# A Hybrid Framework to Select Logistics Service Providers

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## Abstract

Outsourcing logistics is one of the most substantial and strategic decisions in organizations. Organizations that wish to develop and improve their supply chain activities need a comprehensive, economical, and practical framework to assess and select logistics service providers (LSPs). The effectiveness of logistics services helps organizations to meet the expectations of customers. In this paper, a methodological framework comprising Grey Analytic Network Process and Grey Relational Analysis is proposed to evaluate and select preferred LSPs under uncertainty. To illustrate the capability of the proposed framework, the proposed framework is applied to assess LSPs in an Iranian automotive company.

## Keywords
Outsourcing, Third-party logistics, Supplier selection, Survey methods, Multi-criteria decision making

## 1. Introduction
Nowadays, logistics is a complicated business activity that can be measured in various aspects. One of the goals of logistics is ensuring the efficiency and usefulness of all procedures, from start to end, to respond to the customers' expected quality (Domingues, Reis, & Macário, 2015). Logistic is one of the dynamic actions which makes a connection between production and consumption (Bartolacci et al., 2012) and includes several processes such as planning, implementation, and controlling the flow of product, services, and information (Vitasek, 2010). Logistics consists of several operations, which are done by several participants such as cargo senders, transformation operators, third-party logistic service providers, warehouses, transportation companies, manufacturers, and retail sellers. In the current competitive market, companies always search for new opportunities to obtain more benefits compared to others, and outsourcing is the approach that can lead a company to gain a competitive advantage over other competitors (Embleton,1998). Outsourcing is defined as the complete transformation of business activity to an independent external service provider (Handley, 2008).

Third-party logistics (3PL) plays a crucial role in many supply chains. With the growing trend of outsourcing, many organizations outsource their logistic activities to logistics service providers. Outsourcing helps companies to be more focused on their main activities while outsourcing some operations to third-party service providers who are more specialized in the area. This process can lead the core company to experience an increase in service level provided to its customers while the related costs can be reduced. Transportation and storing are two significant duties of logistics, which are the main parts of the service packages provided by 3PL providers (Langley, 2012). Logistics outsourcing implies to using the external companies to do apart or whole logistic duties such as transportation, delivery, storing, inventory management, providing order, and material movement (Sink & Langley, 1997). Due to the importance of logistics outsourcing, the evaluation and selection of appropriate 3PLs are considered as significant steps in the process of outsourcing the logistics services. The complexity of decision and multiplicity of effective factors in selecting LSPs made companies use multicriteria decision-making methods as efficient approaches. The fuzzy calculation is widely used to manage, and it can apply uncertainty in decision making (Ebrahimi & Bridgelall, 2020). However, the main problem of fuzzy calculation is that the experts must have enough knowledge of the expression of membership functions. The need for the large sample size and wide knowledge to define the membership function has limited the application of fuzzy theories on the evaluation and selection of the logistic service providers. The main goal of this study is to present a methodological framework based on the grey theory to consider the uncertainty of making decisions more effectively. In this regard, the grey analytic network process (GANP) is used to determine the weights of effective criteria and sub-criteria to evaluate LSPs, and the grey relational analysis (GRA) is used to compare and prioritize LSPs of the studied company. This paper is organized as follows.

In section 2, the literature review is presented. Section 3 presents the methodology of research and the proposed methodological framework in detail. In section 4, the process of conducting the required surveys is explained, while the results from the proposed approach is presented in section 5. Finally, in section 6, the obtained results are evaluated and discussed.

## 2. Literature review

### 2.1. assessment and selection of LSPs

Logistic outsourcing is considered as a practical approach to obtain competitive advantages, improve services to customers, and decrease the logistic costs (Aguezzoul 2014; Jonsson 2008). Logistic outsourcing provides a situation for core companies to become focused on their core activities and outsource logistics activities to companies more skilled in logistical operations. The transition directly leads the core company to reach more profitable production and increased customer satisfaction (Wan et al., 2015). It also decreases the fixed costs and increases flexibility and provides more focus on the main propose of a company, such as reducing the investment on assets and improving the quality of services. The full attention of companies to Logistic outsourcing and growth of the number and types of LSPs increase the importance of evaluation and selection process of LSPs. Companies apply different approaches to analyze, evaluate, and select their LSP partners. Making decisions about outsourcing can have many risks, such as losing control of some activities, long life commitment, and drawbacks of not doing duties correctly by LSPs (Farahani, Rezapour, & Karadar, 2011; Soeanu et al., 2015; Wang et al., 2014). Based on the literature review, it is found that fewer studies are done on the outsourcing of logistic services and selection of the appropriate provider problems than the supplier selection problem in the supply chain. In continue, a number of most important studies conducted recently are reviewed.

Ho et al. (2012) presented an integrated method that includes quality function development (QFD), fuzzy set theory, and analytic hierarchical process to evaluate and select third-party logistic providers. The results of their research showed that their integrated method had better results than previous studies. Li and Wan (2014) considered the problem of selecting logistic service providers as a multicriteria inhomogeneous fuzzy problem with incomplete weights information. Solving a goal programming model, a large relative closeness degree of the set of alternatives is obtained for the fuzzy positive ideal solutions. Finally, the efficiency of the model is verified by applying it to the problem of selecting outsourcing service providers of information technology companies. In their study, Uygun, Kacamak, and Karajan (2014) proposed a fuzzy integrated multicriteria decision making which comprises the Fuzzy Analytic Network Process (FANP) and Decision-making trial and evaluation laboratory (DEMATEL) methods to evaluate and select the logistics service providers for a communication company. In this approach, the DEMATEL method was used to determine the effective criteria on the outsourcing process, and FANP was used to determine the weights of criteria and sub-criteria. Then, the local weights were applied to the ANP supermatrix followed by selecting the most beneficial logistic service provider. Alkhatib et al. (2015), proposed the integrated logistics outsourcing approach to evaluate and choose the logistics service providers (LSPs) based on their capabilities and logistic sources. This new method was a combination of fuzzy DEMATEL and fuzzy TOPSIS. This method determined the effective relations between decision criteria and prioritized LSPs based on their capabilities and tunable sources. Finally, the effectiveness of this method was shown by implementing it for a real case study, where its stability was confirmed by using a two-step sensitivity analysis method. Santibanez-Gonzalez and Diabat (2015) presented a mathematical model in designing a non-cooperative supply chain, where the 3PLs conduct transportation activities. The model determined the optimal value of products for each manufacturer, the flow of products between manufacturers and retailers, the flow of products transferred by LSPs, and the flow of products between retails and markets in a non-cooperative condition. Appling fuzzy priority relations, Wan et al. (2015), formulated the selection problem of LSPs. To solve the problem, they proposed the intuition-oriented fuzzy linear programming. They used this method to determine the priority weights where the Technique of Order Preference Similarity to the Ideal Solution (TOPSIS) method was used to determine the weights of experts' opinions. Domingues, Reis, and Macario (2015) presented a comprehensive and innovative framework that evaluated the performance of 3PLPs. To validate the proposed framework, the framework was applied to assess the performance of 3PLPs in a company in Portugal.

### 2.2. The effective criteria for the LSPs selection process

According to the literature review, in most of the researches, the evaluation and selection of logistic service providers are made based on some predefined selection criteria. So, in this section, the effective criteria on the assessment and selection of the logistic service providers are reviewed. Based on the literature review, the researchers considered the different frameworks of criteria and sub-criteria to evaluation and selection of logistic service providers. The review study of Aguezzoul (2014) is one of the most comprehensive studies about theoretical frameworks of evaluation criteria of logistic service providers. Summarizing the proposed criteria from the literature, the research presents a conceptual framework (Table 1) in which the final criteria and sub-criteria in selecting LSPs are extracted and assessed based on the experts' viewpoints. Due to the careful consideration of the effective criteria in evaluating and selecting LSPs in the study mentioned above, the same framework will be applied in the current study.

Table 1. The theoretical framework of evaluation criteria of logistic service providers (Aguezzoul, 2014)

| Criteria | Sub-criteria |
|---|---|
| Infrastructure and technical capabilities (C1) | Inventory infrastructure and capabilities (C11) |
| | Transportation infrastructure and capabilities (C21) |
| | Information technology infrastructure and capabilities (C31) |
| Financial Mechanism (C2) | Financial support (C12) |
| | Flexibility in payment(C22) |
| | Service cost (C32) |
| Organizational Capabilities (C3) | Service quality (C13) |
| | Experienced workforce (C23) |
| | Fast and on-time delivery (C33) |
| | Service diversity (C43) |
| | Experience and company reputation (C53) |
| | Management situation and organization's culture (C63) |
| | The level of a company's communication quality (C73) |

## 3. The approaches for evaluation and selection of LSPs

In this study, the weights of effective criteria and sub-criteria in the evaluation of LSPs are determined by using a grey analytic network process when comparing and prioritizing LSPs are performed by grey relational analysis. The two methodologies are described in the following sections.

### 3.1. Grey analytic network process (GANP)

To determine the weights of the effective criteria, GANP approach is used that is presented as a combination of the ANP method (Saaty, 1999), and the grey system theory (Julong, 1989). The ANP method consists of two main parts. The first part includes the hierarchy or a network of criteria and sub-criteria in which the relation between them are controlled. The second part includes in the relationship between criteria and clusters. Based on the types and weights between criteria and sub-criteria and the obtained relative weights, the supermatrix is calculated for each controlling criterion. Finally, each supermatrix is weighted by using the priority of its controlling criterion, and the results are combined by the summation of all controlling criterion (Saaty, 1999). The clusters are also compared with each other based on their weights on the objective. In this paper, the grey numbers are used to implement the pair comparisons. The parameters $\underline{G}$ and $\overline{G}$ are the lower and upper bound of the grey number, respectively. Table 2 shows how the relative priorities of criteria are demonstrated by the verbal scale and their equivalent grey numbers.

Table 2. The equivalent grey numbers of the verbal scale of the relative importance of criteria (Zhang et al., 2009)

| Verbal scale | Equivalent grey numbers | The reverse of grey numbers |
|---|---|---|
| Just Equal (E) | (1,1) | (1,1) |
| Equally Important (EI) | (1/2,3/2) | (2/3,2) |
| Weakly more important (WMI) | (1,2) | (1/2,1) |
| Strongly more important (SMI) | (3/2,5/2) | (2/5,2/3) |
| Very strongly more important (VSMI) | (2,3) | (1/3,1/2) |
| Absolutely more important (AMI) | (5/2,7/2) | (2/7,2/5) |

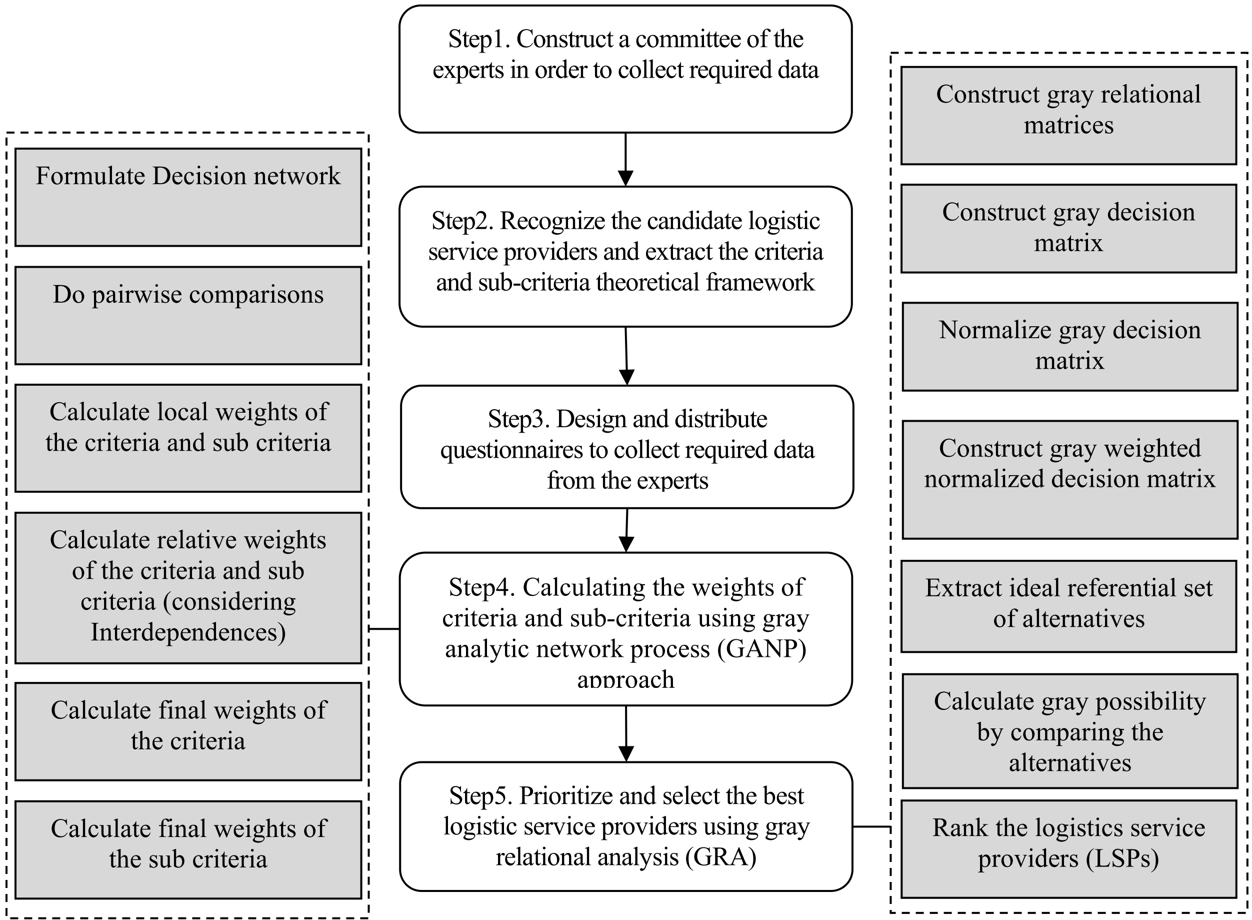


Figure 1. Proposed methodological framework

Based on this table, pairwise comparison matrices are completed by the experts. According to ANP method, defining the inner relations between criteria and clusters is necessary. The inner relations are calculated by the supermatrix. The relative weights are integrated into a supermatrix when the effect of one cluster/criterion to another cluster/criterion is considered. Generally, each supermatrix consists of the following four elements (Dou, Zhu, & Sarkis, 2014):

1) The relation between elements and the final objective;
2) The pairwise comparisons between criteria and clusters;
3) The pairwise comparisons between alternatives based on the criteria;
4) Definition of identity matrix for all alternatives;

In this method, the general weight of each criterion and sub-criterion is calculable. In this paper, GANP method is used to determine the weights of criteria and sub-criteria and consists of the following six steps:

1) Formulate decision network
2) Calculate pairwise comparisons
3) Calculate the local weights of criteria and sub-criteria
4) Calculate the relative weights of criteria and sub-criteria (considering the inner relations)
5) Calculate general weights of criteria

$$W_{factors(global)} = W_{factors(relative\ importance)} \times W_{factors(local)} \quad (1)$$

$$W_{subfactors(initial\ global)} = W_{subfactors(relative\ importance)} \times W_{subfactors(local)} \quad (2)$$

$$W_{subfactors(global)} = W_{factors(global)} \times W_{subfactors(initial\ global)} \quad (3)$$

## 3.2. Grey relational analysis (GRA)

Grey relational analysis is a part of the grey theory, which is used to solve problems with complex relations between factors and variables (Morán et al., 2006). In this method, the vague relationships between one main factor with another one is explored (Liang, 1999). GRA can present satisfying outputs by using a few pieces of information. Some of the benefits of using GRA are listed as follows (Julong, 1989):

1) This approach is simple in the calculation.
2) This approach needs a reasonable level of sample data.
3) Grey relational analysis does not need to know the distribution of samples.

Grey relational analysis is used in various ranges of problems, including the selection of providers and quality evaluation of services (Rajesh & Ravi, 2015). However, there are not enough studies on using this approach to evaluate and select 3PLPs. This paper applies a method that is based on the approach presented by Rajesh and Ravi (2015). Steps of the proposed GRA approach used for comparison, evaluation, and selection of the appropriate 3LSPs are described as follows.

1) Determine the weights of evaluation criteria of logistic service providers
   In this paper, the weights of evaluation criteria are determined by using GANP. For this purpose, pairwise comparisons of recognized criteria and sub-criteria are conducted based on the experts' opinions. Then, the average of experts' views will be considered as the weights for each of the criteria.
2) Define the grey relational matrices
   In this step, the performance of each logistic service provider's candidate in each criterion is determined by using the verbal scales from experts. Table 3 shows the verbal scale and the equivalent grey scale of them.

Table 3. The verbal scales and the equivalent grey number of them for definition the grey relational matrix (Rajesh & Ravi, 2015)

| Verbal evaluation | Equivalent grey number |
|---|---|
| Very Poor (VP) | [0,1] |
| Poor (P) | [1,3] |
| Medium Poor (MP) | [3,4] |
| Fair (F) | [4,5] |
| Medium Good (MG) | [5,6] |
| Good (G) | [6,9] |
| Very Good (VG) | [9,10] |

Assuming that the performance of the logistics service provider $i$ in criterion $j$ which is determined by the expert k is shown by $G_{ij}^{k}$, and $i = 1,2,\dots,m;\ j = 1,2,\dots,n; k = 1,2,\dots,t$, the equivalent grey number is calculated as equation 4.

$$\otimes G_{ij}^{k} = \left[\underline{G}_{ij}^{k}, \overline{G}_{ij}^{k}\right] \quad (4)$$

The average of these numbers is calculated by using equations 5 or 6.

$$\otimes G_{ij} = \frac{1}{t}\left[\otimes G_{ij}^{1} + \otimes G_{ij}^{2} + \dots + \otimes G_{ij}^{t}\right] \quad (5)$$

$$\otimes G_{ij} = \frac{1}{t}\sum_{k=1}^{t}(\otimes G_{ij}^{k}) \tag{6}$$

equation 6 can be rewritten as follows:

$$\otimes G_{ij} = \left[(\frac{1}{t}\sum_{k=1}^{t}\underline{G}_{ij}^{k}), (\frac{1}{t}\sum_{k=1}^{t}\overline{G}_{ij}^{k})\right] \tag{7}$$

1) Define the grey decision matrix

The grey decision matrix D is defined using the average values of grey rank $\otimes G_{ij}$. Each grey number is represented by a lower bound and an upper bound value.

$$D = \begin{bmatrix} \otimes G_{11} & \otimes G_{12} & \dots & \otimes G_{1n} \\ \otimes G_{21} & \otimes G_{22} & \dots & \otimes G_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes G_{m1} & \otimes G_{m2} & \dots & \otimes G_{mn} \end{bmatrix} \tag{8}$$

2) Normalize the grey decision matrix

The normalization is implemented to limit the values of the grey decision matrix on [0, 1]. Based on the characteristics of cost-based criteria and profit-based criteria, the normalization of these two categories of criteria is different. The cost-based criteria (minimization) are normalized by using equations 9 and 10.

$$\otimes G_{ij}^{*} = \left[\frac{G_j^{min}}{\overline{G}_{ij}}, \frac{G_j^{min}}{\underline{G}_{ij}}\right] \tag{9}$$

in which,

$$G_j^{min} = \min_{1\le i\le m}\{\underline{G}_{ij}\} \tag{10}$$

The profit-based criteria (maximization) are also normalized by using equations 11 and 12.

$$\otimes G_{ij}^{*} = \left[\frac{\underline{G}_{ij}}{G_j^{max}}, \frac{\overline{G}_{ij}}{G_j^{max}}\right] \tag{11}$$

In which,

$$G_j^{max} = \max_{1\le i\le m}\{\overline{G}_{ij}\} \tag{12}$$

So, the normalized grey decision matrix $D^{*}$ is obtained as below.

$$D^{*} = \begin{bmatrix} \otimes G_{11}^{*} & \otimes G_{12}^{*} & \dots & \otimes G_{1n}^{*} \\ \otimes G_{21}^{*} & \otimes G_{22}^{*} & \dots & \otimes G_{2n}^{*} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes G_{m1}^{*} & \otimes G_{m2}^{*} & \dots & \otimes G_{mn}^{*} \end{bmatrix} \tag{13}$$

3) Define the weighted normalized grey decision matrix

The weighted normalized grey decision matrix ($\otimes V_{ij}$) is calculated by multiplying the normalized grey decision matrix ($\otimes G_{ij}^{*}$) and the weights of criteria ($W_j$). So,

$$\otimes V_{ij} = \left[(\otimes G_{ij}^{*}) * (W_j)\right] \tag{14}$$

Based on equation 14, the multiplication of these grey numbers can be calculated as follows.

$$\otimes V_{ij} = \left[\underline{G}_{ij} * W_j, \overline{G}_{ij} * W_j\right] \tag{15}$$

In which,

$$\otimes V_{ij} = \left[\underline{V}_{ij}, \overline{V}_{ij}\right] \tag{16}$$

So, the weighted normalized grey decision matrix $D^{**}$ is shown as below.

$$D^{**} = \begin{bmatrix} \otimes V_{11} & \otimes V_{12} & \dots & \otimes V_{1n} \\ \otimes V_{21} & \otimes V_{22} & \dots & \otimes V_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes V_{m1} & \otimes V_{m2} & \dots & \otimes V_{mn} \end{bmatrix} \tag{17}$$

4) Define the ideal referral sets of the alternatives (logistic service providers)

Assuming that $m$ logistic service providers are represent by $LSP_i$ , and $i = 1, 2, \dots, m$, the ideal referral set of criteria which is represented by $LSP^{max} = \{G_1^{max}, G_2^{max}, \dots, G_n^{max}\}$, can be obtained by equation 18.

$$LSP^{max} = \left[\left[\max_{1 \le i \le m} \underline{V}_{i1}, \max_{1 \le i \le m} \overline{V}_{i1}\right], \left[\max_{1 \le i \le m} \underline{V}_{i2}, \max_{1 \le i \le m} \overline{V}_{i2}\right], \dots, \left[\max_{1 \le i \le m} \underline{V}_{in}, \max_{1 \le i \le m} \overline{V}_{in}\right]\right] \tag{18}$$

5) Calculate the grey possibility by comparing alternatives

In this step, the values of grey possibility are calculated by comparing the logistic service providers ($LSP_i, i = 1, 2, \dots, m$) with the ideal values ($LSP^{max}$) (Eq. 19).

$$P(LSP_i \le LSP^{max}) = \frac{1}{n} \sum_{j=1}^{n} [p(\otimes V_{ij} \le G_j^{max})] \tag{19}$$

The possibility of a grey number is less than or equal to the other one, can be calculated by using the following equation.

$$P(LSP_i \le LSP^{max}) = \frac{1}{n} \sum_{j=1}^{n} \left( \frac{\max\left(0, L_j^* - \max\left(0, \overline{V}_{ij} - \underline{G}_j^{max}\right)\right)}{L_j^*} \right) \tag{20}$$

Equation 20 can be described in detail by equation 21.

$$\begin{aligned} P(LSP_i \le LSP^{max}) & \\ = \frac{1}{n} \Bigg[ & \left( \frac{max\left(0, L_1^* - max\left(0, \overline{V}_{i1} - \underline{G}_1^{max}\right)\right)}{L_j^*} \right) \\ & + \left( \frac{max\left(0, L_2^* - max\left(0, \overline{V}_{i2} - \underline{G}_2^{max}\right)\right)}{L_j^*} \right) + \cdots \\ & + \left( \frac{max\left(0, L_n^* - max\left(0, \overline{V}_{in} - \underline{G}_n^{max}\right)\right)}{L_n^*} \right) \Bigg] \end{aligned} \tag{21}$$

In equation 21, $L_j^*$ $(j = 1, 2, \ldots, n)$ is the summation of the grey numbers of $\otimes V_{ij}$ and $\otimes G_j^{max}$ which is illustrated by equation (22).

$$L_j^* = L(\otimes V_{ij}) + L(\otimes G_j^{max}) \tag{22}$$

Equation 22 can be rewritten as follows (Eq. 23).

$$L_j^* = \left[\left(\overline{V}_{ij} - \underline{V}_{ij}\right) + \left(\overline{G}_j^{max} - \underline{G}_j^{max}\right)\right] \tag{23}$$

6) Prioritize the logistic service providers
   In this step, after calculating the possibility values ($P(LSP_i \leq LSP^{max})$), the logistic service providers are prioritized.

## 4. Data collection and survey process

The studied company is one of the corporations in the automobile industry in Iran. Firstly, this main activities in this company is focused on manufacturing 3 groups of products, including engine, gearbox, and axle. The company comprises of 18 Subsidiary companies. The company usually outsources the low value-added actions such as logistics duties to the logistic service providers. After calling logistic service providers by the company and primarily accreditation, seven of them were accepted to be assessed and compared. The steps in implementing the proposed framework are provided as follows.

1) Construct a committee of the experts to collect required data
In the first step, a committee of seven high-level managers in the company agreed to participate in the survey.

2) Recognize the candidate logistic service providers and extract the criteria and sub-criteria theoretical framework
Conducting an initial survey between the committee members on finding the potential LSPs, seven logistic service providers were considered as the candidate alternatives.

3) Design and distribute questionnaires to collect required data from the experts
In this step, to collect the required data of grey pairwise comparisons (in GANP method), and the gray relational matrices (in GRA approach), a questionnaire is designed and distributed among the committee members.

## 5. Results

### 5.1. Grey analytic network process (GANP) approach

After the distributed questionnaires were returned, the average of the experts' viewpoints was calculated. Then, pairwise comparison matrices of criteria and sub-criteria, and the local weights of them were calculated. Due to the possible interdependency of the criteria and sub-criteria, it is necessary to calculate the relative importance of the main criteria and sub-criteria of the "organizational abilities" criterion in the inner dependence matrices. After calculating the local and relative weights of all criteria and sub-criteria, using equations 1 and 2, the final weights of them are obtained and summarized in Table 5.

Based on the conducted calculations, among all criteria of logistic service provides, the "organizational abilities" criterion with the weight of 0.381 is the most critical criterion. Financial mechanism and technical abilities and framework are the next most important criteria with the weights of 0.347 and 0.272, respectively. It is also observed that among the sub-criteria of each criterion, the sub-criterion of transportation abilities and framework with weight of 0.118, the sub-criterion of cost of services with the weight of 0.188, and the sub-criteria of on-time delivery and experience and validity of brand commonly with weight of 0.063 are determined as the most crucial sub-criterion of each criterion.

Table 5. The final weights of criteria and sub-criteria

| Criteria | Sub-criteria | Primary Weight | Final Weight |
|---|---|---|---|
| Infrastructural and technical capabilities 0.272 | Inventory infrastructure and capabilities (C11) | 0.300 | 0.082 |
| | Transportation infrastructure and capabilities (C21) | 0.432 | 0.118 |
| | Information technology infrastructure and capabilities (C31) | 0.267 | 0.073 |
| Financial Mechanism 0.347 | Financial support (C12) | 0.200 | 0.069 |
| | Flexibility in payment(C22) | 0.252 | 0.087 |
| | Service cost (C32) | 0.543 | 0.188 |
| Organizational Capabilities 0.381 | Service quality (C13) | 0.156 | 0.059 |
| | Experienced workforce (C23) | 0.133 | 0.051 |
| | Fast and on-time delivery (C33) | 0.164 | 0.063 |
| | Service diversity (C43) | 0.138 | 0.052 |
| | Experience and company reputation (C53) | 0.165 | 0.063 |
| | Management situation and organization’s culture (C63) | 0.127 | 0.048 |
| | The level of a company's communication quality (C73) | 0.118 | 0.045 |

## 5.2. Grey relational analysis (GRA)

Determining the weights of criteria and sub-criteria, in the next step, the grey relational matrices are calculated based on the experts' opinions. Then, the verbal evaluations are translated into the grey values, and the average of experts' views are calculated by using equations 4-7. In table 6, the grey average rankings of the performance of each logistic service providers are presented.

Table 6. Evaluation of logistic service providers ($LSP_i$)

| Criteria | Logistic service providers ($LSP_i$) | Performance ranking $(G_{ij}^k)$ | | | | | Average of grey performance ranking ($\otimes G_{ij}$) |
|---|---|---|---|---|---|---|---|
| | | $G_{ij}^1$ | $G_{ij}^2$ | $G_{ij}^3$ | $G_{ij}^4$ | $G_{ij}^5$ | |
| Infrastructural and technical capabilities | $LSP_1$ | F | F | F | MG | VG | (4.33, 5.17) |
| | $LSP_2$ | G | VG | G | VG | VG | (5.60, 8.00) |
| | $LSP_3$ | MP | MP | F | F | MP | (2.83, 3.67) |
| | $LSP_4$ | G | MG | G | G | G | (4.83, 7.00) |
| | $LSP_5$ | G | G | G | MG | G | (4.83, 7.00) |
| | $LSP_6$ | G | G | G | G | G | (5.00, 5.70) |
| | $LSP_7$ | G | G | MG | G | MG | (4.67, 6.50) |
| Financial mechanism | $LSP_1$ | G | F | MG | MG | MG | (4.17, 5.33) |
| | $LSP_2$ | MP | MP | F | MG | F | (3.17, 4.00) |
| | $LSP_3$ | F | MG | F | F | F | (3.50, 4.33) |
| | $LSP_4$ | MP | P | F | F | MP | (2.50, 3.50) |
| | $LSP_5$ | MG | F | F | F | F | (3.50, 4.33) |
| | $LSP_6$ | MG | MG | F | MG | MG | (4.00, 4.83) |
| | $LSP_7$ | G | MG | MG | F | G | (4.33, 5.83) |
| Organizational capabilities | $LSP_1$ | G | MG | MG | G | G | (4.67, 6.50) |
| | $LSP_2$ | MG | G | MG | MG | VG | (5.00, 6.17) |
| | $LSP_3$ | F | MG | F | F | F | (3.50, 4.33) |
| | $LSP_4$ | G | VG | VG | G | VG | (6.50, 8.00) |
| | $LSP_5$ | MG | MG | G | MG | G | (4.50, 6.00) |
| | $LSP_6$ | F | F | F | MG | VG | (5.33, 7.17) |
| | $LSP_7$ | G | VG | G | VG | VG | (6.00, 7.83) |

After determination of the gray performance ranking values, the gray decision matrix ($D$), grey normal matrix ($D^*$), and gray normal tunable matrix ($D^{**}$) are obtained by using the equations 8-17. Then, by using equation 18, the ideal referral set of logistic service providers is calculated as follows.

$LSP_{max} = \{(0.22, 0.27), (0.26, 0.35), (0.29, 0.37)\}$
$P(LSP_1 \leq LSP^{max}) = 0.83$
$P(LSP_2 \leq LSP^{max}) = 0.81$

$P(LSP_3 \leq LSP^{max}) = 1$
$P(LSP_4 \leq LSP^{max}) = 0.75$
$P(LSP_5 \leq LSP^{max}) = 0.95$
$P(LSP_6 \leq LSP^{max}) = 0.74$
$P(LSP_7 \leq LSP^{max}) = 0.67$

Finally, the grey possibility value of each provider is obtained by equations 19-23. After determining the grey possibility values of providers, they are prioritized ascendingly in that the lowest value of the grey possibility represents that this provider is the nearest one to the ideal referral value. Based on these calculations, it is observed that provider 7 has the highest priority among the other ones. On the other hand, provider 3, that has the highest difference with the ideal value, is recognized as the weakest provider. According to the obtained results, the priorities of providers in experts' opinions are as follows.

$LSP_7 > LSP_6 > LSP_4 > LSP_2 > LSP_1 > LSP_5 > LSP_3$

## 6. Discussion and conclusions

Considering the importance of outsourcing logistic services to increase the competitive advantage of a company, designing a systematic framework that can evaluate and select the best logistic service providers seems to be necessary. Therefore, in this paper, a methodological framework is proposed based on the grey network analytic process and grey relational analysis approaches. The proposed framework provided a useful tool for the decision-makers to choose the best logistic service provides when considering the importance of the involved criteria in the evaluation process of LSPs. The obtained results of the implementation of the proposed model showed that, based on the experts' views, the criterion of organizational abilities is the most important among all criteria.

Although the organizational abilities of LSPs play an essential role in selecting LSPs by the experts, it doesn't mean that the experts do not pay attention to other criteria. The results from the grey relational analysis approach illustrated that the seventh provider has higher priority than the other ones and is an appropriate alternative in outsourcing the logistics activities of the company. The managers of the studied company can perform the evaluation and selection process of outsourcing logistics services to decrease the massive physical investments on logistics-related properties, increase flexibility, increase the efficiency of the operations in the company, dividing duties and minimizing the risks related to logistics. Besides, activities such as controlling the selected LSP continuously, monitoring the feedbacks, and holding collaborative sessions within the organization to increase the level of consistency can increase the commitment of provider to company and simplify the condition to achieving the company to its goal.

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