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Evaluation and Ranking of Sustainable Third-party Logistics Providers using the D-Analytic Hierarchy Process

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A B S T R A C T

Nowadays, the relative importance of logistics and sustainable supply chain cannot be denied and third-party logistics as one of the logistics management strategies can play an important role for many industry owners to consider their sustainability goals. The goal of this paper is to choose the best third-party logistics provider to achieve a sustainable logistics system, because third-party logistics service is mainly dependent on both transportation and workforces, managing them is one of the important issues of sustainability. Thus, third-party logistics providers need to be concerned about not only the economic criteria but also issues related to environmental and social sustainability in addition to two other dimensions namely technical and reputation. In this paper, a comprehensive classification of related criteria, sub-criteria, and sub-sub-criteria is proposed according to selecting the best third-party logistics provider. To evaluate and rank the proposed criteria, a D Number-Analytic Hierarchy Process method, as one of the proper and popular multi-criteria decision-making (MCDM) approaches, is utilized. Besides, a case study in dairy industry has been accomplished in the real-world to show the effectiveness and a better understanding of the proposed conceptual model. Finally, the best third-party logistics provider was identified among the alternatives for the proposed case study. The results showed that the proposed method could be a good alternative to conduct evaluations and the related sensitivity analysis, considering sustainability.

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1. INTRODUCTION

Based on the definitions, a set of approaches that is utilized for efficient integration of the suppliers, manufacturers, and distributors is known as the Supply Chain Management (SCM). In such a way that, to minimize the system costs, the products are produced and distributed at the right quantities, to the right location and at the right time until the service level requirement is satisfied.

The operations flow includes material flow, financial resources, service and information that are extended in the supply chain from raw material through factories and warehouses to the end-users [1].

To enhance the operational performance, it is crucial for businesses to make the best advantage of their opportunities in the competitive global environment. These days, given the business globalization, customer satisfaction and highly competitive global environment have made the firms collaborate closely with external partners [2]. Efficient cooperation with external partners in supply chain provides competitive advantage to the firms [3]. Outsourcing is known as one of these business practices which can make firms more competitive and profitable. One of the critical processes for achieving success in the business venture is logistics which helps firms to improve their competitiveness and also better responsiveness in customer service. Logistics management as one of the significant parts of the supply chain plays a vital role in increasing the efficiency of the supply chain [3]. Logistics is a part of the SCM which plans, uses, and controls the efficiency and effectiveness of the forward and backward flow as well as the inventory of products, services and information from the

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starting to the final point of the chain, to satisfy the consumers' demands. Accurate logistics management can positively affect the supply chain by creating less inventory lot, high productivity, more agility, short due dates, observing and tracking events and flows, enhancing consumers' service, etc. Some functions can be outsourced as well as some services which can be bought, in order to control logistics to operate effectively and efficiently in companies [4].

A concept called Third-Party Logistics (3PL) becomes immensely useful and a growing interest leading the industry owners to outsource the logistics activities to 3PLs. This concept is helpful for companies in order to decrease their logistics and inventory costs. The 3PL providers work as an independent company and their duties include the transferring of logistics services from a major manufacturer (Origin Company) to the vendor or user of the product or service under a specified contract. The concept of outsourcing is promoted by the advent of third-party logistics which made companies to rely on this concept. The increase of logistics activities outsourcing is mainly leading to benefits such as cost reduction, performance improvement, concentrating on main activities, etc.

Global focus in marketplace development convinced companies to reduce the supply chain management function of business. So, many companies tend to outsource their activities which it leads companies to focus on core business activities. The 3PL usually concentrate on main function such as improving the transportation system, customized services, market penetration, using advanced technologies and better logistic services [5]. Typically, the first party is a core company which provides products or services, the second party is the customer (or customers). Then, a firm which is hired to do either the first or second party's desires is a third party. Companies utilize 3PLs for outsourcing some parts or all of operations in their SCM.

Supply chain has become a complex and global concept that remaining resilient is a crucial factor for businesses for being successful in a fast-changing world [6]. Supply chain professionals have been focused on factors such as cost, quality, delivery and reliability, but over the recent years, the concept of sustainability has been added as one of the procurement criteria for many companies. In the past decade, much more attention has been paid to sustainable business development because of the government s, profit and non-profit organization's special attention to environmental, organization and social responsibility. Also, the emergence of changing economic order is the other think which convinces companies and industry owners to pay close attention to manufacturing and service sustainability [7]. Hence, in recent years, many companies made their activities and operations sustainable [8]. The sustainability concept has three major dimensions such as environmental, social and economic, and companies consider these dimensions separately and simultaneously due to many studies in supply chain and logistics area. Sustainability can play an important role to reduce transportation costs and also environmental and social services constructive (SSC) factors, because of the outsourcing concept is relevant to transportation.

In order to develop SSC participation, it is crucial to evaluate and select the appropriate 3PL [9]. In some cases, risks such as losing control, long-term commitment, and some 3PL's performance failure are involved in the decision to outsource logistics [6]. Thus, it is important for any enterprise to select a suitable and compatible 3PL partner to be successful in competitive market place. In order to choose a well-rounded sustainable 3PL that can enhance the performance of supply chain, dimensions such as environmental, social and economic must be taking into account. The research gap is how to develop 3PLs in order to fulfill supply chain's needs to be sustainable.

In this paper, outsourcing logistics activities could be considered as a lever to achieve sustainability goals. The ability of 3PLs supply chain sustainability can play an important role in supply chain management concept [10]. It should be noted that the studies on this issue have been increased which indicates the importance of this topic. Therefore, it is better to pay more attention to these studies for companies that have internal or outsourced logistics and transportation activities.

Thus, the main purpose of this article is to select the best 3PL based on the concepts of sustainability. In this article, in addition to emphasizing the three main dimensions of sustainability, two other dimensions will be used along with economic, social and environmental dimensions. Selecting the 3PL providers that are famous in the logistics and 3PL area is important because origin companies can rely on 3PL easily. Another critical issue is the technical abilities of the 3PL companies because some products, like dairy products, need special conditions for maintenance and shipment. So, two dimensions including technical and reputation are regarded as criteria.

Regarding the aforementioned gap, among the significant contributions of previous studies on the literature of the sustainable 3PLs, most of them considered environmental as sustainable criteria and there were no studies addressing three main dimensions of sustainability, two other technical and reputation aspects and D-analytical hierarchy process (AHP) approach in 3PL simultaneously [11]. In order to cover the proposed research gap according to the investment as shown in Table 1, in this paper, an integrated MCDM method is provided for evaluating and selecting the best 3PL according to their sustainability performance view, reputation, and technical criteria.

The evaluation and clustering of the 3PLs which

contracts with the intended dairy factory is done by using MCDM approaches. The technique used in this article is AHP based on D numbers, named D-AHP. This method is the complete method in the fuzzy domain and also is based on the fuzzy priority relation. The D-AHP model in this paper evaluates the effects of sustainability on the fulfillment of 3PL service in supply chain [12]. This approach applies in different scenarios, such as the preference relation in the fuzzy environment that can be employed in case of uncertainty between experts' opinions when they have a clear view of the subject. But in some cases, the experts have the authority to not vote for a specific issue in which they do not have any idea. The steps of evaluation and ranking of the 3PL companies are shown in Figure 1.

The rest of this work is provided as follows: The literature of the issue is investigated in the section 2. Section 3 contains the description of the proposed method and material. In section 4, a case study in a famous dairy factory is provided and solved by the proposed method. Finally, conclusion is shown in section 5.

2. LITERATURE REVIEW

2. 1. Sustainable Third-party Logistics To improve the effectiveness of substructure investments for sustainability, a comprehensive evaluation system is essential for supporting decision-making. One of the significant challenges for human society in the twenty-first century is the growing of food demand, developing agriculture systems or enhancing the business and production activities, etc. without compromising the integrity of our environment [13].

Logistics service providers are able to align their current way of working with the sustainability measurement. Sustainable logistics is concerned with industry, city, and too many logistics activities which lead to greenhouse gas. Yang et al. [14] studied tax of carbon which limited the design model of city logistic network in China. Jiang et al. [15] measured the logistics and supply chain sustainability performance by adopting a multi-methodological approach. According to the results, for improving sustainable performance, performance indicators should be considered from different perspectives. Hernadewita and Saleh [16] worked on the sample of 3PL provider by using IT resources and analysis of route. The finding of the paper showed that concentrating on IT and customer centrism is helpful for improving sustainable performance. In order to assist the decision makers in selecting the best 3PL in terms of environmental perspective, a two-phase model consist of analytic network process and data envelopment analysis has been used by Gardas et al. [17].

2. 2. Multi Criteria Decision Making Approach in 3pl Selection There are many methods applied by researchers previously to meet the multi-criterion. It is entirely evident from the literature that 3PL selection consists of identical and mental parameters, but in the past few years, researchers have concentrated forcefully

TABLE 1. Cathegorizing the most related studies

S.no	Reference	Application area	Sustainability dimensions			Additional dimensions	Method
			Social	Environmental	Economical		
1	Yayla et al. [18]	A systematic decision support tool for 3PL provider evaluation, especially for 3PL transportation provider	✓	-	-	-	Buckley Fuzzy-AHP
2	Hwang et al. [19]	Third-party logistics (3PL)					AHP
3	Tajik et al. [20]	Sustainable Third-Party Reverse Logistics Provider Selection	✓	✓	✓	-	FAHP FTOPSIS
4	Datta et al. [21]	Selection of third-party reverse logistics provider	-	-	-	-	Fuzzy environmental
5	Prakash and Barua [22]	3PRL partner selection	-	-	-	Repetition	FAHP VIKOR
6	Govindan et al. [23]	Selection of third-party reverse logistics provider	-	-	-	-	ELECTRE I and SMAA
7	Deng et al. [24]	Supplier selection	-	-	-	-	D-AHP
8	Aslani et al. [25]	Sustainable supplier selection	✓	✓	✓	-	BWM
9	Raut et al. [26]	Third-party logistics (3PL) provider	-	✓	-	-	DEA & ANP
10	Jung [27]	A third-party logistics (3PL) provider	✓	-	-	-	FAHP
11	Choudhury et al. [28]	Evaluation and selection of third party logistics services providers	✓	✓	✓	-	DEA
12	Zarbakhshnia et al. [29]	Outsourcing sustainable reverse logistics	-	✓	✓	-	MOORA-G Fuzzy AHP
13	This work	Sustainable 3Pl provider	✓	✓	✓	✓	D-AHP

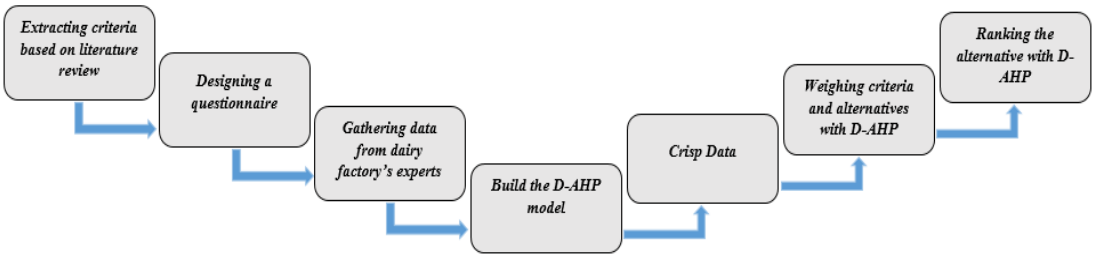

Figure 1. Steps of evaluation and ranking of the 3PL companies

on the analytical hierarchy process (AHP), DEA and fuzzy AHP, etc. [30, 31]. Table 2 indicates the studies which used MCDM approaches to select and evaluate the best 3PL providers by determining different criteria and sub-criteria. According to aforementioned statements in the introduction, AHP method based on D numbering is used in this study.

3. METHOD AND MATERIAL

3. 1. Construct D-Number by a Fuzzy Preference Relation Dempster in his famous paper in last 60s provided a new opinion about the amount of probability in the **Ω** space [22]. Dempster with Shafer in their evidence theory extended the fuzzy theory and uncertainty which investigated in the real-world and their effect was tangible in it. But still, this opinion faults because it does not consider that the real-world and fuzzy space involves comments and the mind of people and possibilities in all of the aspects; for example, in this theory and a similar one in the past personal comments and opinions were not considered [32]. The D-number theory is used in this paper for selecting the best 3PL provider. The umpire on uncertainty in D-S theory is defined by the primary probability assignment (BPA) [33].

In the FPR, we can construct the decision matrices of pairwise comparison, according to the linguistic values of the expert's evaluation. The classic FPR R indicates on a set of alternatives A= $\{A_1, A_2,\ldots, A_n\}$, the fuzzy set on set $A\times A$ and is specipied by a membership function.

$$\mu_R: A \times A \rightarrow [0, 1] \quad (1)$$

When the cardinal of A is small, the FPR can simply be indicated by $n\times n$ matrix namely R=$[r_{ij}]_{n\times n}$ such that r_{ij}= - $\mu_R(A_i,A_j)$, $\forall\, i, j \in \{1, 2,\ldots, n\}$.

$$\mathrm{R}= \begin{matrix} \\ A_1 \\ A_2 \\ A_n \end{matrix} \begin{matrix} \begin{matrix} A_1 & A_2 & A_n \end{matrix} \\ \begin{bmatrix} r_{11} & r_{12}\cdots & r_{1n} \\ r_{21} & r_{22} & r_{2n} \\ \vdots & \ddots & \vdots \\ r_{n1} & r_{n2}\cdots & r_{nn} \end{bmatrix} \end{matrix} \quad (2)$$

where r_{ij} shows the preferred degree from an alternative A_j to alternative A_i.

$$r_{ij} = \mu_R\left(A_i, A_j\right) = \begin{cases} 0 & A_j \text{ is absolutely preferred to} A_i; \\ \in (0, 0.5) & A_j \text{ is preferred to } A_i \text{to some degree;} \\ 0.5 & \text{Indifference between } A_i \text{and } A_j; \\ \in (0.5, 1) & A_i \text{ is preferred to } A_j \text{ to some degree;} \\ 1 & A_i \text{ is absolutely preferred to } A_j. \end{cases} \quad (3)$$

For the one indicating the more uncertainty information, the D number preference relation should be created. To do this, we will represent the *D* number fuzzy preference relation by R_D for a group alternative *A* in set $A\times A$ and define the element as follows:

$$R_D: A\times A \rightarrow D \quad (4)$$

and the D number preference relation is shown as follows:

$$\mathrm{R}_D = \begin{matrix} \\ A_1 \\ A_2 \\ A_n \end{matrix} \begin{matrix} \begin{matrix} A_1 & A_2 & A_n \end{matrix} \\ \begin{bmatrix} D_{11} & D_{12}\cdots & D_{1n} \\ D_{21} & D_{22} & D_{2n} \\ \vdots & \ddots & \vdots \\ D_{n1} & D_{n2}\cdots & D_{nn} \end{bmatrix} \end{matrix} \quad (5)$$

where D_{ij} ={(b_1^{ij},v_1^{ij}),(b_2^{ij}, v_2^{ij}),…, (b_m^{ij}, v_m^{ij}) , D_{ij}={(1-b_1^{ij},v_1^{ij}),(1-b_2^{ij}, v_2^{ij}),…,(1-b_m^{ij}, v_m^{ij})}, ∀i,j ∈{1,2,…,n}, and b_k^{ij} ∈[0,1] ∀ k ∈ {1,2,…m}.

Accordingly, the classic FPR matrix Equation (2) is changed to the *D* numbers preference relation below:

$$\mathrm{R}_D= \begin{matrix} \\ A_1 \\ A_2 \\ A_n \end{matrix} \begin{matrix} \begin{matrix} A_1 & A_2 & A_n \end{matrix} \\ \begin{bmatrix} \{(r_{11}.1\cdot 0)\} & \{(r_{12}.1\cdot 0)\}\cdots & \{(r_{1n}.1\cdot 0)\} \\ \{(r_{21}.1\cdot 0)\} & \{(r_{22}.1\cdot 0)\} & \{(r_{2n}.1\cdot 0)\} \\ \vdots & \ddots & \vdots \\ \{(r_{n1}.1\cdot 0)\} & \{(r_{n2}.1\cdot 0)\}\cdots & \{(r_{nn}.1\cdot 0)\} \end{bmatrix} \end{matrix} \quad (6)$$

Also, the matrix R has some properties: (1)$r_{ij} \gg 0$, (2) $r_{ij} + r_{ji} \equiv 1 \quad \forall\, i.j \in \{1.2.\ldots.n\}, \quad r_{ii}=0.5 \forall i \in \{1.2.\ldots.n\}$. R_D is transformed by Equation (9) to convert the *D* matrix to the crisp matrix by using the integer shown of the D number.

$$R_C=\mathrm{I}(\mathrm{R}_D)=\sum_{i=1}^{n} b_i^{ij}\, v_i^{ij} \quad (7)$$

In another step of the proposed method, the probability matrix should be constructed according to the crisp matrix to show the preference probability between

TABLE 2. Categorize of criteria in 3PL selection

Reference	Criteria	Sub-criteria
Yayla et al. [18]	Sustainable communication	Cost of transportation, Financial Health, Reputation of provider, SV-Similar Values
	Quality of service	On-Time Delivery, Emergency response, Reliability of deliverance, Dispatch Personnel Quality
	Continuous Improvement	Technological Improvement, Firm Infrastructure, Optimization Capability
Hwang et al. [19]	Performance	Accuracy of documents, Safety in transportation , Rate of shipment error, On-time delivery, Responsiveness
	Cost	Continuous cost decreasing, Cost control of value-added services Price
	Service	Problem-solving ability, Service of value-added, Service for customer support
	Quality assurance	Indicators key performance tracking, ISO compliance, Continuous improvement
	Intangible	Experience, Financial stability, Global scope, Profitability
	IT	Function coverage, Data security, System stability, System scalability
Tajik et al. [20]	Economic	Total cost, Quality, Technological abilities, Financial abilities, Delivery, Service, Relationship, Flexibility
	Environmental	Environmental management system, Environmental cost, management, Electrical and electronic equipment, Product recovery management
	Social	Employee interest and rights, Stakeholders rights, Work safety and labor health, Safety training, Respect for policy, Contractual stakeholders influence, Employment practices
Datta et al. [21]	Finance performance	Logistics costs, Financial stability
	Level of service	Being on time and reliable, Service quality, Responsiveness and flexibility
	Client communication	Long term relationship, Trust and information sharing, Benefit and risk-sharing
	Management	Performance management, Security and safety, Fame and experience
	Infrastructure	IT abilities, Logistics workforce
	Enterprise culture	Cultural fitness, Cultural innovation
Prakash and Barua [22]	Performance of firm	Time, Flexible capacity, Convenience
	Capacity of resources	Investment, Capacity, advanced components, equipment, warehousing, and storage
	Delivery of service	Level of service, Customized service, Ability of problem solving
	Reverse Logistics Operations	The collection, process, Sorting, Warehousing, Remanufacturing, Intermediate, Transportation, Recycle, Repair, Disposal
	IT and Communication System	Integrated System, Separate and Shared communication, RFID/EDI enabled the system, Information security system
	Geographical Location	Coverage, Destination and Market, Distribution, Shipment,
	Experience and fame	Image, Benefit and risk Sharing, Structure, Culture
Govindan et al. [23]	Cost Quality	Relationship, RL, Reduction cost, Service, Product/ service/people quality, Performance of product, Improvement in quality
	Capacity of RL	Financial, infrastructures, Skilled, Uncertainty factor
	Technology	Capacity of technology, Warehouse, Transportation, Inventory management, IT, Demand forecasting, Investment
	Relationship and communication	Mutual, Justices, useful, Flexibility, Trust, Quality of service
	Financial	Market share, Profitability, Wealth, popularity, loyalty of customer, Understanding business requirements
	Risk management	Monitoring, Communication, Policies of government, Complaint management, Transportation, order management
	Practices of RL	Redistribution, Feedback policy, packing, delivery
	Green level and Low carbon	recycle, remanufacturing, reuse, disposal, Environmental management, pollution, resource consumption, Oil consumption, carbon emissions
	Environmental management system	ISO 14000, environmental policies, Environmental activities
	Micro-social impact	Employee satisfaction, customer satisfaction, stakeholder satisfaction, overall working relations
	Macro-social impact	Health, local community, human factors

pairwise alternatives. The element of the probability matrix is indicated by R_p and calculated by equation (10) that the symbol "≻" denotes the "prefer to" [25].

$$P_r(A_i \succ A_j) = 1 \text{ if } c_{ij} > 0.5 \text{ and } P_r(A_i \succ A_j) = 0 \text{ if } c_{ij} \leq 0.5 \quad (8)$$

After constructing the probability matrix, the triangulation method is used to rank the alternative. In this method, all of the elements above the main diagonal are nonzero and the process of triangulation is: first, calculating the sum of each row's elements and also finding the largest number between them. Second, deleting the largest number of row and column of the matrix, in the next step, the first and second steps should be repeated until the R_p matrix becomes empty. Finally, a triangular matrix is constructed according to the principle matrix and rows deleting regularity. The triangular matrix is presented by R_p^t then through this matrix, alternatives can be ranked according to the rows deleting order which means that the first alternative is the largest number of the row at the first step of triangulation [32].

To determine the weight of alternative, at first the crisp matrix (R_C) should be triangularized and then, the number above the main diagonal should be used and after determining these using a number, one row above the main diagonal and after specific, Equation (9) is computed.

$$\begin{aligned} &\lambda(W_i - W_j) = X \\ &\lambda(W_j - W_k) = Y \\ &W_i + W_j + W_k = 1 \end{aligned} \quad (9)$$

λ represents the granular information, that shows the expert's cognitive capability, the value of λ is related to the cognitive ability of an expert, as it sees the amount of weight depending on λ. Therefore, for calculating the λ, follow the below scheme:

$$\lambda = \begin{cases} \left\lceil \underline{\lambda} \right\rceil & \text{Information includes the highly credible} \\ n & \text{Information includes the medium credible} \\ \frac{n^2}{2} & \text{Information includes the low credible} \end{cases} \quad (10)$$

n represents the number of alternatives and λ show the lower bound by λ, which $\left\lceil \underline{\lambda} \right\rceil = \min\{k \in \mathbb{Z} | \, k \geq \left\lceil \underline{\lambda} \right\rceil\}$.

After calculating the weight of each level, for determining the preference relation of the decision-making problem, the process of integration of each level's weight is done as shown in Table 3 where m represents the number of criteria. Finally, the best alternative is selected and ranked [33, 34].

The classic AHP method will be condemned due to the inability to show and control the uncertainty in a variable for mental and linguistic data [35]. This factor is the main weakness of this method which is rooted in the scales used in this method. Therefore, for covering this main weakness, the fuzzy approach was created. Fuzzy logic which is against standard reasoning, is considered as a powerful tool for solving issues related to the complex systems including the problems linked to the argument, human inference, and decision [36]. But in this method, the expert could not or will not answer a question in some cases because of the gaps and the lack of sufficient information about an issue. Hence, for covering this defect, a novel method called D-AHP can be proposed which uses the D number, introduced by D-S theory that was described in the last section. As it is shown in Figure 2, the scale used in this method is based on the preference relation that was described in the last section considered the differs to the Saaty's scale and all aspect [37]. The priorities of the alternatives can be reached by integrating each row's weight. Generally, the D relation preference and method are illustrated in Figure 2 that this algorithm is applied to the D-AHP method [34].

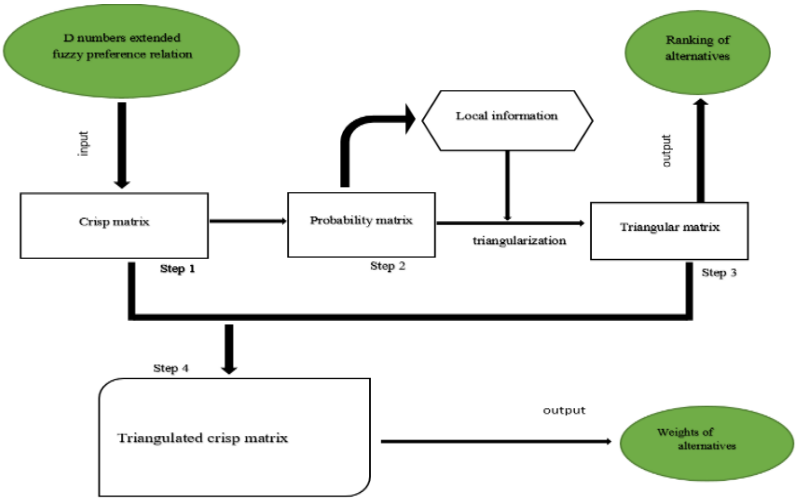

Figure 2. Illustration of the D number preference relation algorithm [25]

TABLE 3. Process the integration of each level's weight

Criteria / Alternative	C_1 / c_1	C_2 / c_2	C_m / c_m	Weight
A_1	a_{11}	a_{12}	a_{1m}	$W_1=\sum_{i=1}^{m} c_i\, a_{1i}$
A_2	a_{21}	a_{22}	a_{2m}	$W_2=\sum_{i=2}^{m} c_i\, a_{2i}$
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
A_n	a_{n1}	a_{n1}	a_{nm}	$W_n=\sum_{i=1}^{m} c_i\, a_{ni}$

4. MODEL TESTING

A case study illustrates the effectiveness and impact of outsourcing transportation activities in our proposed model. In this regard, the real data of a dairy factory operating in northern Iran was examined. The dairy factory has an extensive service network.

The case study is conducted in a famous dairy factory in the north of Iran. One of the affiliated providers of this factory performs the specific distribution process of the products. This factory includes 1200 trucks and 3000 workforces and will respond to 1 million orders each month, which these orders are more than 1250 tons of products monthly.

The proposed factory also contracted with five different 3PL providers out of the factory, named briefly A1, A2, A3, A4, and A5 in order to distribute its products. The aim of this paper is to evaluate and cluster these five 3PL providers, according to the experts' comments and experiences. Thirty experts including logistics manager and transportation experts commented on criteria, sub-criteria, and sub-sub-criteria which were investigated from literature review.

4. 1. Criteria Evaluation for Selecting the 3pl Provider 3PL selection is one of the multi-criteria decision-making problems. Also, it is a complicated process because of multiple criteria like price, quality, delivery, agility, technical, etc [38]. Along with creating a set of criteria, sub-criteria, and sub-sub-criteria, a corporation can be better to choose a 3PL provider. In this way, it chooses the best time and place and can meet its operations and logistics requirements the best, such as transportation [39]. In spite of the beliefs of the majority of people, who believe that the vital step in the problems of 3PLs is the selection of criteria and sub-criteria, in this study the focus is more on the goals of the company and government policies. Therefore, due to this policy, the goals refer to the sustainability aspect, such as social, economic, and environmental, with two additional, technical and reputation, dimensions. The criteria in the 3PL selection subject is impacted by many attributes, such as availability to the international distribution networks [40] and the size of the company used for 3PL. Table 4 shows the criteria, sub-criteria, and sub-sub-criteria considered in this paper, which are categorized according to the articles in Table 2 and the previous studies.

As mentioned above, the main idea of selecting the best 3PL provider in the transportation subject has considered all dimensions of sustainability with two proposed additional dimensions. The technological sub-criteria have included agile, flexible, quality, IT, resource, location, and service. The sub-criteria play an essential role in the definition of criteria. These criteria have all of significant meanings for companies and manufacturers in the field of transportation. Another aspect added to sustainability is reputation, actually when the companies trust the 3PL provider that has an appropriate background and experience during the years of their activities. The extracted criteria, sub-criteria, and sub-sub-criteria were far more than a literary review, which after consulting with one of the experts in the transportation department of the proposed dairy factory, was reduced to the present. The structure of the proposed MCDM model is shown in Figure 3 under the framework of D-AHP that is extended by a D number in fuzzy relation preference and different credibility of scale.

5. RESULTS AND DISCUSSION

In this section, by using the numerical example, the proposed D-AHP method's steps are used to solve the 3PL selection problem. As shown above, Figure 3 demonstrates the five levels of the hierarchical structure of our problem for 3PL selection derived from literature review in Tables 2 and 3. The goal of the study is choosing and ranking the best 3PL provider from the sustainability and two surplus dimensions, among five alternatives. The D number preference relation of criteria, sub-criteria, sub-sub-criteria, and alternatives in each level can be constructed according to this structure.

In this paper, we have utilized points of view of 30 expert's working at the dairy factory. Table 4 shows the D number preference relation of criteria and their pairwise comparison matrix based on expert's suggestion, which the weight of criteria, calculated by the proposed method and the evaluation of the criteria judge to the highly believable that is shown in Table 5. The priority relation of sub-criteria, sub-sub-criteria, and alternative are determined by acquiring the proposed method. The weight of each level is determined by integrating the previous level's weight as shown in Table 3. In this case, experts at first assessed the question then answered it according to company's policy. After evaluating their suggestion, calculated it by D number

algorithm. Hereby determines the weight of all levels separately. Finally integrated the weights of all levels based on D-AHP algorithm. The result of it is represented in Table 5.

As obtained ruslts summarized in Table 6, the alternatives are sorted from A_5 to A_1, respectively according to the expert suggestion. Due to the Equation (20), the validity of information taken from experts depends on the experts' level of ability and their expertise and science. The value of λ will change in case of using the different expert with distinct judging. In this paper, ten experts' opinions with close knowledge and judgment about 3PL selection are used for evaluating the criteria and sub-criteria and sub-sub-criteria. So, the credibility

TABLE 4. Criteria, sub-criteria and sub-sub-criteria

	Criteria	Sub-Criteria	Sub-Sub-criteria
Sustainability	Economically C_1	Overall Cost C_{11}	Revese logistics cost (C_{111}), cost of relationship (C_{112}), Transportation cost (C_{113}), logistic cost (C_{114}), cost reduction (C_{115}), value-added services (C_{116}), price (C_{117})
		Economic C_{12}	Quality (C_{121}), Technology Capabilities (C_{122}), Financial Capabilities (C_{123}), Delivery (C_{124}), Service (C_{125}), Relationship (C_{126}), Flexibility (C_{127})
	Environmental C_2	Green level C_{21}	Pollution (C_{211}), Resource consumption (C_{212})
	Social C_3	Human resource Policies C_{31}	Satisfaction level (C_{311}), Qualified talents (C_{312}), Training (C_{313}), employee performance (C_{314})
		Macro Social C_{32}	Customer satisfaction (C_{321}), Health (C_{322}), safety (C_{323}), Voice of customer (C_{324}), Performance management (C_{325}), security (C_{326})
		Micro Social C_{33}	Transportation safety (C_{331}), employment stability (C_{332}), Financial health (C_{333}), Contractual stakeholders influence (C_{334}), Employment practices (C_{335}), The rights of stakeholders (C_{336}), Work safety (C_{337}), labor health (C_{338})
Two additional dimensions	Technical C_4	Agile C_{41}	Delivery Reliability (C_{411}), Response in an emergency (C_{412}), Delivery Performance (C_{413}), Responsiveness (C_{414}), On- time delivery (C415), Timeless (C_{416})
		Flexible C_{42}	System stability (C_{421}), Flexible Capacity (C_{422})
		Quality C_{43}	Quality of Dispatch (C_{431}), Document accuracy (C_{432}), Quality of product (C_{433})
		IT C_{44}	Information technology capacity (C_{441}), Data security (C_{442})
		Resource C_{45}	Continuous improvement (C_{451}), Financial capability (C_{452}), Specialized infrastructures (C_{453}), Skilled manpower (C_{454}), Investment (C_{455}), capacity (C_{456}), advanced components (C_{457}), equipment (C458)
		Location C_{46}	The geographical range of services (C_{461}), Geographical location (C_{462}), Destination (C_{463}), Market (C_{464}), Coverage (C_{467}).
		Service C_{47}	Problem-solving capability (C_{471}), Value-added service (C_{472}), Customer support service (C_{473}), Global scope (C_{474})
	Reputation C_5	Experience C_{51}	Image (C_{511}), Shared benefits and risks (C_{512}), structure (C_{513}), culture (C_{514})

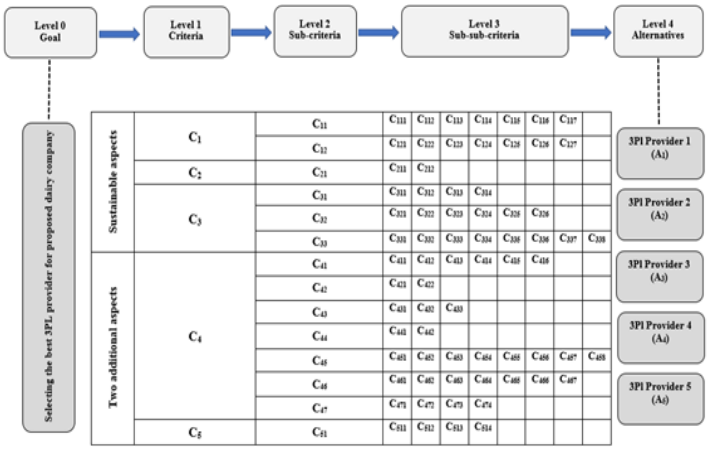

Figure 3. Structure of the proposed model

TABLE 5. D number preference relation of criteria and these weights

Criteria	Economical	Reputation	Social	Technical	Environmental	Weight ($\lambda=\left\lfloor \underline{\lambda} \right\rfloor$)
Economical	{(0.5,1.0)}	{(0.85,1.0)}	{(0.75,0.4), (0.85,0.6)}	{(0.75,1.0)}	{(0.58,1.0)}	0.1328
Reputation	{(0.15,1.0)}	{(0.5,1.0)}	{(0.62,1.0)}	{(0.55,1.0)}	{(0.75,1.0)}	0.2028
Social	{(0.25,0.4), (0.15,0.6)}	{(0.38,1.0)}	{(0.5,1.0)}	{(0.6,1.0)}	{(0.68,1.0)}	0.2268
Technical	{(0.25,1.0)}	{(0.45,1)}	{(0.4,1.0)}	{(0.5,1.0)}	{(0.62,1.0)}	0.2068
Environmental	{(0.42,1.0)}	{(0.25,1.0)}	{(0.32,1.0)}	{(0.38,1.0)}	{(0.5,1.0)}	0.2308

TABLE 6. The weight and ranking of alternative with criteria

Alternative / Criteria	Economically 0.1328	Environmental 0.2308	Social 0.2068	Technical 0.2268	Reputation 0.2028	Weight	Ranking
A1	0.0920	0.0656	0.0625	0.0962	0.0819	0.0787	5
A2	0.1431	0.1236	0.1153	0.1006	0.1430	0.1232	4
A3	0.1931	0.1791	0.1727	0.1806	0.1628	0.1767	3
A4	0.2434	0.3086	0.2539	0.2942	0.2765	0.2788	2
A5	0.3279	0.3231	0.3075	0.3662	0.3336	0.3324	1
Inconsistency Degree=0.0645							

of our information is almost high that subsequently the number of λ is small and for this problem, consider the number of λ equal 1, which equals the minimum number of the column's number (k).

In this case, experts at first assessed the question then answered it according to company's policy. After evaluating their suggestion, calculated it by D number algorithm. Hereby determines the weight of all levels separately. Finally integrated the weights of all levels based on D-AHP algorithm. The results of the weight of alternatives are represented in Table 5.

As data summarized in Table 6, the alternatives are sorted from A_5 to A_1 respectively according to the expert suggestion. Due to Equation (20), the validity of information taken from experts depends on the experts' level of ability and their expertise and science. The value of λ will change in case of using the different expert with distinct judging. In this paper, ten experts' opinions with close knowledge and judgment about 3PL selection are used for evaluating the criteria and sub-criteria and sub-sub-criteria. So, the credibility of our information is almost high that subsequently the number of λ is small and for this problem, consider the number of λ equal 1, which equals the minimum number of the column's number (k).

The inconsistency degree of proposed D number preference relation is calculated as Equation (11) which is defined according to the triangular matrix. The inconsistency degree of this problem, according to the probability triangular matrix is equal to 0.0645.

$$\text{I.D}=\frac{\sum_{i}^{n}=1.R_p^T(i.j)}{\frac{j<i}{n(n-1)/2}} \quad (11)$$

This paper helps the manager and industry owners in reducing their transportation cost, frugality of time and entrust and outsourcing all or some of their transportation parts, as well as the protection of the environment and reducing the pollution in transportation, due to the considering sustainability dimensions along with technical and reputation.

In fact, the managers of the dairy industry can use the proposed concepts and solution methods of this study in order to understand the effect of proper 3PL company selection in reducing transportation cost and also inhancing customer satisfaction. Because outsourcing the transportation activities to a good and well-known 3PL company can play an important role reducing the purchase costs of transportation vehicles and labor costs. Considering good technical condition as mentioned in our study, in tranfering goods lead to least damage which is a factor for increasing customer satisfaction.

The performance of supply chain is as one of most important competitive factors in many industries. As mentioned, selecting the proper third part logistics provider can help companies in transportations cost reduction and better flow of distribution processes, which it leads to better supply chain performance. This paper can be helpful for industry owners to evaluate the best 3PL providers, by considering different criteria such as quick access, security, high capacity and etc., in order to enhance their supply chain efficiency. In this paper, the fifth provider (A5) ranked the best among other considered providers. So, it's clear that the provider A5 is the best candidate if the proposed dairy factory wants to take advantages of 3PLs.

To validate the sensitive analysis of questions, the value of λ is compared with a different rating of credibility. As is shown in Table 7, the value of λ does not affect on clustering of available alternatives in this dairy factory. There are only a few differences in the amount of weight in different situations and it is clear that the alternatives' weights are more than any other cases when the value of λ adopts its highest rate. Also, these variations in the weights of different credibility are shown in Table 6.

Finally, the fuzzy logic and evidence theory assessment is used in many studies [41]. Selection of 3PL companies is done by considering the expert's comment evaluated in this article by using D-number theory based on fuzzy preference relation.

According to Zhou et al. [37] the result of the comparison between D-number theory with fuzzy logic and evidence theory is shown in Table 8. This comparison indicates that the method of D-numbers is more independent in evaluations than other used methods. This method is proper even in the case of experts' lack of knowledge. The reason for this advantage is rooted in linguistic variables and large scales of the method. Due to comparison with the available techniques, founding the D-number theory has Excel to other methods. The pianist's probability transformation process is needed for the evaluation of dependency when evidence theory and AHP are used. But in the proposed method, the dependence is evaluated without this transformation process [37].

TABLE 7. Weight and ranking of the attribute in three situations

3PL provider	High credibility		Medium credibility		Low credibility	
	Weight	ranking	Weight	ranking	Weight	ranking
A_1	0.078	5	0.035	5	0.028	5
A_2	0.123	4	0.111	4	0.092	4
A_3	0.176	3	0.132	3	0.115	3
A_4	0.278	2	0.241	2	0.226	2
A_5	0.332	1	0.315	1	0.298	1

TABLE 8. The superiority of D- number

Method	The linguistic scale of fuzziness	The evaluation of the expert's mental
D number theory	✓	✓
Fuzzy logic	✓	×
Evidence theory	×	✓

5. CONCLUSION

In this paper, the fifth provider (A5) ranked the best among other considered providers with the D-AHP method. So, it's clear that the provider A5 is the best candidate if the proposed dairy factory wants to take advantages of 3PLs. In some industrial companies like dairy companies, logistic activities play a significant role due to the sensitivity of products to decay. In these cases, 3PL companies can have a significant effect on the logistic systems' performance. Therefore, a proper decision making model for evaluating the 3PLs before making contract is helpful for managers to cooperate by third-party logistics with better view of their performance.

Transportation cost and decay reduction are two main reasons that leads dairy companies to collaborate with third-party logistics. Therefore, exact and proper criteria definition is very important to select the best company for outsourcing logistic activities. So, the main aim of this paper is to evaluate the best 3PL providers by considering sustainable aspects, environmental, social and economic, and also two other additional aspects such as technical and reputation. The D-AHP method is used to evaluation of defined criteria, sub-criteria and sub-sub-criteria. Finally, it is found that the company A_5 is best one among all 3PL providers. In this regard, the proposed dairy factory can make the proper policy for sending the products to the retailers and customers by lower costs and higher efficiency. Furthur research in this field could be explored in future studies by considering the following topics; some criteria based

On renewable energy and using another method for evaluating and ranking the alternatives like rough AHP.

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Persian Abstract

چکیده

امروزه نمی‌توان اهمیت نسبی لجستیک و زنجیره تأمین پایدار را انکار کرد، همچنین لجستیک شخص ثالث به عنوان یکی از استراتژی‌های مدیریت لجستیک می‌تواند برای بسیاری از صاحبان صنایع نقش مهمی ایفا کند تا اهداف پایداری خود را در نظر بگیرند. هدف این مقاله انتخاب بهترین ارائه‌دهنده تدارکات شخص ثالث برای دستیابی به یک سیستم تدارکات پایدار است. زیرا خدمات تدارکات شخص ثالث عمدتا به هر دو نیروی حمل و نقل و نیروی کار وابسته است. مدیریت آنها یکی از موضوعات مهم پایداری است. بنابراین، ارائه‌دهندگان تدارکات شخص ثالث باید علاوه بر ابعاد اصلی پایداری که اقتصادی، اجتماعی و زیست محیطی می‌باشند، در مورد دو بعد فنی و شهرت که به ابعاد اصلی اضافه شده‌اند نیز دغدغه داشته باشند. در این مقاله، با توجه به انتخاب بهترین ارائه‌دهنده تدارکات شخص ثالث، طبقه‌بندی جامعی از معیارها، زیرمعیارها و زیر-زیرمعیارهای مرتبط ارائه شده است. برای ارزیابی و رتبه‌بندی معیارهای پیشنهادی، از روش فرایند تحلیل سلسله مراتبی عددی D، به عنوان یکی از رویکردهای تصمیم‌گیری چند معیاره، استفاده شده است. علاوه بر این، یک مطالعه موردی در صنعت لبنیات برای نشان دادن اثربخشی و درک بهتر از مدل مفهومی پیشنهادی، در دنیای واقعی انجام شده است. سرانجام، بهترین ارائه‌دهنده تدارکات شخص ثالث در میان گزینه‌های مورد مطالعه موردی مشخص شد. نتایج نشان داد که روش پیشنهادی با توجه به پایداری می‌تواند جایگزین مناسبی برای انجام ارزیابی‌ها و تجزیه و تحلیل حساسیت مربوطه باشد.