can be seen in table 2.

Table 2 The Criteria List gathered by Kar and Pani (2014)

Snapshot of different supplier evaluation criteria used across literature		
Product quality	Delivery reliability	Warranties
Product pricing	Production capability	Technical capability
Management capability	Supplier's reputation	Financial position
Labor relations	Service quality experience	Past business records
Reciprocal arrangements	Cultural fitment	Communication barriers
Geographical distance	Foreign exchange rates	Trade tariffs
Trade restrictions	Buyer's commitment	e-transaction capabilities
Quality management	IT standards	Cost reduction capability
Documentation	Design capability	Supply variety
Lead time/response time	Indirect costs	Response flexibility
Innovation	Facility planning	Safety adherence
Domain experience	Exporting status	Conflict resolution systems
Customs duties	Product line diversity	Intimacy of relationships
Inventory position	Electronic data interchange	Value-added productivity
Total cost of acquisition	Risk perception	Certification and standards
Research and development	Organizational culture	Availability of parts
Sub-component pricing	Regulatory compliance	Self-audits
Billing accuracy	Cost reduction performance	Indirect costs
Service quality credence	Supplier's commitment	Skill level of staff
Exporting status	Packaging capability	Intellectual property rights
Data administration	Improvement commitment	Procedural compliance

Having generated the initial list, they collected the data from 188 firms across 12 industries. Then by using the Fuzzy-AHP method, they assign weights to the criteria to combine the opinion of both academia and the experts. The executives' opinion in various fields was taken. Industries such as Iron and Steel, Pharmaceutical, Automobile, Consumer packaged goods, Agriculture, Petrochemicals, Consumer durables, Cement production, Construction material, Electrical machinery, and Engineering services. The initial list was narrowed down into two steps. In the first step, which was executed based on Delphi responses, researchers selected 14 criteria. Then the final list was constructed by using the Fuzzy-AHP method. The final list of the most important criteria with their relative importance is shown in table 3. Geographical location, Responsiveness to fluctuations, Experience in the domain, and Relationship with the buyer were among the criteria included in the second list and were removed from the final result as they have less importance with the ultimately chosen criteria.

Table 3 The relative importance of the supplier selection criteria (Kar and Pani, 2014)

Rank	Criteria
1	Product Quality
2	Delivery Compliance
3	Price
4	Product Capability
5	Technological Capability
6	Financial Position
7	E-Transaction Capability

Şen et al. (2008) executed a thorough study on this matter. They identified 49 criteria that were used the most in the literature from 1966 to 2005. Subsequently, they categorized these criteria and defined six main criteria, under which the other criteria are placed in level 2 and level 3 sub-criteria. The main categories are Cost criteria, Quality criteria, Service criteria, Reliability criteria, Management and organization criteria, and Technology criteria. They also used their model in a real-world problem for selecting a Turkish audio electronic company supplier.

Vonderembse and Tracey (1999) executed an extensive survey to study the impact of supplier selection criteria on manufacturing performance. Interestingly, they found that most purchasing managers participating in the survey linked their satisfaction to product quality, product availability, delivery reliability, and product performance. The researchers maintained that the executives are more concerned about the criteria that can be evaluated during the time and not instantly. For example, some criteria like price are discussed and negotiated in the first step of signing a contract with a new vendor; however, the criteria mentioned by purchasing managers need time to be evaluated or verified. Those criteria are at a higher level of importance.

Having reviewed all the mentioned studies and researches, we specifically focused on the researches on the domain of the automotive industry. These researches, which were also discussed extensively in the literature review section, have used the very same important criteria mentioned in this section, and the researchers did not have a different perspective in this field. Finally, the initial list of the criteria was created and is shown in table 4.

Table 4 The initial list of picked criteria

Net Price	Defect Rate	Coverage Rate
Geographical Location	Delivery Time	Market Share
Product Durability	Training Support	Proximity
Product Reliability	Technical Support	
Quality Assurance Certificate	Warranties	

3.1.2 Finalizing the Selected Criteria

After reviewing the literature thoroughly, we narrowed down the criteria list to the most important criteria. A cross-functional team was formed in the company for reviewing the list and making modifications. This team consisted of a product manager, a senior market manager (from the product department), and the replenishment manager (from the supply chain department). The academic supervisor was also an indirect member of this committee.

In this step, the first measure was sharing the list in table 4 with the academic supervisor. After in-depth considerations, he proposed four additional criteria to be included in the model—first, the financial performance and situation of the supplier, which is broadly mentioned in the literature. Then, the sustainability criteria, which nowadays are the point of many academic and professional discussions. Thus, we introduced three sustainability criteria: Environmental sustainability, Social sustainability, and Geopolitical sustainability.

We updated the list of criteria and shared it with the members of the cross-functional team. In this stage, the focus was primarily on two points. First, we wanted to evaluate the criteria and investigate if the proposed criteria, which are the essential criteria mentioned in the literature, are meaningfully necessary for the Company's purchasing operation. Second, what other critical criteria in the Canadian automotive aftermarket business are possibly missed from our initial list.

Having reviewed the initial list and confirmed all proposed criteria as relevant criteria to the Company's business, the committee proposed adding a handful of more important criteria for the decision-makers in the Company. These criteria are mostly the criteria that are important for the Company's operations and are related to its business targets. These criteria are Market share, Having a business with competitors, Brand awareness, Offered promotions, and online catalog. Once we create the ultimate list of the criteria, we shared it with the Product Development vice president of the Company. He provided new insights and also modified the definition of some criteria. The definition of criteria is essential for the surveys as it helps participants have an identical perception of each criterion.

Once the criteria list and definitions were confirmed and finalized, it is crucial to categorize them and define the main criteria and sub-criteria adequately. As described in the methodology section, we will use three different methods: AHP, Fuzzy-AHP, and TOPSIS. The ideas behind AHP and Fuzzy-AHP are similar, and we use the same hierarchy for comparing the criteria. However, the TOPSIS method is somewhat different and needs a different categorization. We will elaborate upon the differences in creating the model section. The final list of the criteria with their definitions is shown in table 5.

3.2 Creating the Model

After determining the criteria, we need to form the models based on the selected methods. As mentioned earlier, AHP and Fuzzy-AHP are based on similar ideas, and a hierarchy must be constructed for pairwise comparison in these methods. On the other hand, TOPSIS is somewhat different, not based on the pairwise comparison.

3.2.1 AHP and Fuzzy-AHP Models

We defined four main criteria for the hierarchy used in AHP and Fuzzy-AHP to categorize the criteria mentioned in table 5. The four main criteria are Product, Supplier, Service, and Sustainability. The constructed hierarchy for AHP and Fuzzy-AHP models is shown in figure 3-3. This hierarchy model consists of three levels. The first level is the main criteria, as can be seen in figure 3-3. The second level is the sub-criteria. Finally, the third level is the alternatives. The precise and confirmed definition of all criteria can be found in table 5.

There are three alternatives in this project. The Company intends to select one of these vendors as the ultimate supplier for a specific product line. The selected supplier will be offered a long-term contract, and the product line is among the most critical categories in the Company's business. Thus, the selection and evaluation process is fundamental and will significantly influence the Company's operation and business.

Table 5 List of finalized criteria

No	Criteria	Description
1	Financial status and strength	one of the essential elements in the supplier-buyer relationship is a long-term commitment and supporting different programs which need financial strength. The financial status of the supplier can be an excellent indicator to provide this key element.
2	Geographical location	it is vital as it affects delivery times, probable overhead expenses, tariffs, transport costs.
3	Market share	the current supplier situation in the domestic market
4	Having a business with competitors	the supplier's relationship with the company's competitors in the Canadian market
5	Brand awareness	Knowledge of the brand(s) manufactured by the supplier
6	Coverage rate and the product range extensiveness	Supplier's ability to offer broad product range meeting majority of customer expectations
7	Net price	The price of the product.
8	Offered promotions	Suppliers (or a program) support promotion during the year.
9	Product reliability	The likelihood that a product will not fail within an expected period.
10	Product durability	The ability of a product to remain functional without requiring excessive maintenance or repair when faced with the challenges of regular operation over its design lifetime.
11	Certification and Quality Assurance	Certificates and standard confirmations acquired by the supplier for their products confirming the expected qualities and standards.

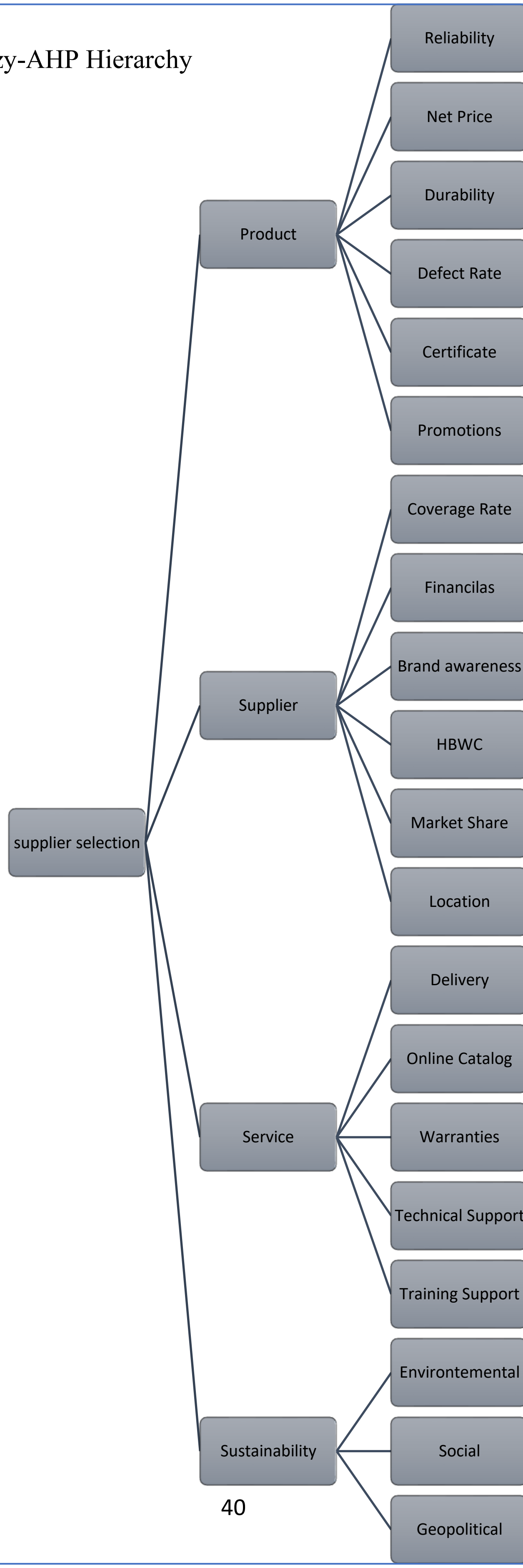
12	Defect Rate	The percentage of defected or rejected products in case we have access to this information.
13	Delivery time	The time between when an order is placed and when it is received.
14	Training Support	Supplier’s capability, resources, and engagement for providing technical training for the technicians.
15	Technical Support	Supplier's capability and dedication for having a technical customer service team responding to field calls.
16	Warranties	The length of the warranty for a specific product and the simplicity of the warranty process.
17	Online Catalog	An online catalog that has broad technical information and helps the customers to pick the right product.
18	Environmental sustainability	responsible interaction with the environment to avoid depletion or degradation of natural resources and allow for long-term environmental quality. The practice of environmental sustainability helps to ensure that the needs of today's population are met without jeopardizing the ability of future generations to meet their needs.
19	Social sustainability	social sustainability performance issues include human rights, fair labor practices, living conditions, health, safety, wellness, diversity, equity, work-life balance, empowerment, community engagement, philanthropy, volunteerism, and more.
20	Geopolitical sustainability	political and social status in the country that the supplier has based their business. It is not limited to that specific region or country situation but relates mainly to that country or region's collaboration with other parts of the world (in this case, the U.S. and Canada).

According to the designated process shown in figure 3-1, after confirming and categorizing the main criteria and their associated sub-criteria, it is time to determine the surveys' participants. As recommended by the project academic advisor, we designed two surveys for two different phases. Before explaining these phases, we need to describe the Company’s business and sales strategies.

The Company owns hundreds of stores in Canada, and each store has a store manager, and the manager is relatively independent in making business decisions. However, there are some limitations and constraints that should be respected. An extensive network of sales representatives is the bridge and the connection point between the Company headquarters and the stores. This network consists of four levels of sales representatives that manage different targeted customers and different product categories. These sales forces, who report to regional sales executives, have many tasks, and their performance is vital. They are aware of the installers' and end users' expectations as they constantly contact them and receive complaints or suggestions about the products. They also understand the competition, and they perform as the Company's sensors once there is a meaningful change underneath the market. By and large, they are connection points between the market and the headquarter and are aware of the customers and store managers' expectations. Therefore, we decided to conduct the first survey by asking questions from these sales forces. The rationale behind executing this phase, which will not be used directly in the model creation, is to give the executives an image of the market and customers' expectations. We would have liked to show the executives the importance of the criteria from the customers' perspective and their preferences. So, this can indirectly affect the result once the executives participate in our second phase survey.

For instance, one executive can think that price is more important than quality. Nevertheless, the feedback from the customers derived in the first phase survey shows otherwise. This information can give the participants of the second phase some more insights and indirectly change or impact their opinion. On the one hand, this approach is unique, and we have not seen some similar practices in the reviewed literature in the context of AHP. On the other hand, getting sales forces involved in the decision-making process, in which high-rank executives will make the final decision, is a very new concept in the Company.

Figure 3-3 AHP and Fuzzy-AHP Hierarchy



For the first phase, we decided to exclude the strategic criteria from the survey and focus on the more relevant criteria to the customers' perspective. For doing so, we had to change the categorization of the criteria and sub-criteria such that the grouping became more relevant to the sales aspect of the business. The list of included criteria is shown in figure 3-4. The descriptions are as same as those indicated in table 5.

The designed survey for the first phase, which can be found in the Appendix section, was shared with 65 sales forces in the whole country. We used the hybrid method to reduce questions and facilitate the survey's execution, which Kallas (2011) suggests. The survey is based on a Likert scale instead of directly pairwise comparison questions in this hybrid method. This method will help us to reduce the number of questions significantly and ensure the accuracy of responses. For example, we would have had more than 25 questions in the first phase using the simple AHP pairwise questionnaire. Instead, we have only 15 questions. Indeed, it is easier for participants to answer a questionnaire with way fewer questions. The complexity of the basic AHP questionnaire can cause inaccuracy in the responses, especially for those not very familiar with academic surveys.

Forty-three responses were returned out of 65 sent requests which is a very high participation rate. The weight of each criterion was calculated using the AHP method, and the results were shared with the executives participating in the second phase survey, which is the project's primary survey. As explained earlier, this phase's goal was to indirectly affect the executives' opinion and show them how the market is thinking and how the sales forces prioritize the criteria that are important in the sales aspect of the business.

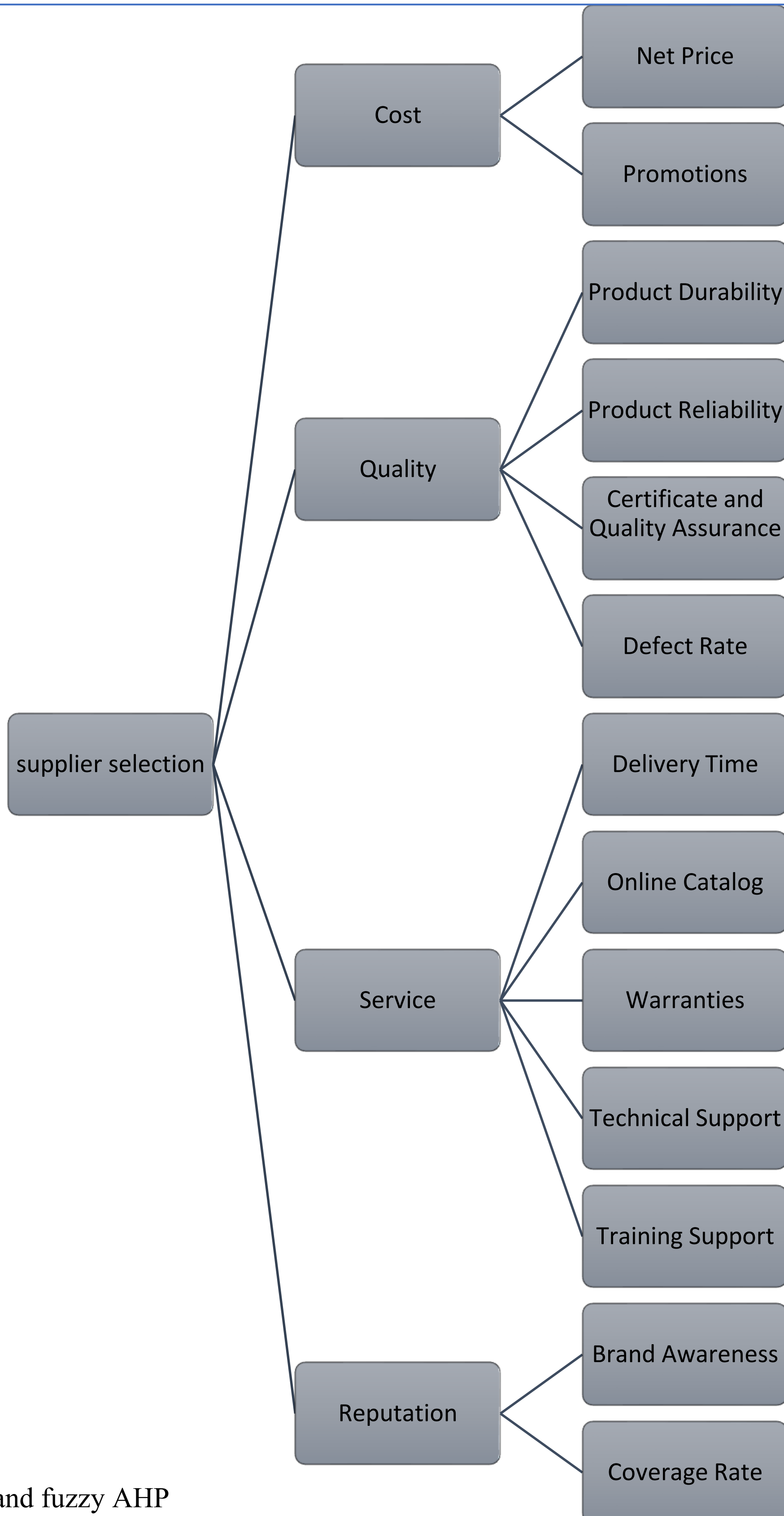


Figure 3-4 AHP and fuzzy AHP hierarchy used for the first phase survey

After the conduction of the first phase survey, it is time for the second phase survey. In the second phase, the questionnaire was based on the hierarchy shown in figure 3-3 and included all the chosen criteria. We sent the questionnaire to 40 executives in various positions and departments. CEO, Regional VPs, Supply Chain VP, Product development VP, Marketing VP, Product Directors, Replenishment Manager, Senior Buyers, Senior Category Managers, Product Managers, Sales Team Lead, and directors are among the executives invited to participate in the survey. Eighteen responses were returned, which is still an acceptable participation rate. The questionnaire can be found in the Appendix section.

After receiving all the responses, we started the calculations using the AHP and Fuzzy-AHP method for determining the weight of each main criterion and sub-criteria. Afterward, a decision-maker team was formed in the product department consisting of the Product development VP, a Senior Category Manager, and a product manager to assign weights to the alternatives and reach the final decision. The results are discussed in the next chapter.

3.2.2 TOPSIS Model

TOPSIS method differs from AHP and its derivatives. The calculation process aside, the TOPSIS model is not based on the hierarchy as AHP is. Also, the TOPSIS model behaves differently with cost criteria and benefit criteria. The way of calculation can be different for the net price criterion compared with the quality criterion. Since TOPSIS maximizes the benefit and minimizes the cost, we cannot use the categorization that was used for AHP and Fuzzy-AHP because, in that categorization, we put a cost criterion, like net price, with a benefit criterion, like quality, in the same category which is the product category. Also, TOPSIS is quite suitable for a small group of decision-makers. Many researchers used TOPSIS with a small group of decision-makers. For instance, Stević et al. (2016) used TOPSIS with three DMs.

On the one hand, we decided to use TOPSIS for evaluating the results of AHP and Fuzzy-AHP and compare the outcome of these models. On the other hand, the decision-makers whose opinions were taken for the AHP and Fuzzy-AHP models are from different departments and backgrounds, which do not necessarily have the same idea and opinion as DMs in the Product Development Department. Thus, using TOPSIS with a smaller group of DMs, who are only from the Product Development Department, will let the company executives compare a more extensive model with a more specialized one.

For constructing the TOPSIS model, a group of four DMs was formed, two Senior Category Managers and two Product Managers. The DMs categorized the criteria as shown in table 6.

Table 6 Criteria for TOPSIS Model

Category	Criteria
Cost	Net price
	Promotions and special offers
Quality	Product durability
	Product reliability
	Certificates
	Defect rate
Service	Delivery time
	Training support
	Technical support
	Warranties
	Online catalog
Reliability	Brand awareness
	Coverage rate
	Market share
Organization	Financial status
	Having a business with competitors
	Location
Sustainability	Environmental sustainability
	Social sustainability
	Geopolitical sustainability

After finalizing the criteria for the TOPSIS model, the DM team realized that there are some criteria in which all suppliers have similar characteristics and scores. Criteria like promotions or quality assurance certificates. Thus, the DM tea decided to run the model only with the criteria, the scores of which are different for the alternatives. Then, they rank the criteria by assigning the importance and weights using the AHP scoring method. Eventually, by using the TOPSIS method and formulation, the best alternative was chosen. The results will be discussed in the next chapter.

4 Data Collection and Analysis

In this chapter, we discuss our data collection approach and methods to analyze the collected data. We will demonstrate how this information could be used in different models. We will analyze the results obtained from different models.

4.1 The First Phase Survey

The very first step, which includes calculations, was after gathering the data. As explained in chapter three, we designed a two-phase surveys approach. In the first phase survey, we only included the participation of sales forces of the Company, who are the connection point between headquarter and the market, to show the main targeted participants, the executives of the Company, the importance and weight of the criteria from customers' perspective.

To facilitate the survey for the participants from different backgrounds, we decided to use the approach suggested by Kallas (2011). In this approach, instead of using a pairwise comparison survey and the complex comparing scale shown in table 1 in the survey, we used a Likert scale for the survey, and after collecting all the data, we transformed the Likert scale to AHP scale using equation 27. The Likert scale is shown in table 7. The Likert scale is easy to follow, and most importantly, it reduces the number of questions significantly. A compact survey questionnaire reduces confusion for the participants, which can jeopardize the consistency of the results.

$$\hat{a}_{ij} = \left| Sc_{ik} - Sc_{jk} \right| + 1 \quad (27)$$

Table 7 Likert Scale (Kallas,2011)

Attributes and Levels	1: Non-important, 5: Indifferent, 9: Very important								
A	1	2	3	4	5	6	7	8	9
L	1	2	3	4	5	6	7	8	9

Equation 27 calculates the difference between the scores given to each criterion based on the Likert model for the kth participant. By using this equation, we can transform the Likert comparison to a pairwise comparison.

After collecting the data from the questionnaire, responses were transformed to a pairwise comparison using equation 27. That is, for every participant, we used this equation for all the criteria to transform to AHP scales shown in table 1. Then, the geometric mean for all the transformed results was calculated to construct the main decision matrix for both the main criteria and the sub-criteria. The decision matrices are shown in tables 8 to 12.

Table 8 Decision matrix for the main criteria

	COST	QUALITY	SERVICE	REPUTATION
COST	1.0000	0.3965	0.3901	0.6663
QUALITY	2.5219	1.0000	0.9707	1.6531
SERVICE	2.5636	1.0302	1.0000	1.7737
REPUTATION	1.5009	0.6049	0.5638	1.0000

Table 9 Decision matrix for the sub-criteria of Cost

	NET PRICE	PROMOTION
NET PRICE	1.0000	1.4742
PROMOTION	0.6783	1.0000

Table 10 Decision matrix for the sub-criteria of Quality

	DURABILITY	RELIABILITY	CERTIFICATE	DEFECT RATE
DURABILITY	1.0000	0.8184	1.7125	1.6544
RELIABILITY	1.2219	1.0000	2.0225	2.0351
CERTIFICATE	0.5840	0.4944	1.0000	0.9937
DEFECT RATE	0.6045	0.4914	1.0063	1.0000

Table 11 Decision matrix for the sub-criteria of Service

	DELIVERY	TRAINING	TECHNICAL	WARRANTY	ONLINE
DELIVERY	1.0000	1.7423	1.3750	1.3914	1.2939
TRAINING	0.5740	1.0000	0.7840	0.7809	0.7684
TECHNICAL	0.7273	1.2755	1.0000	1.0187	0.9656
WARRANTY	0.7187	1.2805	0.9816	1.0000	0.9577
ONLINE	0.7729	1.3013	1.0356	1.0441	1.0000

Table 12 Decision matrix for the sub-criteria of Reputation

	BRAND	COVERAGE
BRAND	1.0000	0.6308
COVERAGE	1.5854	1.0000

Then by using equations 2 and 3, we normalized these decision matrices. Subsequently, by using equations 4 and 5, the weight of each attribute is calculated. The results are shown in tables 13 to 17.

Table 13 Calculated weight of the main criteria

Rank	Criteria	weight
1	SERVICE	0.34
2	QUALITY	0.33
3	REPUTATION	0.20
4	COST	0.13

Table 14 Calculated weight of the sub-criteria for service

Rank	Sub-Criteria	weight
1	DELIVERY	0.26
2	ONLINE	0.20
3	TECHNICAL	0.19
4	WARRANTY	0.19
5	TRAINING	0.15

Table 15 Calculated weight of the sub-criteria for quality

Rank	Sub-Criteria	weight
1	RELIABILITY	0.36
2	DURABILITY	0.30
3	DEFECT RATE	0.18
4	CERTIFICATE	0.17

Table 16 Calculated weight of the sub-criteria for reputation

Rank	Criteria	weight
1	COVERAGE RATE	0.61
2	BRAND	0.39

Table 17 Calculated weight of the sub-criteria for cost

Rank	Criteria	weight
1	NET PRICE	0.60
2	PROMOTION	0.40

As seen from the sales force's perspective, service is the main criteria closely followed by quality. Interestingly, the cost is the least important main criterion in their opinion. This result is aligned with the general sales strategy of the Company. The Company offers the best possible quality products with trustworthy and eye-catching support programs for stores and installers. Therefore, the final price is not usually the cheapest in the market, and the cost is not the competition point in the Company's marketing strategy. Thus, it is understandable why the cost has the least importance from sales forces' opinion, as they already know, that this is not their point of strength. However, services like on-time delivery, comprehensive online catalog utilizing which they can find the most appropriate parts for the specific application, and reliability and durability of products are from a higher level of importance, and these are the strongest points of the sales strategy they offer. For the sub-criteria of reputation, we can see that brand awareness is not the most important one, and the sales forces prefer a less known brand with high quality and better coverage rate.

The consistency test was also conducted using equations 6,7 and 8, and the consistency indices were way below the threshold of 0.1, which shows the accurate and consistent responses from the participants. One of the main reasons for these consistent responses is using the Likert scale and survey method, which reduce the number of questions and mitigate the risks of participants' confusion. Also, we can see that this approach can be combined with AHP very smoothly and lead to acceptable results.

4.2 The Second Phase Survey

Having attained the opinion of the sales force, who can represent the market sentiment, it is time for conducting the second phase survey. As described in the previous chapter, 36 participants were invited to fill the questionnaire from various roles and positions, from the CEO to the product managers. Eighteen responses were returned ultimately. The result of the first phase was shared with the participating executives to let them know about the market sentiment. The rationale behind this was impacting the executives' opinion with the market's reality and indirectly incorporating the sales force's perspective. After receiving the responses, two models were based upon this survey, AHP, and Fuzzy-AHP.

4.3 AHP Model

After collecting the data and transforming the Likert result to the AHP scale as described earlier, the weight of the main criteria and sub-criteria were calculated. Subsequently, the decision-maker team was formed in the product development department consisting of a product manager, a senior category manager, and the product VP. The pairwise comparison was executed for the three alternatives, identified as S1, S2, and S3. The comparison for the AHP model was based on the AHP scale shown in table 1. The result of the AHP model attributes weight, and the alternatives' priorities are shown in table 18.

According to the executives' opinion, service is the most important main criteria with a meaningful difference from other criteria. Product is the second most important criteria following by Supplier. Sustainability is the least important in executives' opinion.

By looking into the sub-criteria, we can see that the executives give more importance to price versus service by sales forces which were extracted from the first phase survey. However, product reliability is more important than price. Also, delivery can be identified as the most important sub-criteria.

Table 18 Priority vectors for the decision hierarchy AHP model

Variable in level 1	Level 1 priorities	Variable in level 2	Level 2 priorities	Variable in level 3	Level 3 priorities
SUPPLIER	0.22	COVERAGE RATE	0.31	S1	0.62
				S2	0.14
				S3	0.24
		FINANCIAL	0.25	S1	0.06
				S2	0.64
				S3	0.30
		BRAND	0.14	S1	0.50
				S2	0.25
				S3	0.25
		HBWC	0.12	S1	0.72
				S2	0.17
				S3	0.11
		MARKET SHARE	0.09	S1	0.60
				S2	0.20
				S3	0.20
		LOCATION	0.09	S1	0.12
				S2	0.12
				S3	0.76
SERVICE	0.37	DELIVERY	0.27	S1	0.06
				S2	0.47
				S3	0.47
		ONLINE CATALOG	0.21	S1	0.33
				S2	0.33
				S3	0.33
		WARRANTIES	0.20	S1	0.33

				S2	0.33
				S3	0.33
		TECHNICAL	0.18	S1	0.33
				S2	0.33
				S3	0.33
		TRAINING	0.14	S1	0.33
				S2	0.33
				S3	0.33
PRODUCT	0.28	RELIABILITY	0.23	S1	0.20
				S2	0.40
				S3	0.40
		NET PRICE	0.20	S1	0.06
				S2	0.64
				S3	0.30
		DURABILITY	0.18	S1	0.27
				S2	0.36
				S3	0.36
		DEFECT RATE	0.16	S1	0.08
				S2	0.46
				S3	0.46
		CERTIFICATE	0.13	S1	0.33
				S2	0.33
				S3	0.33
		PROMOTIONS	0.10	S1	0.33
				S2	0.33
				S3	0.33
SUSTAINABILITY	0.13	ENVIRONMENTAL	0.37	S1	0.33
				S2	0.33
				S3	0.33
		SOCIAL	0.32	S1	0.33
				S2	0.33
				S3	0.33
		GEOPOLITICAL	0.31	S1	0.14
				S2	0.14
				S3	0.71

Interestingly, delivery is the most important sub-criteria, and probably it is due to supply chain disruptions we experienced after Covid-19. The executives realized that an abrupt supply chain failure could cause significant adverse impacts to the Company’s business. Although delivery is among the fundamental attributes, the geographical location itself is not as important as delivery. Since many components of automotive spare parts are being manufactured in Asia, Latin America, and Mexico, having a domestic DC or facility cannot guarantee a shorter lead time. That is why delivery is of more importance than geographical location. However, its score is not zero and is not even a significant factor, yet it can help a supplier gain more scores than those without facilities in Northern America.

After calculating the normalized priority weight of each alternative regarding the sub-criteria, the very same process should be executed to attain the priority based on the main criteria, leading to each alternative's final priority weight. The result is shown in table 19.

Table 19 Main attributes of the AHP model and final result

	SERVICE	PRODUCT	SUPPLIER	SUSTAINABILITY	Alternative Priority Weight
weight	0.37	0.28	0.22	0.13	
Alternative					
Supplier 1	0.26	0.21	0.43	0.27	0.29
Supplier 2	0.37	0.46	0.28	0.27	0.36
Supplier 3	0.37	0.32	0.28	0.45	0.35

Based on the AHP model, Supplier 2 is identified as the best alternative, followed by Supplier 3.

As described in chapters 2 and 3, we will use the same data and create a fuzzy-AHP model. The rationale behind it is to use a more helpful method in situations with the highest uncertainties. Also, as the result of AHP is very close, we can use another method for having more analysis on this situation.

4.4 Fuzzy-AHP Model

For creating the fuzzy-AHP model, we used the same collected data used for AHP. This approach is prevalent, and it is not needed to conduct separate surveys for different methods. However, it is needed to transform the raw data to designated scales. In this case, we took the decision matrices shown in the table 8 series and converted the AHP scale to linguistic variables and their corresponding fuzzy numbers. The scale is shown in table 20.

Table 20 The linguistic variables and their corresponding fuzzy and AHP numbers (Kilincci and Onal,2011)

AHP Score	Linguistic Variable	Fuzzy Number
1	Equally preferred (EP)	(1,1,1)
1-3	Weakly preferred (WP)	(2/3,1,3/2)
3-5	Fairly strongly preferred (FSP)	(3/2,2,5/2)
5-7	Very strongly preferred (VSP)	(5/2,3,7/2)
7-9	Absolutely preferred (AP)	(7/2,4,9/2)

The decision matrices are shown in tables 21 to 25.

Table 21 fuzzy Decision matrix for main criteria

	SUPPLIER			PRODUCT			SERVICE			SUSTAINABILITY		
SUPPLIER	1.00	1.00	1.00	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50
PRODUCT	0.67	1.00	1.50	1.00	1.00	1.00	0.67	1.00	1.50	1.50	2.00	2.50
SERVICE	0.67	1.00	1.50	0.67	1.00	1.50	1.00	1.00	1.00	1.50	2.00	2.50
SUSTAINABILITY	0.67	1.00	1.50	0.40	0.50	0.67	0.40	0.50	0.67	1.00	1.00	1.00

Table 22 fuzzy Decision matrix for sub-criteria of Product

	NET PRICE			PROMOTIONS			RELIABILITY			DURABILITY			CERTIFICATE			DEFECT RATE		
NET PRICE	1.00	1.00	1.00	1.50	2.00	2.50	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50
PROMOTIONS	0.40	0.50	0.67	1.00	1.00	1.00	0.40	0.50	0.67	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50
RELIABILITY	0.67	1.00	1.50	1.50	2.00	2.50	1.00	1.00	1.00	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50
DURABILITY	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	1.00	1.00	1.00	0.67	1.00	1.50	0.67	1.00	1.50
CERTIFICATE	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	1.00	1.00	1.00	0.67	1.00	1.50
DEFECT RATE	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	1.00	1.00	1.00

Table 23 fuzzy Decision matrix for sub-criteria of Supplier

	FINANCIAL			LOCATION			MARKET SHARE			HBWC			BRAND			COVERAGE RATE		
FINANCIAL	1.00	1.00	1.00	1.50	2.00	2.50	1.50	2.00	2.50	1.50	2.00	2.50	0.67	1.00	1.50	0.67	1.00	1.50
LOCATION	0.40	0.50	0.67	1.00	1.00	1.00	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	0.40	0.50	0.67
MARKET SHARE	0.40	0.50	0.67	0.67	1.00	1.50	1.00	1.00	1.00	0.67	1.00	1.50	0.67	1.00	1.50	0.40	0.50	0.67
HBWC	0.40	0.50	0.67	0.67	1.00	1.50	0.67	1.00	1.50	1.00	1.00	1.00	0.67	1.00	1.50	0.40	0.50	0.67
BRAND	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	1.00	1.00	1.00	0.40	0.50	0.67
COVERAGE RATE	0.67	1.00	1.50	1.50	2.00	2.50	1.50	2.00	2.50	1.50	2.00	2.50	1.50	2.00	2.50	1.00	1.00	1.00

Table 24 fuzzy Decision matrix for sub-criteria of Service

	DELIVERY			TRAINING			TECHNICAL			WARRANTIES			ONLINE		
DELIVERY	1.00	1.00	1.00	1.50	2.00	2.50	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50
TRAINING	0.40	0.50	0.67	1.00	1.00	1.00	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50
TECHNICAL	0.67	1.00	1.50	0.67	1.00	1.50	1.00	1.00	1.00	0.67	1.00	1.50	0.67	1.00	1.50
WARRANTIES	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	1.00	1.00	1.00	0.67	1.00	1.50
ONLINE	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	0.67	1.00	1.50	1.00	1.00	1.00

Table 25 fuzzy Decision matrix for sub-criteria of Sustainability

	ENVIRONMENT			SOCIAL			GEOPOLITICAL		
ENVIRONMENTAL	1.00	1.00	1.00	0.67	1.00	1.50	0.67	1.00	1.50
SOCIAL	0.67	1.00	1.50	1.00	1.00	1.00	1.00	1.00	1.00
GEOPOLITICAL	0.67	1.00	1.50	1.00	1.00	1.00	1.00	1.00	1.00

After constructing the decision matrices, we can now take measures towards calculating the weights of the attributes. Using equations 11 to 18 described in chapter two, each attribute's priority score or weight is calculated and shown in tables 26 to 30.

Table 26 Calculated weight of the main criteria

Rank	Criteria	weight
1	PRODUCT	0.30
2	SERVICE	0.30
3	SUPPLIER	0.24
4	SUSTAINABILITY	0.16

Table 27 Calculated weight of the sub-criteria for Product

Rank	Sub-Criteria	weight
1	NET PRICE	0.19
2	RELIABILITY	0.19
3	DURABILITY	0.16
4	CERTIFICATE	0.16
5	DEFECT RATE	0.16
6	PROMOTIONS	0.14

Table 28 Calculated weight of the sub-criteria for Service

Rank	Sub-Criteria	weight
1	DELIVERY	0.23
2	TECHNICAL	0.20
3	WARRANTIES	0.20
4	ONLINE	0.20
5	TRAINING	0.17

Table 29 Calculated weight of the sub-criteria for Supplier

Rank	Sub-Criteria	weight
1	COVERAGE RATE	0.28
2	FINANCIAL	0.25
3	BRAND	0.14
4	LOCATION	0.11
5	MARKET SHARE	0.11
6	HBWC	0.11

Table 30 Calculated weight of the sub-criteria for Sustainability

Rank	Criteria	weight
1	ENVIRONMENTAL	0.33
2	SOCIAL	0.33
3	GEOPOLITICAL	0.33

Once the weight of all the attributes is calculated, we took into account the comparison which was done previously for alternatives pairwise comparison. Once again, using the scales described in table 20, we transformed the linguistic comparison to fuzzy numbers. The results can be seen in table 31.

Table 31 Priority vectors for the decision hierarchy fuzzy-AHP model

Variable in level 1	Level 1 priorities	Variable in level 2	Level 2 priorities	Variable in level 3	Level 3 priorities
PRODUCT	0.30	NET PRICE	0.19	S1	0.00
				S2	1.00
				S3	0.00
		RELIABILITY	0.19	S1	0.33
				S2	0.33
				S3	0.33
		DURABILITY	0.16	S1	0.00
				S2	0.50
				S3	0.50
		CERTIFICATE	0.16	S1	0.33
				S2	0.33
				S3	0.33
		DEFECT RATE	0.16	S1	0.00
				S2	0.50
				S3	0.50
		PROMOTIONS	0.14	S1	0.33
				S2	0.33
				S3	0.33
SERVICE	0.30	DELIVERY	0.23	S1	0.00
				S2	0.50
				S3	0.50
		TECHNICAL	0.20	S1	0.33

				S2	0.33
				S3	0.33
		WARRANTIES	0.20	S1	0.33
				S2	0.33
				S3	0.33
		ONLINE CATALOG	0.20	S1	0.33
				S2	0.33
				S3	0.33
		TRAINING	0.17	S1	0.33
				S2	0.33
				S3	0.33
SUPPLIER	0.24	COVERAGE RATE	0.28	S1	0.71
				S2	0.15
				S3	0.15
		FINANCIAL	0.25	S1	0.00
				S2	0.66
				S3	0.34
		BRAND	0.14	S1	0.33
				S2	0.33
				S3	0.33
		LOCATION	0.11	S1	0.00
				S2	0.00
				S3	1.00
		MARKET SHARE	0.11	S1	1.00
				S2	0.00
				S3	0.00
		HBWC	0.11	S1	1.00
				S2	0.00
				S3	0.00
SUSTAINABILITY	0.16	ENVIRONMENTAL	0.33	S1	0.33
				S2	0.33
				S3	0.33
		SOCIAL	0.33	S1	0.33
				S2	0.33
				S3	0.33
		GEOPOLITICAL	0.33	S1	0.00
				S2	0.00
				S3	1.00

After calculating the normalized priority weight of each alternative regarding the sub-criteria, the very same process should be executed to attain the priority based on the main criteria, leading to each alternative's final priority weight. The result is shown in table 32.

Table 32 Main attributes of the fuzzy-AHP model and final result

	SERVICE	PRODUCT	SUPPLIER	SUSTAINABILITY	Alternative Priority Weight
weight	0.30	0.30	0.24	0.16	
Alternative					
Supplier 1	0.26	0.16	0.46	0.22	0.28
Supplier 2	0.37	0.51	0.25	0.22	0.36
Supplier 3	0.37	0.33	0.28	0.56	0.36

As can be seen with the fuzzy-AHP method, we have two equal alternatives. Although in the AHP model, supplier 2 was chosen as the best alternative, in the fuzzy-AHP model, supplier 2 and supplier 3 have identical importance scores. Both suppliers obtained the same score regarding their service, yet, supplier 2 has a higher score for the product criteria by virtue of their better price. The only category in which supplier 1 is leading is the supplier criteria. Although they do not have a good score regarding their financial situation, they managed to be selected as the leading supplier in this category thanks to their extensive coverage rate and not having a vast business relationship with other Canadian competitors. Supplier 3 is also leading the sustainability category. The reason is supplier 3 got more scores for geopolitical sustainability because of their Canadian facilities. Supplier 3 is the only alternative that has facilities and distribution centers in Canada. This factor will give them the upper hand in case of any possible political conflict or natural disaster overseas. This factor also contributed a lot to the location attribute and led supplier 3 to a better position in the supplier category compared to supplier 2.

4.5 TOPSIS Model

AHP and fuzzy-AHP models were formed based on the surveys with very diverse participants. From sales forces to the CEO of the company. Different groups were involved, and obviously, each group of people has their biased preferences based on their background and specialties. For instance, it is assumed that the members of the supply chain department have different perceptions about the criteria compared with the product department team or the sales department. Consequently, we decided to run the TOPSIS model only with the executives in the product development department, who are the final decision maker in choosing a new supplier. Also, based on the pairwise comparison of the alternatives done by the product department executives, it was determined that the suppliers are equal for various criteria. So, we decided to remove the criteria, the score of which for all suppliers are identical from the criteria list, and form a decision-maker team consisted of the product development executives and see if the result is different from AHP and fuzzy-AHP model.

First, the decision-maker (DM) committee was formed. The committee members are the product development VP, two senior market managers, and two product managers to join the team. A new list of criteria consisted of those with unequal scores for the alternatives was given to the DM team to assign their importance. As discussed previously, we used the Likert scale for the questionnaire and eventually converted the Likert scale to the AHP scale. Subsequently, the weight of the criteria was calculated using the AHP method. The list of the criteria and their assigned weights are shown in table 17. The consistency ratio is also calculated, and it is 0.5% which is way below the 10% threshold. This number shows the consistency of the given answers.

As can be seen, the most important criterion is delivery which is aligned with the result of other methods. Financial status, coverage rate, net price, durability, and reliability are of equal importance.

Table 33 Criteria importance assigned by product department DM using AHP

Criteria	Weight	Rank
DELIVERY	0.1428	1
FINANCIAL STATUS	0.1232	2
COVERAGE RATE	0.1232	2
NET PRICE	0.1232	2
RELIABILITY	0.1232	2
DURABILITY	0.1232	2
HBWC	0.0600	7
DEFECT RATE	0.0600	7
BRAND	0.0438	9
LOCATION	0.0301	10
MARKET SHARE	0.0238	11
GEOPOLITICAL	0.0238	11

In the next step, the DM team confirmed their previous pairwise comparison for the alternatives and assigned the same weights associated with each criterion. The normalized decision matrix for alternatives and criteria is shown in table 34. Using equations 20 and 21 and assigned weights for each supplier, the standardized decision matrix is calculated and shown in table 35.

The most and the least distance of the ideal solution for each supplier and criteria are calculated in the next step. That is, the alternatives distance from the most negative and the most favorable solutions. Using equations 22, 23, 24, and 25, we calculated the geometric distances. The result is shown in table 36.

Table 34 normalized decision matrix

	S1	S2	S3
FINANCIAL STATUS	0.0609	0.6366	0.3025
LOCATION	0.1151	0.1211	0.7638
MARKET SHARE	0.6000	0.2000	0.2000
HBWC	0.7225	0.1741	0.1033
BRAND	0.5000	0.2500	0.2500
COVERAGE RATE	0.6232	0.1373	0.2395
NET PRICE	0.1374	0.7798	0.0828
DELIVERY	0.0588	0.4706	0.4706
GEOPOLITICAL	0.1429	0.1429	0.7143
RELIABILITY	0.2000	0.4000	0.4000
DURABILITY	0.2741	0.3630	0.3630
DEFECT RATE	0.0774	0.4613	0.4613

Table 35 weighted standardized decision matrix

	S1	S2	S3
FINANCIAL STATUS	0.0075	0.0784	0.0373
LOCATION	0.0035	0.0036	0.0230
MARKET SHARE	0.0143	0.0048	0.0048
HBWC	0.0433	0.0104	0.0062
BRAND	0.0219	0.0110	0.0110
COVERAGE RATE	0.0768	0.0169	0.0295
NET PRICE	0.0169	0.0960	0.0102
DELIVERY	0.0084	0.0672	0.0672
GEOPOLITICAL	0.0034	0.0034	0.0170
RELIABILITY	0.0246	0.0493	0.0493
DURABILITY	0.0338	0.0447	0.0447
DEFECT RATE	0.0046	0.0277	0.0277

Table 36 Geometric distances

	Si Plus			Si Minus		
	S1	S2	S3	S1	S2	S3
FINANCIAL STATUS	0.0050	0.000	0.002	0.0000	0.0050	0.0009
LOCATION	0.0004	0.000	0.000	0.0000	0.0000	0.0004
MARKET SHARE	0.0000	0.000	0.000	0.0001	0.0000	0.0000
HBWC	0.0000	0.001	0.001	0.0014	0.0000	0.0000
BRAND	0.0000	0.000	0.000	0.0001	0.0000	0.0000

COVERAGE RATE	0.0000	0.004	0.002	0.0036	0.0000	0.0002
NET PRICE	0.0063	0.000	0.007	0.0000	0.0074	0.0000
DELIVERY	0.0035	0.000	0.000	0.0000	0.0035	0.0035
GEOPOLITICAL	0.0002	0.000	0.000	0.0000	0.0000	0.0002
RELIABILITY	0.0006	0.000	0.000	0.0000	0.0006	0.0006
DURABILITY	0.0001	0.000	0.000	0.0000	0.0001	0.0001
DEFECT RATE	0.0005	0.000	0.000	0.0000	0.0005	0.0005

Eventually, by using equation 26 relative closeness of the alternatives is calculated. The final result is shown in table 37.

Table 37 Closeness to the positive ideal solution

alternatives	Closeness	Rank
S1	0.3594	3
S2	0.6397	1
S3	0.4120	2

TOPSIS model by emphasizing criteria, the suppliers' score for which are not equal, and taking the product department executives' opinion also leads to the same selection and choosing supplier 2 as the selected alternative. However, it gives more scores to the selected supplier.

4.6 Result Analysis

In this section, we intend to discuss the results and evaluate the situation such that under what condition the selected alternative could be different.

As explained earlier, we have three alternatives with different statuses. Supplier 1 is a well-known manufacturer which is respected in the field. They had many innovations and initiations in this field and developed many different product lines. Thus, they have the most extensive offering program and coverage rate. Although their famousness lets them have various customers in the North American market, they do not have business with Canadian competitors, which is a significant advantage. The company has been in business with Supplier 1 for a very long time, and there is an existing relationship. Recently, Supplier 1 showed weakness in delivering the orders promptly, and there is some verified news that they have financial difficulties, which was the main reason for the recent supply chain disruptions.

Supplier 2 is a first-tier manufacturer with a very vast production capacity and operations. They have verified quality and enjoy state-of-the-art technology. They offer a relatively acceptable coverage rate which covers the most popular items. They also quoted very competitive pricing along with promotional programs. They have been very flexible during the negotiations, which is very satisfying for the executives. They have some domestic customers, which is a negative point for them.

Supplier 3 is also a first-tier manufacturer with a very extensive offering, and their coverage rate is better than supplier 2. However, their pricing was not even close to that of supplier 2. The most significant advantage of Supplier 3 is their Canadian facilities. They are the only alternative with facilities in Canada which led to higher scores in associated criteria.

Having described the weakness and strengths of each alternative, we can now analyze the result and consider different scenarios. Figures 4-1 and 4-2 depict the score of each alternative for all the criteria. As shown in figure 4-1, Supplier 1 has the least score for service and product criteria. Supplier 2 got the best score for the Product criterion under their competitive pricing, advanced technology, and potentially better quality. Although Supplier 1 has weak financials, they got the best score for the Supplier criterion because of their relationship with the Company and their widely accepted market share. Supplier 3 got a better score for the Supplier criterion than Supplier 2 and got the best score for sustainability, thanks to their Canadian facilities.

The scores related to the sub-criteria are shown in figure 4-2. Some interesting facts are illustrated in this figure. As can be seen, S2 has the best-quoted price, and the difference is so significant that the fuzzy-AHP model gives all the scores of this criterion to Supplier 2. Supplier 1 got the lowest score for the delivery criterion, which severely impacted their final score. Supplier 2 is also the best alternative in terms of financial situation. Canadian facilities led S3 to become the best alternative in terms of location and geopolitical sustainability.

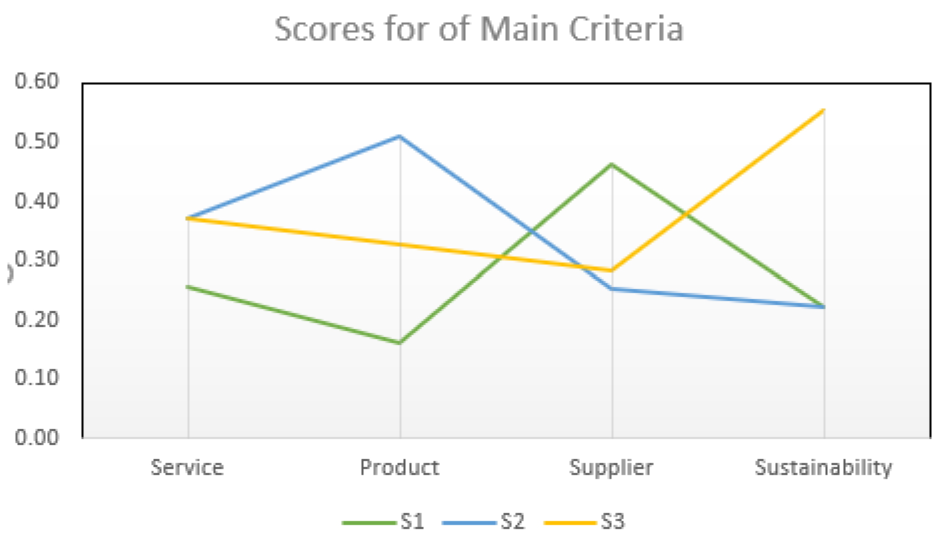


Figure 4-1 Scores of Main Criteria

Using these analyses, we can see that if Supplier 2 will be able to open one or two distribution centers in Canada, they will be better positioned in this competition, and there will be more gaps between Supplier 2 and Supplier 3. On the other hand, Supplier 3 can become the best alternative by improving their pricing and offering more promotional and supporting programs, which will be interpreted as their financial strength. Supplier 1 can solve their supply chain bottleneck and repair the disrupted product network by improving their financials. They also need to find more qualified vendors to offer better and qualified products as they used to do so.

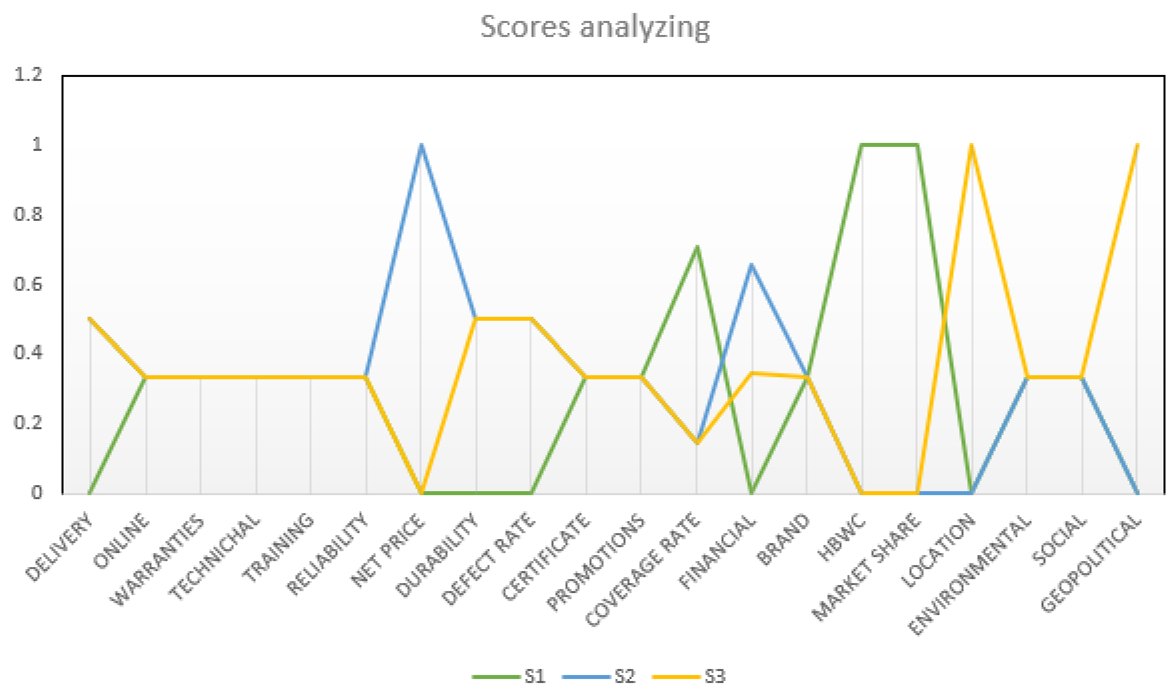


Figure 4-2 Scores of Sub Criteria

5 Conclusion

This project was conducted with the collaboration of a leading company in the automotive aftermarket spare parts business. The company was facing some supply chain disruptions from one of its suppliers, which caused lower fill rates and significant delays. This negative aspect could cause lost sales and client dissatisfaction. Therefore, I decided to use a multi-criteria decision-making process to help the company make the ultimate decision. There were three alternatives, including the current supplier, among which one alternative had to be selected. The very first step in any MCDM problem is determining the methods. There are numerous methods in this domain, and as was explained in the literature review and model description (chapters 2 and 3), we chose three methods for constructing the model AHP, fuzzy-AHP, and TOPSIS. There are two reasons that these methods were chosen. First, these are among the most popular and used methods for MCDM problems in the literature. Second, similar studies that were conducted in the automotive business also applied these methods. It is noteworthy that the rationale behind selecting more than one method is to compare the results. In this project, we compared the results of different methods and took initiation of focusing on more important criteria among the selected criteria in the TOPSIS model to have a better understanding of the weaknesses and strengths of the alternatives

5.1 Using Results in Practice

Having selected the methods, I needed to identify the criteria. An extensive list of criteria was derived from the literature. Then, a group of managers was formed, and the more important criteria from that list were picked. The group also added some criteria that are important in the company's strategy.

For the next step, I had to conduct surveys to gather the information and data to determine the criteria' importance and weight. The targeted participants of the primary survey were high-rank executives of the company (from product managers to the CEO). However, I took another initiation in this project and executed the surveys in two phases. For the first phase, I asked the sales forces to participate in the survey as I wanted to take their opinion and share it with the executives. In other words, I wanted the sales forces' opinion to impact the result by affecting the executives' opinion indirectly. The participation rate for both phases was acceptable.

After gathering the data, the calculations were done, and the weight of each criterion was determined. Then, one more time, a group of managers was formed for ranking the alternatives in pairwise comparisons. Subsequently, the calculations were done for each method, and the results were on hand.

Supplier 2 was selected as the best alternative in the AHP method. The gap between the first rank and second rank, Supplier 3, was tight (0.36 vs. 0.35). By virtue of very competitive pricing and good quality, Supplier 2 could gain more scores for the criteria within the product category. However, Supplier 3 has the best score in sustainability thanks to their facilities in Canada which mitigate the risk of any unforeseen tariff changes or political conflicts. This advantage also led them to gain more scores for the criteria within the supplier category.

I thought that fuzzy-AHP would help us to have a meaningful difference between the selected alternative and the second rank. On the one hand, fuzzy-AHP is well-known for uncertain situations, and it is a useful method in conditions with high uncertainties. On the other hand, in fuzzy-AHP, if the difference between alternatives for specific criteria is meaningful, the method gives all the scores for that specific criterion to the best alternative. For example, in our model, Supplier 2 had all scores for the net price as they have better pricing than other alternatives. This does not mean that other alternatives' pricing is not acceptable. It implies that since one alternative is meaningfully better than the others, the supplier with the best price gets all the available scores for that criterion. This approach is the big difference between AHP and fuzzy-AHP.

Interestingly, Supplier 2 and Supplier 3 gained the very same score in the fuzzy-AHP method. Although they have advantages and disadvantages in different fields, the general score is identical based on the given weights to the criteria.

Having run two models, I realized that there are criteria for which all alternatives have equal scores. So, I decided to run the TOPSIS model to evaluate the suppliers based on the criterion, the scores of which are different for the alternatives. The other difference is the fact that only product executives were involved in creating the TOPSIS model. The result was aligned with other methods. Nevertheless, the difference is more noticeable, which shows Supplier 2's strengths are those for which product development department executives are looking. Thus, the result was shown that Supplier 2 is meaningfully better than Supplier 3. In all models, Supplier 1 had the lowest rank.

After analyzing the results, the decision-maker team comprehended that the considerable advantage for Supplier 3 is their Canadian facilities. So, if Supplier 2 had a distribution center in Canada, they would have been selected as the best alternative with a big difference in all models. Consequently, Supplier 2 was advised to open some facilities in Canada. After some rounds of negotiations, they accepted to use a third party logistic company (3 PL) to stock the popular items in Canada in advance, which also let them ship the products from their factory in East Asia directly to Canada and avoid tariffs that they had to pay to the U.S. government.

Since Supplier 1 has had a history of having business with the company for many years, the DM team shared the results and their identified weaknesses. If they can enhance their supply chain and reduce the lead time, use cost-saving methods for reducing the net price, and use more qualified suppliers, they can continue competing in the market. Otherwise, the company will not be the last customer, which will end the business with them.

5.2 Contributions and Limitations

This project was done using actual business world data, provided some insights for the company's executives, and contributed to their final decision. Although there are many studies on the supplier selection problem for the automotive industry, we have not seen any study conducted in North America in general and the Canadian market in particular.

Some limitations can be indicated. First, the supplier selection for this project mainly focused on a specific product line, and the DM team had to focus on associated criteria for this product category. Also, the project was conducted during the Covid-19 supply chain disruptions, which might have led to a biased emphasis on the criterion related to delivery and financials criteria. The other noteworthy limitation was the limited number of participants in our surveys. Since we only gathered the information from one company in the field, we had few participants for our surveys—43 in the first phase and 18 in the second one. Although the result was helpful for the company, one should pay attention that the result cannot be interpreted as the whole business ideas and opinions.

We recommend conducting a study with different weights for participants in the survey or the DM team members for future studies. Also, a study with various product lines and executives from different companies can contribute to the studies in the MCDM field.

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7 APPENDIX

7.1 First Phase Survey Questionnaire

Please rank the criteria and their components in the provided tables per your expertise and experience.

Please compare the criteria for suppliers or manufacturers of application parts, which are in high demand and require medium labor for installing—the products like brake pads, hub bearings, belts, filters, etc.

The definitions of criteria are provided in the tables. Please read them thoroughly as it let you have a better comparison.

Your time and cooperation are much appreciated.

Main Criteria: Please assign your preference to the following criteria. 0 means not important at all, and 9 is a score to the most important criterion.

Main Criteria	0	1	2	3	4	5	6	7	8	9
Cost										
Quality										
Service										
Reputation										

Cost: the final price which a product has considering the net price and the associated discounts and promotions.

Quality: Product performance to expected standards and OEM fit, form, and function.

Service: A supplier's ability to consistently supply an acceptable and correct product at the required time and provide services that help us have the upper hand in the market.

Reputation: The market perception of a supplier, their products, and trustworthiness.

1) Components of criteria: Cost

Sub-Criteria	0	1	2	3	4	5	6	7	8	9
Net Price										
Promotions and special offers										

Net Price: The price of the product.

Promotions and special offers: Suppliers (or a program) support promotion during the year.

2) Components of criteria: Quality

Sub-Criteria	0	1	2	3	4	5	6	7	8	9
Product Durability										
Product Reliability										
Certification and Quality Assurance										
Defect Rate										

Product Durability: Ability of a product to remain functional without requiring excessive maintenance or repair when faced with the challenges of regular operation over its design lifetime.

Product Reliability: The likelihood that a product will not fail within an expected time period.

Certification and Quality Assurance: Certificates and standard confirmations acquired by the supplier for their products confirm the expected qualities and standards.

Defect Rate: The percentage of defected or rejected products in case you have access to this information.

3) Components of criteria: Service

Sub-Criteria	0	1	2	3	4	5	6	7	8	9
Delivery Time										
Training Support										
Technical Support										
Warranties										
Online Catalog										

Delivery time: The time between when an order is made and when it is received.
Training Support: Supplier's capability, resources, and engagement for providing technical training for the technicians.

Technical Support: Supplier's capability and dedication to have a technical customer service team respond to field calls.

Warranties: The length of the warranty for a specific product and the simplicity of the warranty process.

Online Catalog: An online catalog with broad technical information that helps you pick the right product.

4) Components of criteria: Reputation

Sub-Criteria	0	1	2	3	4	5	6	7	8	9
Brand Awareness										
Coverage Rate										

Brand awareness: Knowledge of the brand(s) manufactured by the supplier.

Coverage Rate: Supplier's ability to offer a broad product range meeting majority of customer expectations.

7.2 Second Phase Survey Questionnaire

Dear Sir/Madam

This project aims to deliver a model to rank suppliers in the automotive aftermarket based on specific criteria. Your positions uniquely qualify you to comment on market expectations and the importance of the criteria.

First, we asked the sales forces, who are the bridge between the customers and the company, to rank the criteria upon the market expectations they are aware of. We have this presumption that the sales forces are in touch with the customers and know their expectations. The results are exciting and are consistent with our strategy in the market. The rationale behind doing the first phase with the sales forces is to let the executives and managers rank the criteria considering the market's expectations. In other words, the main result will be determined by the second phase survey being executed with managers and executives. However, we would like to have the sales forces opinion as an indirect factor affecting the executives' opinion.

In the first phase, we defined four main criteria, each of which has components. We asked sales forces to assign an importance score (on a zero to ten scale) to any of these criteria.

Here is the ranking and the weights of the main criteria from the first phase. As you can see, service is the most important criterion and is following closely by quality. Interestingly, the cost has the least importance upon our sales force's opinion.

Main Rank	Criteria	weight
1	SERVICE	0.3420
2	QUALITY	0.3297
3	REPUTATION	0.1966
4	COST	0.1317

As mentioned before, each criterion has some components. Here is the ranking for the components:

COST		rank
NET PRICE	0.5958	1
PROMOTION	0.4042	2

QUALITY		rank
RELIABILITY	0.3563	1
DURABILITY	0.2936	2
DEFECT RATE	0.1759	3
CERTIFICATE	0.1741	4

SERVICE		rank
DELIVERY	0.2637	1
ONLINE	0.2002	2
TECHNICAL	0.1933	3
WARRANTY	0.1913	4
TRAINING	0.1515	5

REPUTATION		rank
COVERAGE	0.613206	1
BRAND	0.386794	2

Comparison:

Please rank the criteria and their components in the provided tables per your expertise and experience.

Please compare the criteria for suppliers or manufacturers of application parts, which are in high demand and require medium labor for installing—the products like brake pads, hub bearings, belts, filters, etc.

The definitions of criteria are provided in the tables. Please read them thoroughly as it lets you have a better comparison.

Your time and cooperation are much appreciated.

Main Criteria: Please assign your preference to the following criteria. 0 means not important at all, and 9 is a score to the most important criterion.

Main Criteria	0	1	2	3	4	5	6	7	8	9
Supplier										
Product										
Service										
Sustainability										

Supplier criteria: evaluates whether the supplier fits its supply and business strategy. It includes vital strategic points associated with the supplier—factors like financial status, management, geographical location, etc.

Product Criteria: Product performance criteria examine essential characteristics of the purchased product, such as price and quality.

Service Criteria: A supplier's ability to consistently supply an acceptable and correct product at the required time and provide services that help us have the upper hand in the market.

Sustainability Criteria: The supplier commitment to environmental and social sustainability as well as the political and social situations in the country where they have facilities

Components of criteria: Supplier

Sub-Criteria	0	1	2	3	4	5	6	7	8	9
Financial status and strength										
Geographical location										
Market share										
Having a business with competitors										
Brand awareness										
Coverage rate and products offering extensiveness										

Financial status and strength: one of the essential elements in the supplier-buyer relationship is a long-term commitment and supporting different programs which need financial strength. The financial status of the supplier can be an excellent indicator to provide this key element.

Geographical location: it is vital as it has effects on delivery times, probable overhead expenses, tariffs, transport cost, etc.

Market share: the supplier's current situation in the domestic market.

Having a business with competitors: the supplier’s relationship with our competitors in the Canadian market.

Brand awareness: Knowledge of the brand(s) manufactured by the supplier.

Coverage rate and the product range extensiveness: Supplier’s ability to offer broad product range meeting majority of customer expectations.

Components of criteria: Product

Sub-Criteria	0	1	2	3	4	5	6	7	8	9
Net price										
Offered promotions										
Product reliability										
Product durability										

Certification and Quality Assurance										
Defect rate										

Net price: The price of the product.

Offered promotions: Suppliers (or a program) support promotion during the year.

Product reliability: The likelihood that a product will not fail within an expected time period.

Product durability: Ability of a product to remain functional without requiring excessive maintenance or repair when faced with the challenges of regular operation over its design lifetime.

Certification and Quality Assurance: Certificates and standard confirmations acquired by the supplier for their products confirm the expected qualities and standards.

Defect Rate: The percentage of defected or rejected products in case you have access to this information.

Components of criteria: Service

Sub-Criteria	0	1	2	3	4	5	6	7	8	9
Delivery Time										
Training Support										
Technical Support										
Warranties										

Online Catalog										

Delivery time: The time between when an order is made and when it is received.

Training Support: Supplier's capability, resources, and engagement for providing technical training for the technicians.

Technical Support: Supplier's capability and dedication to have a technical customer service team respond to field calls.

Warranties: The length of the warranty for a specific product and the simplicity of the warranty process.

Online Catalog: An online catalog with broad technical information that helps you pick the right product.

Components of criteria: Sustainability

Sub-Criteria	0	1	2	3	4	5	6	7	8	9
Environmental										
Social										
Geopolitical										

Environmental sustainability: responsible interaction with the environment to avoid depletion or degradation of natural resources and allow for long-term environmental quality. The practice of environmental sustainability helps to ensure that the needs of today's population are met without jeopardizing the ability of future generations to meet their needs.

Social sustainability: social sustainability performance issues include human rights, fair labor practices, living conditions, health, safety, wellness, diversity, equity, work-life balance, empowerment, community engagement, philanthropy, volunteerism, and more.

Geopolitical sustainability: political and social status in the country where the supplier or its main facilities are located. It is not limited to that specific region or country situation but relates mainly to that country or region's collaboration with other parts of the world (in this case, the U.S. and Canada).