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Evaluating and Ranking Supply Chain Distributors Using FAHP and FANP Methods

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Abstract

The current trend of the global market highlights the necessity of establishing long-term relationships between organizations and global distributors worldwide. The selection of unknown international distributors represents a highly critical multi-criteria decision-making problem for organizations. With the increasing importance of purchasing and procurement activities, purchasing decisions have become more crucial. Moreover, as organizations have become increasingly dependent on distributors, the direct and indirect consequences of poor decision-making have become more severe. In most industries, the cost of raw materials and product components constitutes a major portion of the total product cost. In this study, after reviewing previous research in the field of supply chain management, the selection of a distribution network from among available distributor alternatives is addressed. To this end, relevant scientific articles and books were first reviewed, and based on the research literature, critical and influential factors for achieving effective supply chain management were identified. Subsequently, by consulting experts from the relevant company, the desired and important factors specific to the company were determined. The identified criteria were then weighted using the Fuzzy Analytic Hierarchy Process (FAHP) and the Fuzzy Analytic Network Process (FANP). Finally, using these methods, the best distribution network was selected.

Keywords: Fuzzy analytic hierarchy process, Fuzzy analytic network process, Supply chain, Distribution network.

1 | Introduction

In the 1960s and 1970s, organizations sought to enhance their competitive capabilities by standardizing and improving their internal processes in order to produce higher-quality products at lower costs. At that time, the dominant view was that strong engineering and design, along with integrated and coordinated production operations, were prerequisites for meeting market demands and, consequently, gaining a larger market share. For this reason, organizations focused all their efforts on increasing efficiency.

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In the 1980s, with the growing diversity of customer expectations, organizations increasingly became interested in developing and introducing new products to satisfy customer needs. In the 1990s, alongside improvements in production processes and the adoption of reengineering approaches, managers in many industries realized that merely improving internal processes and enhancing organizational flexibility were no longer sufficient to remain competitive in the market. Rather, suppliers of parts and materials also had to produce inputs of the highest quality at the lowest possible cost, and product distributors needed to maintain close alignment with the manufacturer's market development policies.

Distribution and delivery systems consist of a chain of businesses or intermediaries through which a product or service is delivered accurately to the customer. One of the most important concerns of both customers and producers is the proper distribution of products to the right locations and target customers. Effective product distribution can serve as a competitive advantage for an economic enterprise over its rivals. Moreover, selecting the distribution channel and distribution method is one of the most critical decisions that managers and producers must consider, since the distribution and delivery system plays a prominent and significant role in achieving companies' sales objectives and in exposing their products to buyers and consumers. When this process is carried out correctly, positive outcomes are achieved.

The most common distribution systems in Iran are generally classified into several categories:

I. Distribution through wholesale networks.

II. Distribution through distribution companies and the design of various sales networks.

III. Capillary (intensive) distribution.

IV. Distribution through independent distributors.

Current global market trends highlight the necessity of establishing long-term relationships between organizations and global suppliers worldwide. Selecting the optimal distribution network is a highly critical multi-criteria decision-making problem for organizations [1].

The distribution system of goods and services is among the most important sectors in national economies. On the one hand, it provides goods and services to consumers, and on the other hand, it delivers information and liquidity to production sectors (domestic or international). In most countries, the expanded use of modern tools and methods for storage, arrangement, transportation, and ultimately distribution of goods and services—while complying with various standards and minimizing costs and time in the relevant processes—is considered an indicator of development and progress in the distribution system. It is worth noting that, in addition to the vital role of an efficient distribution system in supporting consumers, the growth and development of production sectors in a dynamic economy also require the existence of an effective distribution system. What contributes to the efficiency of such a system is the operation of distribution enterprises within a competitive environment, with minimal cost and time, while complying with various health standards and consumer rights throughout all processes of transportation, storage, and sales [2].

Accordingly, based on existing research, three key factors, cost, time, and distribution quality, are among the most important criteria for product distribution. In practice, considering the shortcomings of existing distribution systems, most producers with high volume and product diversity, recognizing the critical importance of distribution strategy, product delivery, customer accessibility, and control over distribution methods, seek to select the most suitable distribution system for their products. Therefore, this study examines the selection of the optimal distribution method for automotive parts. The main issue addressed in this research is solving the current problems of the automotive parts distribution system. According to research findings and expert opinions, today's automotive parts distribution system faces major challenges, including the added value of the distribution process reflected in product prices and deficiencies in distribution quality, which are among the most significant problems of traditional and current distribution systems.

Decision-making regarding the structure of distribution channels is of particular importance for at least two reasons. First, the choice of distribution channel has a substantial impact on other company programs. For example, a company's pricing policy depends on whether sales rights are granted to a limited number of intermediaries with high profit margins or whether the product is distributed widely. Likewise, the extent of advertising for a product depends on the level of cooperation among channel members. Second, selecting a distribution channel requires a long-term commitment [3].

In this project, the researcher aims to examine various dimensions of the subject and, by providing justifications, to answer the following questions:

In this research, the methodology is divided into two parts: theoretical and practical. In the theoretical section, information related to selecting the optimal distribution network is gathered from relevant articles and books and documented in different sections of the study. In the practical section, a manufacturing company producing automotive parts is examined, and with the participation of company managers, the most important criteria for selecting an appropriate distribution network are identified. In the practical phase, after collecting the required data and information, the Analytic Hierarchy Process (AHP) is used to weight the identified criteria. Subsequently, based on the prioritized criteria, a suitable distribution network is selected from among existing alternatives using the Fuzzy Analytic Network Process (FANP).

2 | Literature Review

The national goods distribution system requires the establishment of a new institution entitled the National Marketing Center for purposes such as branding, targeted advertising, coherence within the distribution network, clustering, and related activities. Through managing and supervising a modern procurement and distribution network with the participation of six governmental ministries and private and cooperative distribution entities such as distribution companies, chain stores, guilds, wholesalers, and others, the National Marketing Center can contribute to shortening distribution channels, reducing commodity prices, and improving overall efficiency. At the end of the article, a network-based model of goods procurement and distribution is presented, illustrating the position, roles, and interactions of various actors within the national distribution network. The first step in developing the distribution industry is to introduce its position and functional role within the economic system. Authorities in different sectors must shift their perspective from viewing this industry as merely intermediary-based (brokerage-oriented) toward recognizing it as an influential industry in the core dynamics of the market. This industry has the potential to enter highly challenging sectors such as fruit markets or strategic commodities like flour and wheat sectors, in which, due to significant information gaps, substantial national resources are lost annually. The distribution industry in the country should be freed from the dominance of manufacturing companies and the government and operate independently with the participation of the private sector and domestic and foreign investors. Only under such conditions can the true form of this industry and its optimal performance be observed at full capacity [2]. In the past, various manufacturing conglomerates that produced large volumes of nationally reputable branded products, recognizing the critical importance of distribution strategy, product delivery, ease of access for customers, control over distribution methods, and market management, established their own specialized distribution companies. These entities are currently regarded as some of the strongest and most reputable distribution companies in the country. An important point is that large manufacturing complexes and firms with independent distribution networks generally enjoy stronger brand recognition, more active market presence, and generate substantial profits for their factories through product sales. In contrast, companies that rely on external distribution networks do not benefit from these advantages or benefit only marginally, while incurring high costs for product distribution and brand positioning in the market [4].

Among the advantages of purchasing from extensive distribution networks for retail businesses are free transportation services, the ability to manage store inventory at minimal levels, and rapid access to required goods. Moreover, wide distribution networks provide various benefits to different segments of society. End consumers are able to obtain products from different manufacturers within their place of residence, even in very remote areas of the country, and make use of them [5]. The distribution industry is one of the key and infrastructural industries in the economy of any country. Its 8–9% share of national income clearly indicates the vast scale of this industry and, consequently, its crucial role in the supply chains of many national industries. At a time when producers are striving to secure liquidity and profitability for survival and growth, while consumers struggle to maintain their purchasing power, improving the efficiency of the distribution industry as the intermediary link between producers and consumers, which accounts for a significant portion of the final price, is of great importance. In other words, reducing transaction costs in the distribution industry can lead to lower final prices, increased profit margins for producers, and reduced purchase prices for consumers, especially under current conditions where economic recession affects many industries. This is while, in some cases, the share of the distribution industry in the final price of products reaches nearly 50%. What matters most in a national distribution network is the transfer of goods at the lowest possible cost and time, while adhering to standards required to maintain product quality and ultimately better protect consumer rights. The distribution network in Iran faces numerous and diverse challenges, including the excessive number of traditional retail units, the prevalence of unlicensed retail businesses, the dominance of the unorganized sector over the organized distribution network, insufficient use of modern distribution tools and methods, and a lack of adequate interest from private and foreign investors in modern distribution networks. These are among the most significant challenges facing the distribution industry in Iran [3].

2.1|Types of Distribution Networks

A distribution network refers to a group of companies and individuals who receive products from manufacturers and deliver them to consumers. In most cases, intermediaries and brokers perform this function. It is commonly believed that brokers and intermediaries cause prices to rise, particularly when their number within a distribution network is high. This belief is partly correct; however, eliminating intermediaries does not necessarily lead to price reductions. Intermediaries also offer certain benefits. Their positive roles can be explained as follows: to increase efficiency and reduce operational workload, it is preferable to use intermediaries and brokers for product distribution. If manufacturers were to sell their products directly themselves, it would not be financially or economically viable. Intermediaries act as a link between producers and consumers. Manufacturers often lack sufficient information about customers and consumers, especially when export markets are targeted, making intermediaries the best option for facilitating communication between producers and consumers. Distribution networks not only deliver produced goods to consumers or wholesalers but also play a role in advertising and product promotion [6].

Distribution refers to delivering the right product, at the right time, and in the right place to target customers. Distribution is one of the fundamental pillars of marketing tactics and, together with other factors such as product, price, and promotion, is used to persuade customers. Effective distribution can create a competitive advantage for a firm over its competitors.

The five main categories of tasks in a distribution network are:

I. Storage and warehousing of goods for distribution

II. Receiving orders from customers

III. Delivering goods to customers

IV. Collecting receivables

V. Monitoring and obtaining market information

The first type of distribution network involves distributing goods through wholesale distribution networks. These companies hold large inventories of various products in warehouses owned by them, employ sales forces, and are able to sell goods on credit (installment basis), granting buyers credit and delivering sold goods either at the origin or destination. Most of their transactions are conducted with retailers. They often operate across several product lines and may specialize in one or two product lines or even a segment of a single product line. Wholesalers operating in various industries supply producers with required inputs and may also provide services such as credit provision and transportation (delivery of sold goods).

The second model of distribution networks is distribution through distribution companies. Essentially, because any individual with any level of experience and capital can establish a distribution company, as is clearly observed in the country, especially in large cities such as Tehran, numerous small distribution companies operate in different areas. The risk of working with such companies, both in terms of repayment for sold goods and control over their operational practices, is so high that collaboration with them often lacks any practical justification.

There are also manufacturing complexes with independent distribution networks. Investors and market experts are well aware of the fundamental shortcomings of large distribution companies, and for many years, the country has witnessed the establishment of various distribution companies within manufacturing complexes—a trend that continues to this day. As noted earlier, large manufacturing firms with independent distribution networks generally enjoy stronger brand reputations, more active market presence, and significant profits from product sales. In contrast, firms that rely on external distribution networks lack these advantages or benefit minimally, while bearing high costs for product distribution and brand strengthening in the market.

Capillary (direct) distribution refers to delivering products to the very last retailer. This concept is inspired by the blood circulation system in living organisms. In the human body, blood circulation begins at the heart and flows through arteries and veins, eventually reaching all parts of the body via capillaries. The key point is that this flow originates from a constantly active central heart, an essential principle in capillary distribution networks for goods and services. By simulating the human circulatory system, a continuous and uninterrupted flow is maintained at all times. Similarly, capillary distribution requires a central source, such as a company or its representatives, from which goods and services are distributed through a continuous, ongoing, and uninterrupted flow.

However, it should be noted that capillary distribution is not entirely a new method in practice. As discussed in the review of various distribution channels, all established channels from manufacturing firms to retailers and kiosks collectively form a physical distribution system that starts from a central source and extends to the smallest endpoints, analogous to capillaries in the human body.

2.2 | Criteria for Selecting a Distribution Network

The selection of an appropriate distribution network for delivering goods depends on the type and nature of the product. Based on the studies conducted, the criteria considered by researchers and experts are presented as keywords in *Table 1*.

Table 1. Criteria.

Year & Reference	Selection Criteria
Dickson [7]	Quality, on-time delivery, track record, warranty and return policy, production capability, price, technical capability, financial position, complaint handling system, communication system, reputation and credibility, level of business interest, organizational management, performance controls, after-sales service, staff ethics and behavior, company standing, packaging capability, employee working relationships, geographical location, prior business volume, training support, level of bilateral agreements.
Muralidharan et al. [8]	Quality, on-time delivery, price, technical capability, financial position, supplier work record, flexibility, services.
Humphreys et al. [9]	Price, quality, costs, supplier brand name, use of environmentally friendly materials, flexibility, reputation and credibility, distributor brand.

Table 1. Continued.

Choy et al. [10]	Price, delivery time, customer satisfaction, product quality, after-sales service, supplier flexibility, organizational culture, working relationships, and long-term supply experience.
Dulmin and Mininno [11]	Quality, delivery time, product costs, customer satisfaction, management costs, and transportation process.
Wang et al. [12]	Delivery reliability, delivery flexibility, supply chain responsiveness, price, product flexibility, product transportation costs, product warranty, return parts costs, and return on investment.
Degraeve et al. [13]	Cost, quality, final product price, prior cooperation record with distributor, distributor competence and experience, sales staff capability, and integrity.
Bharadwaj et al. [14]	On-time delivery, product quality, ability to respond to urgent requests, financial transparency, product design capability, after-sales service, and product price.
Lin et al. [15]	Final product quality, cost, delivery time, trust, flexibility and innovation, cooperation, long-term customer–manufacturer relationships, distributor's adoption of new technology, financial transparency, product design capability, component quality.
Liu et al. [16]	Quality, responsiveness, on-time delivery, financial capability, management, technical capability, and supplier facilities.
Araz et al. [17]	Financial strength, reliability, flexibility, information flow, product quality, on-time delivery.
Shyur and Shih [18]	On-time delivery, product quality, product price, technology and production level, responsiveness to customer needs, professionalism of sales staff, and relationship quality.
Chan et al. [19]	Cost, customer satisfaction, quality, financial capability, technical capability, staff training, organizational culture, research and development, and safety.
Hou and Su [20]	Quality, cost, technology, production capability, research and development, on-time delivery, and services provided.
Ha and Krishnan [21]	Production capability, quality management, pre- and after-sales services, quality, on-time delivery, level of organizational control, business planning, and customer communication.
Mendoza and Ventura [22]	Flexibility, quality, price, services, and on-time delivery.
Ho et al. [23]	Quality, on-time delivery, price, services, management, research and development, financial capability, flexibility, reputation, and credibility.

In this study, after collecting the criteria proposed by other researchers, the most frequently cited criteria in the reviewed articles were identified and listed in the form of a frequency table, as presented below.

Table 2. Criteria frequency.

Criterion	Frequency in Articles
Quality	17
Delivery time	15
Cost	14
Services	11
Distribution system flexibility	6
Reputation and credibility	3
Customer communication	5
Financial capability	4
Technology	4
Research and development	3
Customer satisfaction	4

Various methods for distributor selection can be found in the literature, among which linear weighting models are widely used. In these models, weights are assigned to distributors based on different criteria, and by aggregating these weights, each distributor obtains an overall score. By comparing these scores, the most appropriate distributor is selected. This model, which operates based on the classification of criteria, is a simple approach and is considered the fastest, simplest, and least costly to implement. However, it relies heavily on human judgment and is therefore regarded as an imprecise method. The weighted point model can also be implemented easily and is highly flexible and relatively effective in distributor-based decision optimization problems. Compared to the classification method, this approach is more costly; nevertheless, despite still relying on the buyer's judgment, it is more goal-oriented. Total cost–based methods aim to select distributors by assigning numerical values to all cost-related criteria. These methods include the cost ratio method and the Total Cost of Ownership (TCO) method. The cost ratio method is highly flexible; however, it is a complex approach and requires the concurrent development of a cost accounting system. The TCO method is more accurate but significantly more complex and requires greater time and expertise. Fuzzy logic–based methods are used to evaluate the performance of distributors. These methods assist decision-makers in determining the most appropriate order quantities from different distributors [24].

3.2 | Decision-Making Methods: Analytic Hierarchy Process and Analytic Network Process

In 1973, Professor Lotfi Zadeh introduced the concept of linguistic variables or fuzzy variables. In fact, one of the key characteristics of fuzzy logic is the use of a rule-based structure, through which control problems are transformed into a set of rules of the form "if x and y then z", which provide the desired system output for given input conditions. These simple and explicit rules describe the desired system behavior using linguistic variables rather than mathematical formulas. An interesting point is that although fuzzy systems are used to describe uncertain and imprecise phenomena, fuzzy theory itself is a rigorous and well-defined theory [25].

The AHP is one of the most well-known multi-criteria decision-making techniques, first developed by Saaty [26], an Iraqi-born scholar, in the 1970s. This method can be applied when decision-making involves multiple competing alternatives and decision criteria. The criteria may be both quantitative and qualitative. The foundation of this decision-making approach lies in pairwise comparisons. The decision-maker begins by constructing a hierarchical decision tree. This hierarchy illustrates the factors being compared and the competing alternatives under evaluation. Subsequently, a series of pairwise comparisons is conducted. These comparisons determine the relative weights of each factor with respect to the competing alternatives. Finally, the AHP logic integrates the matrices obtained from the pairwise comparisons in such a way that an optimal decision is achieved. The application of AHP in group decision-making not only preserves the advantages of group decision-making techniques but also mitigates their disadvantages (such as speed, cost, and one-dimensional thinking). In this study, an attempt is made to examine the application of AHP in coordinating the decisions of group members. AHP assists senior decision-makers in reaching an optimal decision that incorporates the viewpoints of all members.

The Analytic Network Process (ANP) decision-making method was subsequently developed in 1996 to account for dependence and feedback among decision elements. In 2001, it was revised to consider the analysis of benefits, opportunities, costs, and risks, and finally, in 2005, it was further refined to incorporate negative priorities and various aggregation formulas in both the theory and application of ANP. The network structure used in the context of benefits, opportunities, costs, and risks enables the identification, classification, and organization of all influential factors and components that affect the outcomes of a decision. A decision is only as effective as the framework used to represent the categories (clusters), their elements, and the relationships identified among them that reflect the observed influences. The objective of the ANP decision-making method is to structure the decision-making process according to a scenario influenced by multiple independent factors [27]. This technique enhances the ANP decision-making process as a multi-criteria decision-making tool by replacing hierarchical structures with network structures. A complex problem can be decomposed into several subproblems consisting of hierarchical levels, such that each level contains a set of criteria and alternatives related to each subproblem. In this hierarchical approach, the goal of the problem is considered the highest level, the intermediate levels include factors representing the higher levels, and the final level consists of alternatives or activities that must be considered to achieve the objective.

Among the shortcomings of existing studies is the lack of attention to the country's economic conditions and distribution strategies; most studies have focused solely on distribution systems themselves. However, the essential need today is the selection of distribution networks compatible with the operating environment, which has become one of the major challenges for manufacturers in determining quality, cost, and delivery time to consumers. Therefore, in this study, which focuses exclusively on the distribution of automotive parts, an effort is made to identify the optimal method for distributing automotive parts by taking into account the current conditions of the country. Considering the mathematical approach required to determine the optimal distribution network, the multi-criteria decision-making method FANP is selected as the tool to achieve the research objective, which has been briefly discussed in this chapter.

3 | Research Methodology

Overall, this research is divided into four phases. In the first phase, the criteria for selecting the best distribution network are examined. As mentioned in the previous chapter, the criteria for selecting a distribution network include distribution network quality, delivery time, distribution cost, services, flexibility, professionalism of sales staff, transparent financial performance, transportation process, research and development, financial capability, and others, as identified in prior studies. These criteria will be examined in more detail in the following sections. The second phase involves reducing the number of criteria for selecting the best distribution network using the AHP, in order to achieve greater focus and enable a more effective selection of the optimal distribution network in subsequent stages. The third phase of the research focuses on selecting the best distribution network for automotive parts. In this phase, based on the criteria selected in the previous phase, the FANP is applied to evaluate the distribution networks within the company under study, thereby enabling the selection of the most appropriate automotive parts distribution network. The fourth and final phase of the research involves proposing the selected optimal distribution network from the previous phase to the target factory and collecting the factory's opinions and suggestions.

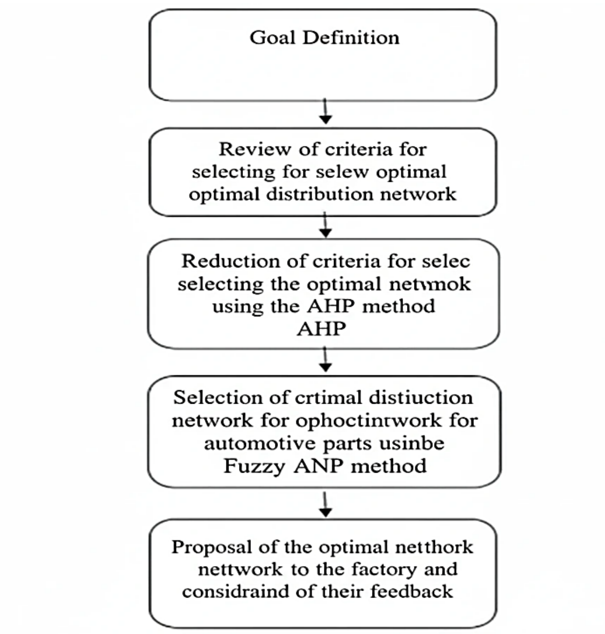

Fig. 1. Diagram of research steps.

After reviewing the criteria based on expert opinions and the conducted studies, several criteria for selecting the optimal automobile parts distribution network were collected, which were presented in the previous section. In this phase, the AHP is employed to weight the criteria and to identify those with higher and more influential weights. The steps of this process are explained as follows.

The questionnaire used for hierarchical analysis and multi-criteria decision-making is known as the expert questionnaire. The expert questionnaire is not particularly complex; rather, it requires accuracy and an appropriate structure. To design the expert questionnaire, pairwise comparisons of the alternatives are used, and none of the pairwise comparisons should be omitted. For scoring, Saaty's nine-point scale is applied. After forming the pairwise comparison matrix, the normalization process is performed to obtain the normalized matrix. This is done by dividing each element of the pairwise comparison matrix by the sum of the elements in its corresponding column and placing the result in the normalized matrix. Subsequently, the weight of each criterion is calculated by dividing the sum of each row by the number of elements in that row, as shown in *Eq. (1)*.

$$\begin{gathered} c_1 = \frac{\frac{x_{11}}{x_{11}+\ldots+x_{m1}} + \ldots + \frac{x_{1n}}{x_{11}+\ldots+x_{m1}}}{n} \\ \ldots \\ c_m = \frac{\frac{x_{m1}}{x_{11}+\ldots+x_{m1}} + \ldots + \frac{x_{mn}}{x_{1n}+\ldots+x_{mn}}}{n} \end{gathered} \tag{1}$$

Next, the criteria are ranked in descending order based on the weights obtained from the above formula. In the subsequent stage, using the FANP decision-making method, the objective is to select the optimal automobile parts distribution system. To this end, the solution procedure of the FANP is first explained. In this section, the fuzzy ANP method is introduced based on the study by Önüt and Soner [28]. This method is particularly suitable in situations where the interdependencies among the criteria for selecting feasible alternatives are substantial. FANP is capable of determining the relationships among criteria straightforwardly. In this approach, the pairwise comparison matrix among the criteria in each row is completed using triangular fuzzy numbers. Accordingly, the parameter values are obtained in the form of triangular fuzzy numbers and are computed under a fuzzy framework.

Saaty's scale is employed for pairwise comparisons in ANP. Although this discrete scale offers considerable simplicity and ease of use, it does not capture the uncertainty and ambiguity associated with an individual's perception and judgment regarding the degree of preference. In other words, a decision-maker may not be able to specify an exact numerical value to express the preference intensity when comparing certain alternatives. For this reason, a fuzzy 1–9 scale based on triangular fuzzy numbers can be used instead of the conventional crisp 1–9 scale. When criterion i is compared with criterion j, the values 1, 3, 5, 7, and 9, respectively, indicate equal importance between the compared criteria, weak preference of i over j, strong preference of i over j, very strong preference, and absolute preference of i over j.

To evaluate the preferences of the decision-maker, the pairwise comparison matrix is constructed using triangular fuzzy numbers (l,m,u). The m×n matrix of triangular fuzzy numbers can be represented accordingly. In the pairwise comparison of alternatives (criteria), the decision-maker (expert) can use triangular fuzzy numbers to determine the degree of preference among alternatives. At the higher level, elements are compared pairwise, and their weights are calculated; these weights are referred to as relative weights. In these comparisons, decision-makers rely on verbal (linguistic) judgments.

There are numerous methods for estimating fuzzy weights W_i based on matrix A, with the approximate relationship $a_{\delta} = w_i/w_j$ such that the fuzzy weight vector $w_i = (w_i^l, w_i^m, w_i^u)$ is obtained for $i = 1,2, \ldots, n$. One of these methods is the logarithmic least squares method [29]. Using this method, triangular fuzzy weights can be calculated for criteria, alternatives, and other elements [30]. Moreover, the fuzzy weights derived from this method can be employed within the fuzzy TOPSIS approach for ranking alternatives [28].

The logarithmic least squares method for calculating fuzzy weights is implemented according to *Eqs. (2)* and *(3)*.

$$w_i = \left(w_k^i, w_k^m, w_k^u\right), k = 1,2,3,\ldots,n. \quad (2)$$

$$w_k^s = \frac{\left(\prod_{i=1}^{n} a_{ij}^s\right)^{\wedge} 1/a}{\sum_{i=1}^{a}\left(\prod_{j=1}^{a} a_{ij}^m\right)^{\wedge} 1/a}. \quad (3)$$

The tools used in this study include library (desk) research, Microsoft Excel software, Expert Choice software, Super Decisions software, and MATLAB software.

4 | Results

In this section, using the designed questionnaire, the opinions of five experts were collected regarding three criteria practical applicability in industry, understandability by managers, and measurability and eleven previously identified criteria, namely distribution quality, delivery time, distribution cost, services, financial capability of distributors, reputation and credibility, customer satisfaction, customer relationship, flexibility of the distribution system, research and development, and technology. These criteria were evaluated based on the three aforementioned dimensions, and their weights were determined using the steps of the AHP.

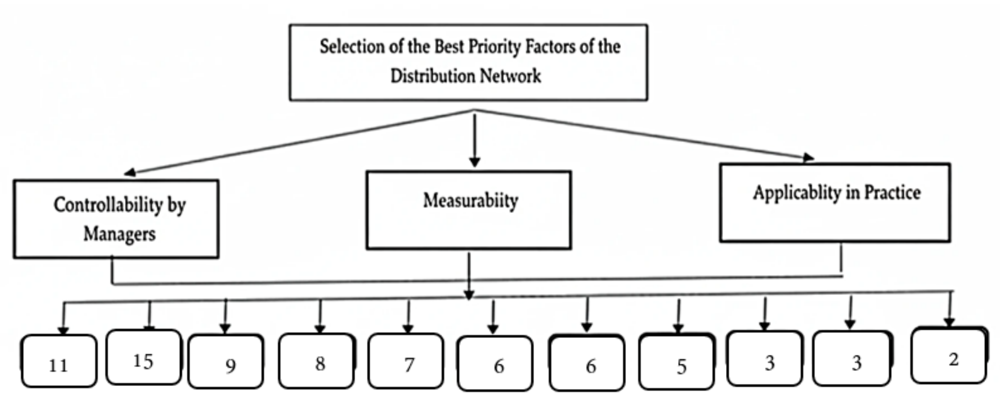

Fig. 2. Analytic hierarchy network diagram.

At this stage, opinions and a decision-making matrix are given to each expert, and their opinions are entered into the software mentioned in the previous section, and the output is listed in the figures below.

Fig. 3. Measurement of criteria by expert 1.

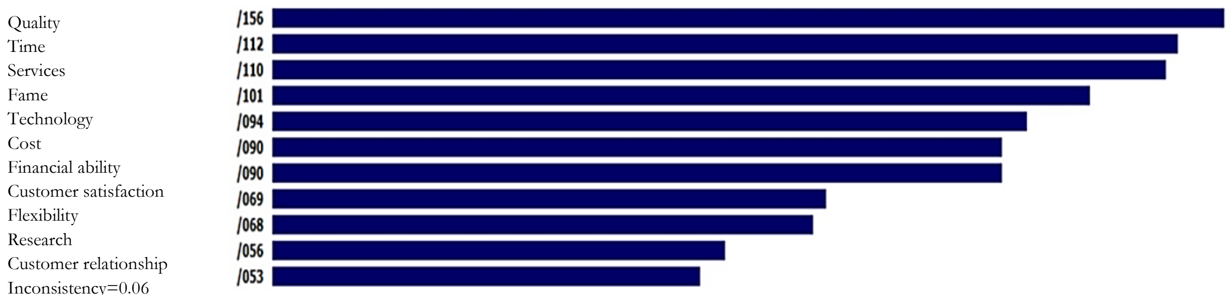

Fig. 4. Software output for industry-applied benchmark by expert 1.

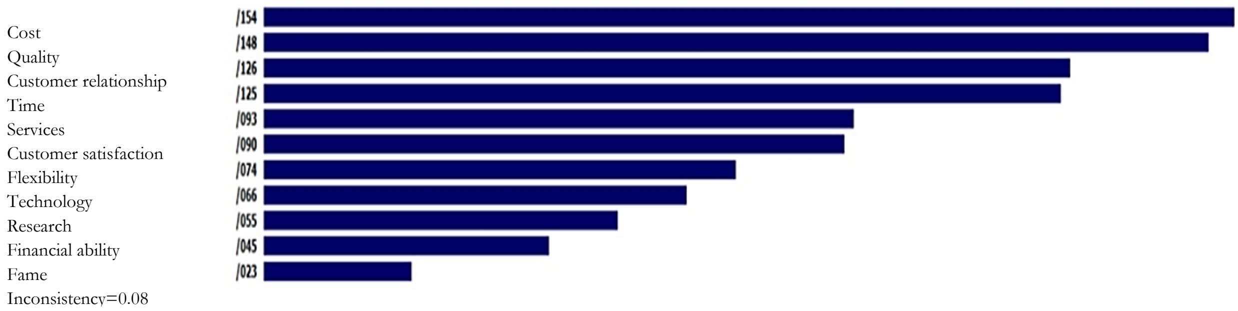

Fig. 5. Software output for the measureability criterion by expert 1.

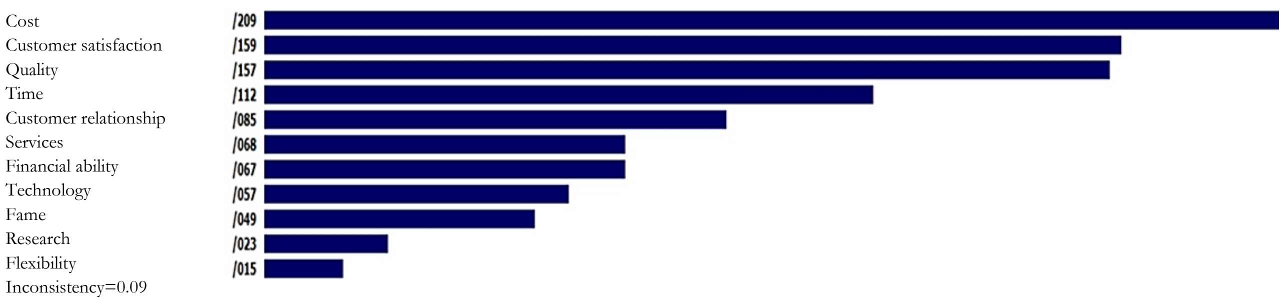

Fig. 6. Software output for the measure of managers' understanding by expert 1.

The following is the measurement of the criteria by Expert 2 in each figure.

Fig. 7. Measurement of criteria by expert 2.

Fig. 8. Software output for industry-applied benchmark by expert 2.

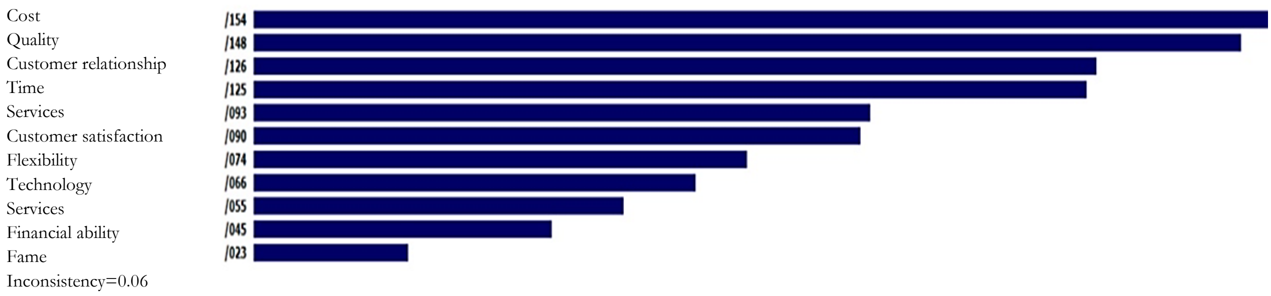

Fig. 9. Software output for the measureability criterion by expert 2.

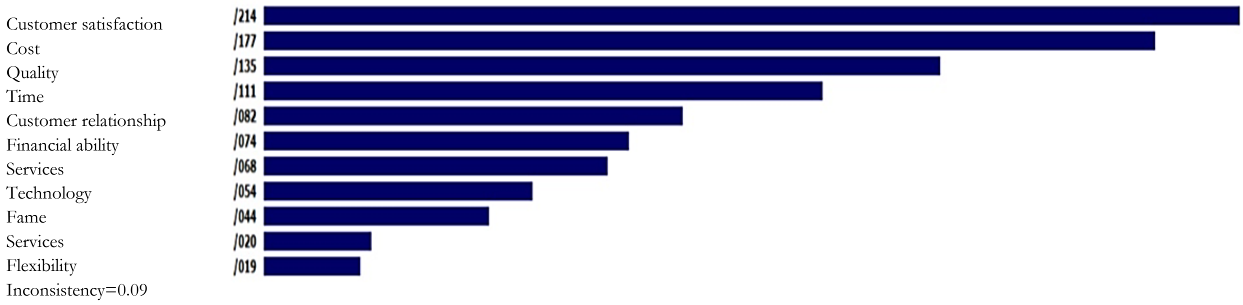

Fig. 10. Software output for the managers' perception measure by Expert 2.

This review was also conducted by expert 3 and obtained the following outputs for each criterion.

Table 3. Calculation table in the software for Expert 3.

Criterion	Real Application in Industry	Weight	Measurability	Weight	Understandability by Managers	Weight	Final Score
Cost	0.263	0.141	0.547	0.152	0.134	0.167	0.14261
Distribution quality	0.263	0.112	0.547	0.151	0.134	0.134	0.13001
Customer satisfaction	0.263	0.127	0.547	0.099	0.134	0.224	0.11757
Time	0.263	0.106	0.547	0.129	0.134	0.124	0.11506
Customer relationship	0.263	0.095	0.547	0.013	0.134	0.087	0.04375
Service	0.263	0.102	0.547	0.089	0.134	0.065	0.08422
Reputation	0.263	0.047	0.547	0.024	0.134	0.04	0.07909
Financial capability	0.263	0.068	0.547	0.072	0.134	0.069	0.06651
Technology	0.263	0.075	0.547	0.068	0.134	0.053	0.06402
Flexibility	0.263	0.068	0.547	0.054	0.134	0.021	0.05024
Research and development	0.263	0.058	0.547	0.039	0.134	0.016	0.03873

Finally, Experts 4 and 5 have their opinions listed in *Tables 4* and *5* using the Fuzzy Analytic Hierarchy Process (FAHP) method.

Table 4. Calculation table in the software for Expert 4.

Criterion	Real Application in Industry	Weight	Measurability	Weight	Understandability by Managers	Weight	Final Score
Cost	0.21	0.101	0.24	0.189	0.55	0.166	0.15787
Distribution Quality	0.21	0.125	0.24	0.187	0.55	0.136	0.14593
Customer Satisfaction	0.21	0.145	0.24	0.105	0.55	0.225	0.1794
Time	0.21	0.123	0.24	0.125	0.55	0.116	0.11963
Customer Relationship	0.21	0.117	0.24	0.168	0.55	0.071	0.10394
Service	0.21	0.122	0.24	0.118	0.55	0.07	0.09244
Reputation	0.21	0.039	0.24	0.03	0.55	0.03	0.03189
Financial Capability	0.21	0.062	0.24	0.081	0.55	0.095	0.08471
Technology	0.21	0.059	0.24	0.057	0.55	0.049	0.05302
Flexibility	0.21	0.074	0.24	0.014	0.55	0.021	0.03045
Research and Development	0.21	0.03	0.24	0.028	0.55	0.022	0.02512

Table 5. Calculation table in the software for Expert 5.

Criterion	Real Application in Industry	Weight	Measurability	Weight	Understandability by Managers	Weight	Final Score
Cost	0.474	0.106	0.376	0.216	0.149	0.176	0.15768
Distribution Quality	0.474	0.148	0.376	0.16	0.149	0.081	0.14238
Customer Satisfaction	0.474	0.113	0.376	0.164	0.149	0.231	0.14565
Time	0.474	0.102	0.376	0.121	0.149	0.155	0.11694
Customer Relationship	0.474	0.108	0.376	0.068	0.149	0.122	0.09494
Service	0.474	0.128	0.376	0.09	0.149	0.048	0.10119
Reputation	0.474	0.037	0.376	0.037	0.149	0.023	0.03488
Financial Capability	0.474	0.079	0.376	0.045	0.149	0.067	0.06435
Technology	0.474	0.065	0.376	0.053	0.149	0.05	0.05819
Flexibility	0.474	0.073	0.376	0.016	0.149	0.015	0.04285
Research and Development	0.474	0.044	0.376	0.031	0.149	0.03	0.03698

In this section, we take the average of 11 options from the experts' point of view, then the first 5 options are our choices:

Table 6. First option of alternatives.

Criterion	Average Weight
Distribution quality	0.1457876
Time	0.1258388
Service	0.0967004
Reputation	0.0633844
Technology	0.0682786
Cost	0.14361378
Financial capability	0.0708778
Customer satisfaction	0.10780468
Flexibility	0.0527158
Research and development	0.041302
Customer relationship	0.0844084

In this section, using the fuzzy network method and the five criteria selected in the previous section, the best distribution network is chosen from among the six proposed distribution networks with the assistance of three experts:

I. Distribution of goods through wholesale distribution networks.
II. Distribution of goods through distribution companies' networks.
III. Manufacturing complexes and independent distribution networks.
IV. Cost justification for establishing distribution networks for large manufacturing complexes.
V. Independent distribution networks and the Tehran Grand Bazaar.
VI. Capillary (intensive) distribution network.

If you want, I can also polish this translation to a journal-ready academic style or align terminology with the rest of your paper.

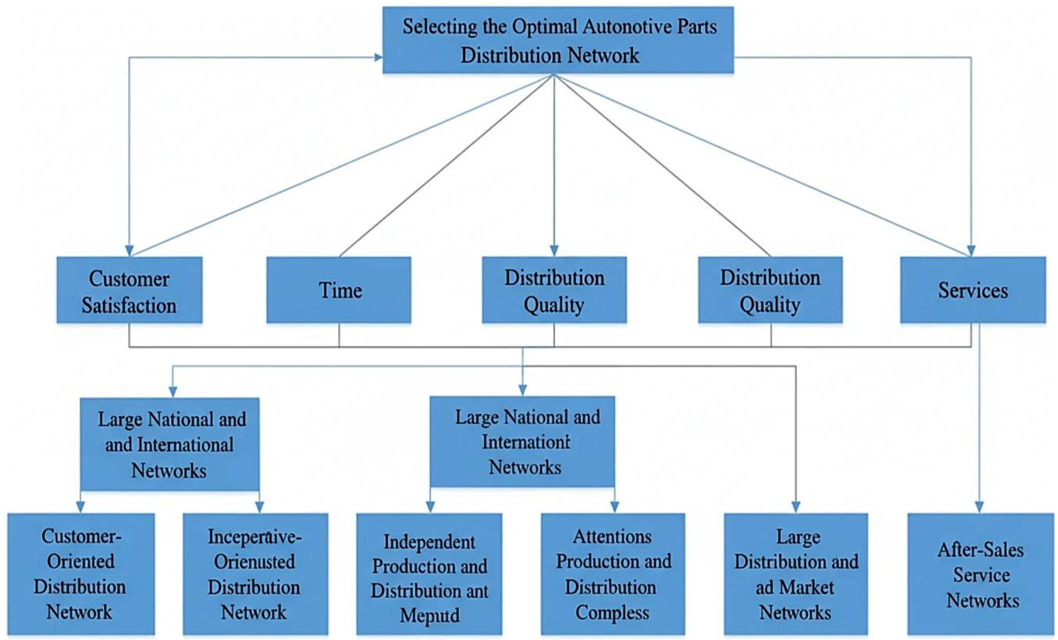

Fig. 11. Network analysis diagram.

All the opinions of the 3 experts, collected and compared using the FANP method and with the help of different software, have been averaged in the tables below to arrive at a single answer.

Table 7. Criteria comparison table.

Goal	Expert 1	Expert 2	Expert 3	Average
Distribution quality	0.05429	0.05851	0.06555	0.05945
Cost	0.13818	0.13959	0.13487	0.137547
Time	0.2503	0.23939	0.25534	0.248343
Customer satisfactory	0.16714	0.16876	0.14594	0.160613
Service	0.39009	0.39381	0.3983	0.394067

Table 8. Relationships between criteria.

Time	Expert 1	Expert 2	Expert 3	Average
Distribution quality	0.810	0.125342	0.888593	0.60812
Cost	0.206	0.874658	0.111407	0.397346

Table 9. Relationships between criteria.

Customer Satisfactory	Expert 1	Expert 2	Expert 3	Average
Cost	0.677002	0.631337	0.515861	0.608067
Time	0.200424	0.26198	0.342249	0.268218
Service	0.122574	0.106682	0.14189	0.123715

Table 10. Average comparison table of alternatives against the cost criterion.

Cost	Expert 1	Expert 2	Expert 3	Average
Capillary distribution network	0.261145	0.282498	0.281166	0.274936
Independent distribution networks and the Tehran market	0.218336	0.211117	0.223049	0.217501
Cost justification of creating distribution networks for large production complexes	0.190722	0.196817	0.197676	0.195071
Production complexes and independent distribution networks	0.111099	0.107561	0.095286	0.104649
Distribution of goods through a network of distribution companies	0.109947	0.106415	0.10688	0.107747
Distribution of goods through wholesale distribution networks	0.108752	0.095592	0.095943	0.100096

Table 11. Average comparison table of alternatives with respect to quality criteria.

Quality	Expert 1	Expert 2	Expert 3	Average
Capillary distribution network	0.247896	0.231997	0.218813	0.232902
Independent distribution networks and Tehran Market	0.232525	0.245638	0.233753	0.237305
Cost justification of creating distribution networks for large production complexes	0.164721	0.189083	0.189359	0.181054
Production complexes and independent distribution networks	0.154531	0.115234	0.155302	0.141689
Distribution of goods through a network of distribution companies	0.107912	0.125814	0.094721	0.109482
Distribution of goods through wholesale distribution networks	0.092415	0.092233	0.108053	0.097567

Table 12. Average comparison table of alternatives against service criteria.

Services	Expert 1	Expert 2	Expert 3	Average
Capillary distribution network	0.289853	0.289162	0.281738	0.286918
Independent distribution networks and Tehran Market	0.18523	0.184769	0.229752	0.199917
Cost justification of creating distribution networks for large production complexes	0.162118	0.172882	0.146845	0.160615
Production complexes and independent distribution networks	0.141415	0.141157	0.146845	0.143139
Distribution of goods through a network of distribution companies	0.123283	0.107524	0.11239	0.114399
Distribution of goods through wholesale distribution networks	0.098102	0.104506	0.08243	0.095013

Table 13. Average comparisons of alternatives with respect to customer satisfaction.

Customer satisfaction	Expert 1	Expert 2	Expert 3	Average
Capillary distribution network	0.29296	0.33455	0.26134	0.296283
Independent distribution networks and Tehran Market	0.23210	0.16660	0.24099	0.21323
Cost justification of creating distribution networks for large production complexes	0.16435	0.16956	0.18304	0.17232
Production complexes and independent distribution networks	0.11692	0.12980	0.11224	0.119655
Distribution of goods through a network of distribution companies	0.11692	0.09714	0.10731	0.107124
Distribution of goods through wholesale distribution networks	0.07674	0.10235	0.09507	0.091387

Table 14. Average comparisons of alternatives over time.

Time	Expert 1	Expert 2	Expert 3	Average
Capillary distribution network	0.26544	0.25963	0.26784	0.264302
Independent distribution networks and Tehran Market	0.18701	0.21186	0.19050	0.196457
Cost justification of creating distribution networks for large production complexes	0.19942	0.17297	0.17825	0.183549
Production complexes and independent distribution networks	0.12437	0.14130	0.13587	0.133849
Distribution of goods through a network of distribution companies	0.13364	0.11549	0.11890	0.122676
Distribution of goods through wholesale distribution networks	0.09012	0.09874	0.10864	0.099167

According to the calculations, the best distribution network for automotive parts is as follows:

Table 15. Calculations performed for the best distribution network.

Row	Alternative	Weight
1	Capillary distribution network	0.259
2	Independent distribution networks and Tehran Market	0.199
3	Cost justification of creating distribution networks for large production complexes	0.167
5	Production complexes and independent distribution networks	0.142
4	Distribution of goods through a network of distribution companies	0.123
6	Distribution of goods through wholesale distribution networks	0.107

5 | Conclusion

By applying the fuzzy ANP decision-making method and examining the structure and environment of the company under study, the following results were obtained. The criteria for selecting the optimal automotive parts distribution network in this research include distribution quality, cost, time, customer satisfaction, and service. Based on the fuzzy network analysis calculations performed using the Super Decisions software, service was identified as the most important criterion. After determining the criteria and their respective weights, the main research question was addressed: which distribution network is the most suitable for automotive parts manufacturers? Considering the nature of the company and using the fuzzy ANP method, the related calculations and procedural steps led to the conclusion that, based on the criteria discussed in previous chapters, the capillary (intensive) distribution network is the most appropriate distribution network. Finally, it can be stated that, according to the evaluated criteria, the capillary distribution network was selected through expert opinions and scoring within the target automotive manufacturing complex using the fuzzy network analysis method, and the trend over time confirms the validity of the experts' judgments. Since the profitability and quality of a company's manufactured products largely depend on the selection of distributors, several suggestions are proposed for future research. Decision-making methods are extensive and diverse; although a fuzzy decision-making method was used in this study, researchers may employ other methods depending on different conditions and environments. Moreover, implementing distribution network selection in various organizations, particularly manufacturing organizations, plays a significant role in improving profitability and product quality. Therefore, conducting similar studies in other organizations, especially those in which distribution has a substantial impact on profitability, can be highly beneficial. Additionally, in long-term contracts, the use of forecasting tools can be useful for predicting the future performance of distribution networks based on historical data and making decisions accordingly. It is recommended that factory experts, given the importance of the product distribution system, use not only the capillary distribution network, which achieved the highest score in this study, but also the grand market distribution network, since due to the long-term nature of distribution network outcomes, potential liquidity problems may arise in the future given the country's current conditions.

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Data Availability

The data used in this study are available from the corresponding author upon reasonable request.

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