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Russia-Iran Logistic and Engineering Center Location Selection by Incorporating Gray Relational into MCDM

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ABSTRACT: The success of a logistic center fundamentally depends on the cost-minimizing and on-time delivery of services to its customers. Location selection problem in an international scope is the main factor in providing an appropriate service. Thus, we aimed to find the best location to establish the logistic center. Here, two robust multi-criteria decision-making (MCDM) methods of gray relational analysis and analytic hierarchy process (AHP) were applied for the selection of a logistic center location in the Iranian northern territory. The application of these methods can be reduced by decision-makers subjectively, which ultimately results in consistency in the weight value of the criteria. The criteria were evaluated based on various industrial project establishment requirements, including environmental, accessibility, social and economic, and location factors. These distinguish the current research from the other studies that focus on the demand and supply of a logistic to establish such a center. The results suggest that the AHP and gray relational are feasible methods for logistic and engineering location selection that effectively investigate this project's most important factors and identify a suitable alternative. The findings of our data suggest that in terms of environmental and accessibility factors, Astara port with grades of gray 0.8018 and 0.8184, was the best alternative compared to its competitors. However, in socioeconomic and location factors, the other ports were the best option. In conclusion, we recommend a short and long-term analysis of the financial and economic consequences of the project where all the alternatives' related costs are investigated in detail.

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1- Introduction

Due to globalization, the growth in world merchandise trade has a growth greater than both global production and the worldwide economy. Logistics companies in the supply chain play a significant role and connect firms to markets, including cargo shippers, supply management, warehousing, and multimodal transportation. However, uncertainties and risks were described in several researches domains as an impacting factor concerning the logistics industry. Uncertainty arises when there are several possible results, some or all of which are unknown, and the calculation of the probability of each is hard to predict(1) Uncertainties may have multidimensional sources, including the producers, shippers, control structures, end users, and other independent variables. The risk in logistics is an interruption factor in regular activities and planned operations. In previous researches, it was found that uncertainties generate and amplify risk which leads in a more complex supply chain(2) Nowadays, many logistic companies want to increase their customers satisfaction by reducing the time of delivery while minimizing the material handling expenses. In order to mitigate pressure on supply chain partners, to optimize operations and to decrease uncertainty and risks, logistic companies want to take the advantages of effective logistics and engineering platforms designed for each customer's specific position. These services can be classified from inbound processes to value-added services, assembling and repacking of various goods.

In total, Russia-Iran trade volume exceeded over $3 Billion in 2021. This is an increase of 300% during the last 23 years, emphasizing the importance of trade for Russia-Iran. A great share of Russian exports to Iran by over 60% were comprised of animal and vegetable bi-products while it can be seen from the reports that Iran's main exports to Russia were fresh vegetable products by over 75%(3). An increase in the share of logistic operations along with transportation has resulted in an active environment for the supply chain, specifically for logistic companies, as they have helped to evolve world trade. This has paved the way for more advanced logistic systems compared to traditional methods. Thus, over the last two decades, logistics has moved to provide not only operational services but corporate-level services4) .)

Logistic management improved a situation in which the performance of supply chain management developed tremendously. Some lessons to be learned from these changes for every organization are to have a strong knowledge

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of logistic systems, including supply/demand logistics, manufacturing logistics, sales logistics, reverse logistics, and green logistics, for maximizing profits and be able to provide customers the most positive experience of the product. These objectives are achievable by developing a logistics-based business model. More so, the integration of the materials, information, and value flow was widely used to improve the productivity of the logistic production system (5)

In supply chain management, collecting necessary information with respect to the logistic systems is of particular importance among the producers, the shippers, and the end users. Oftentimes, there is no clear information on demand and supply due to uncertainties and risks, and this leads to delays in delivering goods in the supply chain flow. This can negatively affect the logistic system's expected arrangement, which amplifies ambiguity with respect to its logistic plan, disruption in the scheduled plans for first-mile and last-mile delivery, and engaged inbound capacity. These brought a lot of attention to various discussions among the various groups with a role in logistic systems; several different solutions from artificial intelligence to mathematical have been proposed to develop the situation to a better point, yet there has been no final comprehensive solution. (6)

In logistic literature, the adverse effects of demand and supply uncertainty are commonly acknowledged. Specifically for logistic management, the low reliability of supply and demand, insufficient information about cargo movement modes from an origin to a destination, and the low trustworthiness of infrastructure are major concerns in operational-level arrangement. On top of the uncertainty in supply and demand flow, dynamism complicates logistic management. A logistic manager has to decide based on incomplete information on raw material and commodity flow from the suppliers to the final product for the customer(7). The existing International North-South Corridor (INTSC), which was initiated by India and continues by Russia, can be a great opportunity for Iran, Russia, and India to develop their trade by investing in the logistic infrastructures. This goal can be achieved by establishing a logistic center in the selected location.(8). Due to all these issues, the most important aims of this study are to assess the most influential factors that affect logistic management and to examine the best location for the establishment of a logistic complex for the Russia-Iran center in Iranian territory.

More efficient logistic systems minimize cargo operational costs, inbound/outbound time, and negative environmental effects. In particular, logistic companies can be better of an extra operational space. Under other conditions, they have to expand their existing infrastructure (e.g., buying new unloading/loading equipment, warehousing, and human resources). Various parties, including suppliers, shippers, and end users, would take advantage of an efficient logistic system. Therefore, in the current study, we seek to find an answer to the following question:

Where is the best location for the establishment of a logistic center for the Russia-Iran logistic center?

To find an appropriate answer to the research question, the rest of the study was structured as follows: Section 2 focuses on the previous works in this domain and the literature review. The study's line of research and its methodology are discussed in Section 3. Next to that, the outcomes are presented in Section 4. We elaborated on the related results in Section 5. Ultimately, the study's conclusion and further recommendations are figured out in Section 6.

2- Literature Review

Supply chain systems, regardless of all developments in terms of technology, mainly in information exchange and infrastructure domains, still have to provide responses to pressure that comes from customers who are demanding their products or services come faster and cheaper than ever before. The future of the logistics industry like most other industrial sectors is now facing an enormous change that brings both risk and opportunities. In that sense, there are many approaches the sector could develop to meet challenges, including new customers' expectations, new business models, new technology, and new market entrants(9) However, the logistics industry to facilitate trade between Russia and the Middle Eastern countries, India, and African countries is as not efficient as it should be where more than 50% of Russian trade volume is divided between China and Europe's northwestern countries(10) Providing logistical activities can provide some macro advantages to both adjacent areas and regional development in developing countries(11). Some advantages at the macro level can be pointed out as social and environmental problems in a minor aspect, decreased freight movement congestion, and low air pollution. More so, the selection of a logistic center is an important criterion for companies providing better operation efficiency at the micro level. In order to decrease transportation costs and traffic problems, an optimal location selection will be critical; and it will improve the performance, benefit, and competitiveness of firms(12)

A familiar list of key areas can be drawn up to represent the main components of distribution and logistics. These will include inbound/outbound solutions, value-added services, assembling, repacking, transport, stock, information, and multi-customer plans of action (see Figure 1). Multi-customer or distribution platforms are formed to add a competitive opportunity for customers. A majority of the cost assessment breakdown within logistics showed that transport was the most important one at 50 percent, next to it inventory at 7 percent, storage/warehousing causing cost at 20 percent, followed by customer service/order at 7 percent, and at the end administration at 3 percent

In recent decades, the United Nations Sustainable Development Goals (SD) have been widely recognized as a guideline among decision-makers and politicians. These goals want to stimulate action to emphasize human and environmental issues and also want to encourage consumers and producers to understand air-to-land, water resources, and ocean sustainability. Consequently, in the application of any technology and industrial project development, the harmony between biodiversity, living wildlife, and natural balance

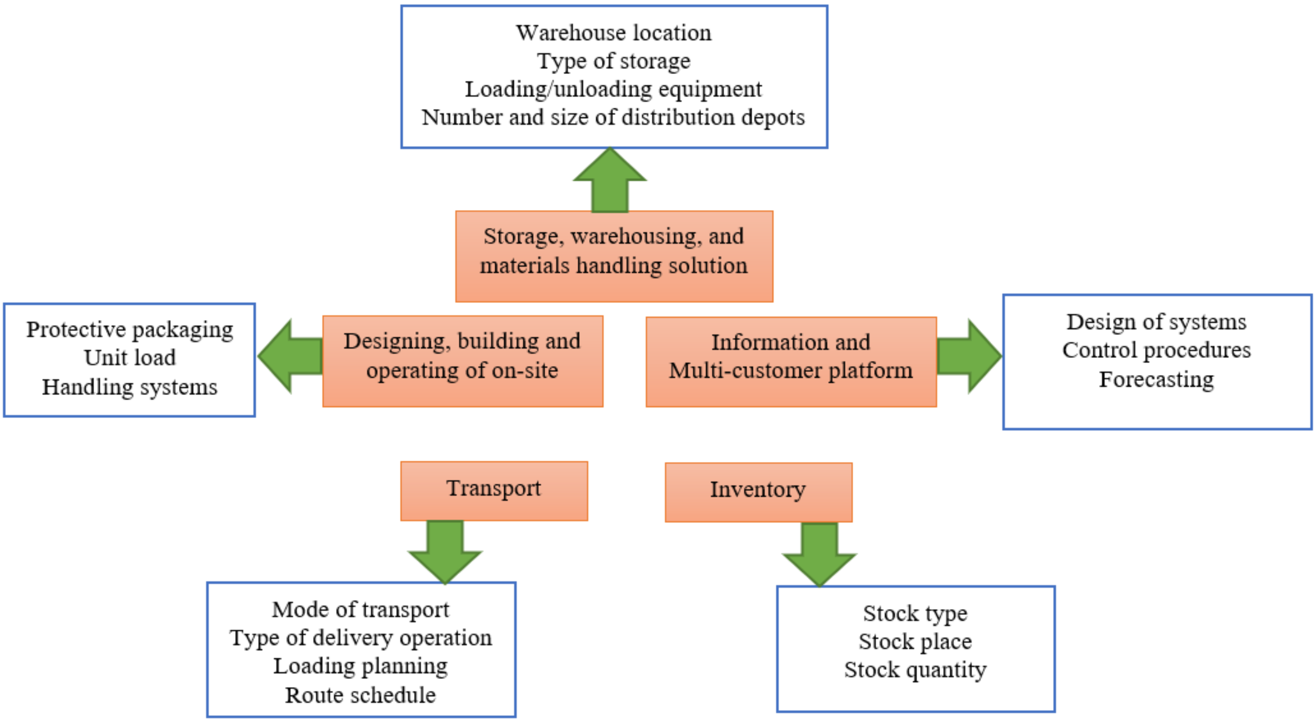

Fig. 1. The major component of distribution and logistics [Source: own figure based on authors' compilation].

should be taken into consideration. Moreover, any project success relates to the overall objectives defined and the amount of those goals reached as well as the use after the completion of the project(13) The diversity of factors has an impact on creating an industrial project. Previous research has explained the complexity of the real world. The importance of transport location can be explained by three independent factors in the global location, including connectivity, proximity, and accessibility. Generally speaking, two controllable (internal and company-specific) and uncontrollable (external and regional) factors, are always taken into account whenever companies want to select a location for their facilities by considering the aim of benefit maximization.

Logistic center location selection problems have been investigated in previous research. Of those, a Quality Function Deployment (QFD) method was applied to find the best distribution center from the perspective of a firm's customers, suppliers, and employers. A multi-criteria approach was conducted by Farahani et al(14). To evaluate different levels of problems from bi-objective to multi-objective. More so, to locate a suitable geographic location using a Center of Gravity (CoG) method, there was a focus on minimizing the cost of transporting raw materials from suppliers and finished products to customers

While all the above-mentioned problem-solving methods were basically focused on quantitative factors with costs as the main concern. However, the logistic center selection is a multi-objective issue that both qualitative and quantitative approaches should be taken into consideration. Next to that, there has been not too much attempt to address the locational decision-making for the logistic centers in an international logistic center. Therefore, this study investigates different logistic centers' locations for identifying the best Iran-Russia logistic and engineering solutions.

3- Methodology

3- 1- Research Approach

In the current study, we employed a quantitative method to get the final conclusion, based on two steps as briefly presented:

1- Development of multi-criteria decision-making criteria based on the literature review for a possible solution to find the best location of the logistic center.

2- Development of a gray relational model to assess the different locations earlier developed.

In order to develop the MCDM process, four main criteria of environment, accessibility, social and economic, and location were considered. Next to that, one way of matching logistic strategy to business strategy is to determine some associated qualitative analysis.

These can be addressed as measures to use qualitative analysis where it is impossible to drive good quantitative

Table 1. Effective Factors for Logistic Center Selection.

Row	Main Factors	Sub- Factors
1	Environmental	• Impact on region environment, • Distance to urban areas, • Accessibility to water resources, • Flooding level.
2	Accessibility	• Accessibility to railways, • Accessibility to roads, • Accessibility to air transportation, • Accessibility to seaports.
3	Social and Economic	• Land price, • Supply of low-cost labor, • Supply of specialized labor, • Industrial production, • Population's density.
4	Location	• Weather condition, • Excavatability, • Distance to main production centers, • Port's infrastructure.

measures. Therefore, a number of main and assessment criteria can be developed to investigate the different logistic centers' alternatives (see Table 1).

In this section, the gray relational model is explained. This system theory is based on uncertain and insufficient information to construct a relational analysis or to build the system-characterized model. Gray theory denotes a gray relation space and a series of non-functional type models. It constructs the space to control the demand for a massive number of samples in general statistical models, or the normal distribution and a broad amount of computation effort(15)

Based on the early developed decision-making process and considering the existing infrastructure space in the northern ports of Iran, we selected three main ports and their economic zones, including Astara, Anzali, and Amir Abad, to establish an exclusive logistic center for facilitating Iran-Russia trade. Figures 2, 3, and 4 represent the location of the proposed ports for the establishment of a logistic center in Astara, Anzali, and Amir Abad ports, respectively

3- 2- Gray Relational Model

Models provide a simple presentation of the existing complicated systems and help in procedure optimization even before real-world model initialization. To evaluate different logistic centers' locations, the main criteria and their sub-criteria were determined based on the literature. Since each criterion varied in type (qualitative, quantitative criterion) and tended to a different direction (negative/cost, positive/benefit, and optimal). Then, the measurement scales must be determined to clarify the criteria. Each criterion is denoted via C_i :

C_1. Impact on region environment. "Leopold Matrix" was used to identify the potential impact of a project on the surrounding environment(19).

C_2. Distance to urban areas. Geographic proximity was used to determine this criterion.

C_3. Accessibility to water resources. Geographic proximity was used to determine this criterion

C_4. Flooding level. To find out this criterion, the distance to permanent rivers and streams was calculated

C_5. Accessibility to railways. The results of physical movement (mobility), the affordability and quality of transport modes, mobility substitutes, transport system connectivity, and land use model criteria were used to measure this criterion(20)

C_6. Accessibility to roads. The results of physical movement (mobility), the affordability and quality of transport modes, mobility substitutes, transport system connectivity, and land use model criteria were used to measure this criterion (20)

C_7. Accessibility to the airport. The results of physical movement (mobility), the affordability and quality of transport modes, mobility substitutes, transport system connectivity, and land use model criteria were used to measure this criterion (20)

C_8. Accessibility to seaports. The results of physical movement (mobility), the affordability and quality of transport modes, mobility substitutes, transport system connectivity, and land use model criteria were used to measure this criterion (20)

C_9. Land cost. A field survey was conducted to evaluate prices in the selected places.

C_{10}. Supply of low-cost labor. The low-skilled workforce data based on the National Statistic Organization of Iran database were used to determine this criterion (19)

C_{11}. Supply of specialized labor. The high-skilled

Fig. 2. Astara port and its special economic zone(16)

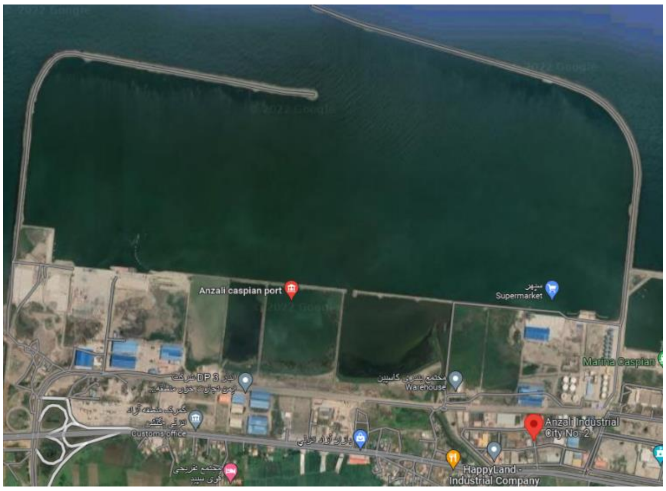

Fig. 3. Anzali port and its free zone(17)

Fig. 4. Amir Abad port and its special economic zone(18)

workforce data based on the National Statistic Organization of Iran database were used to determine this criterion

C_{12}. Industrial production. The number of small, medium, and large-sized industrial companies in a radius of 100km was used to measure the industrial production

C_{13}. Population density. The population density was calculated by the population divided by the size of the area(20)

C_{14}. Weather condition. To evaluate this criterion temperature deviation to 20 □ was evaluated.

C_{15}. Excavatability. The Excavatability criterion was measured by a 5-scale index(19)

C_{16}. Distance to main production centers. Geographic proximity to Tehran (the capital city of Iran), as the main production center with 14% of Iran's GDP, was used to determine this criterion(20)

C_{17}. Port's infrastructure. Base port information was used to determine this criterion (20)

3- 3- Definitions of Gray Relational Model

Definition .1.

The gray number exact value is unknown, although the range in which it is located is clear. In other words, gray numbers verify an interval or set of numbers. In general, suppose, if X be a referential set, then the gray set (G) is defined by $\overline{\mu}_G(x)$ and $\underline{\mu}_G(x)$ as shown in Relation (1)

$$\begin{cases} \overline{\mu}_G\ x\ : x \rightarrow\ 0,1 \\ \underline{\mu}_G\ x\ : x \rightarrow\ 0,1 \end{cases} \quad (1)$$

Here $\overline{\mu}_G \geq \underline{\mu}_G, x \in X .\overline{\mu}_G(x), and\ \underline{\mu}_G(x)$ are defined as the upper and lower limit of membership function (G), respectively. $\underline{\mu}_G(x) = \underline{\mu}_G(x)$, then the gray set (G) transforms into a fuzzy set. This capability reflects the inclusion of gray theory over fuzzy conditions and its flexibility in dealing with uncertain issues [47]. For instance, the excvatability criterion is a qualitative and positive criterion. This criterion can be calculated as a gray number below:

very poor [0,1], poor [3,4], medium poor [4,5], fair [5,6], good [6,9], very good [9,10].

Definition 2. Gray Main Operators

The gray sets can be extended to define relations among the real number(13) Interval operator developed by Moore. Operators can be defined by Relations (2), (3), (4), and (5) between two gray numbers of $=\left[,\overline{G}_1\right] and \otimes G_2 = \left[\underline{G}_2, \overline{G}_2\right]$

$$\otimes G_1 + \otimes G_2 = \left[\underline{G}_1 + \underline{G}_1, \overline{G}_1 + \overline{G}_2\right] \quad (2)$$

$$\otimes G_1 - \otimes G_2 = \left[G_1 - \overline{G}_2, \overline{G}_1 + \underline{G}_2\right] \quad (3)$$

$$\otimes G_1 \times \otimes G_2 = \left[\min\ \underline{G}_1 \underline{G}_2, \underline{G}_1 \overline{G}_2, \overline{G}_2 \overline{G}_2\ \right], \left[\max\ \underline{G}_1 \underline{G}_2, \underline{G}_1 \overline{G_2}, \overline{G_1} \overline{G}_2\ \right] \quad (4)$$

$$\otimes G_1 \div \otimes G_2 = \left[\underline{G}_1, \overline{G_2}\right] \times \left[\frac{1}{\underline{G_2}}, \frac{1}{\overline{G_2}}\right] \quad (5)$$

If k be a real positive number, then Relation (6) will determine the numerical multiple of that in a gray set (G):

$$k \otimes G = \left[k\underline{G}_1, k\overline{G}_2\right] \quad (6)$$

Definition 3. Minkowski Distance

The Minkowski distance can be used to calculate the distance between two gray numbers using Relation (7) as follows

$$D_{G_1G_2} = \frac{1}{\sqrt[P]{2}}\left[\ \underline{G}_1 - \underline{G}_2\ ^P + \ \overline{G}_1 - \overline{G}_2\ ^P\right]^{\frac{1}{P}} \quad (7)$$

Where $\underline{G}_1 - \underline{G}_2$ demonstrates the referential sequence of the alternative distance to the lower bound of the alternative in the normalized matrix, and $\overline{G}_1 - \overline{G}_2$ shows the referential sequence of the alternative distance to the upper bound of the alternative in the normalized matrix. In this study, p = 2 was determined as the Euclidean distance between two gray numbers.

When if, $\otimes G_1$ and $\otimes G_2$ be two definite numbers and membership of the real number set, i.e. $\underline{G}_1 = \overline{G}_1$, $\underline{G}_2 = \overline{G}_2$, then Relation (8) exists as follows:

$$D_{G_1G_2} = \frac{1}{\sqrt[P]{2}}\left[2\ \ \underline{G}_1 - \underline{G}_2\ ^P\right]^{\frac{1}{P}}\left(\frac{\sqrt[P]{2}}{\sqrt[P]{2}}\right)\left|\underline{G}_1 - \underline{G}_2\right| \quad (8)$$

3- 4- Methodology Application Steps

Given a discrete set of alternatives $A = \{A_1, A_2, ..., A_m\}$ and also $Q = \{Q_1, Q_2, Q_K, ..., Q_n\}$ be a set of nth independent criteria. These criteria can have k qualitative criteria and n-kth quantitative criteria. Thus, a comprehensive decision-making method can be determined as below steps:

Step1. Decision Matrix Formation

$\otimes Gij$ 1, shows the uncertainty attributes for qualitative criteria. R_{ij}, presents the crisp numbers in the real set numbers and was used to evaluate each option in terms of quantitative criteria ($(Q_{K+2}, Q_{K+2}, ..., Q_n)$ Therefore, the decision matrix was formed using Relation (9) corresponding to both the gray and crisp elements, simultaneously.

Uncertainty attributes ⟷ Crisp attributes

$$D=\begin{bmatrix}\otimes G_{11} & \otimes G_{12} & \otimes G_{1K} & R_1,k+1 & R_{1n}\\ \otimes G_{21} & \otimes G_{22} & \otimes G_{2K} & R_2,k+1 & R_{2n}\\ \otimes G_{m1} & \otimes G_{m2} & \otimes G_{mK} & R_m,k+1 & R_{mn}\end{bmatrix}\begin{matrix}A_1\\A_2\\ \vdots\\A_m\end{matrix} \quad (9)$$

Step2. Normalizing Decision-Making Matrix

Due to the differences in direction and type of criteria, the calculation process of the factors is impossible. Therefore, a series of non-dimensional equations was proposed to overcome this problem as shown in Table 2.

Table 2. Dision-making normalizing relations

Decision-making normalizing relations	
Positive and Quantitative Criteria	
$R_ij^*=\frac{R_ij}{R_j^{max}}, R_j^{max}=max_{(1<i\leq m)}\ R_ij\ ,k+1\leq j\leq n$	(10)
Positive and Qualitative criteria	
$\otimes G^*{}_ij=[\frac{G_ij}{G_j^{max}},\frac{\overline{G_ij}}{G_j^{max}}],G_j^{max}=max_{(1\leq i\leq m)}\ \overline{G_ij}\ ,j=1,2,...,k$	(11)
Negative and Quantitative criteria	
$R_ij^*=\frac{R_j^{min}}{R_ij}, R_j^{min}=min_{(1\leq i\leq m)}\ R_ij\ ,k+1\leq j\leq n$	(12)
Negative and Qualitative criteria	
$\otimes G^*{}_ij=\frac{G_j^{min}}{G_ij},\frac{G_j^{min}}{G_ij}],G_j^{min}=min_{(1\leq i\leq m)}\ G_{ij}\ ,j=1,2,...,k$	(13)
Optimal and Quantitative criteria	
$R_{ij}^*=1-\lvert\frac{R_{ij}}{\mu}-\frac{R_{oj}}{R_{oj}})\begin{cases}\mu=R_j^{max} & if\ \lvert R_j^{max}-R_{Oj}\rvert\geq\lvert R_{oj}-R_j^{min}\rvert\\ \mu=R_j^{min} & if\ \lvert R_j^{min}-R_{Oj}\rvert\geq\lvert R_{oj}-R_j^{min}\rvert\end{cases}$	
$R_j^{max}=max_{1\leq i\leq m}\ R_{ij}\ ,R_j^{min}=min_{(1\leq i\leq m)}\ R_ij\ ,k+1\leq j\leq n$	
$G^*{}_{ij}=\left[1-\lvert\frac{G_{ij}-G_{oj}}{\mu_1-G_{oj}}\rvert,1-\left\lvert\frac{\overline{G}_{ij}-\overline{G}_{oj}}{\mu_2-G_{oj}}\right\rvert\right]G_{ij}^*\leq\overline{G}_{ij}^*,,j=1,2,...,k$	(14)
$\begin{cases}u_1=\underline{G}_j^{max} & if\ \lvert G_j^{max}-\underline{G}_{oj}\rvert\geq\lvert\underline{G}_{oj}-G_j^{min}\rvert\\ u_1=\underline{G}_j^{max} & if\ \lvert G_j^{max}-\underline{G}_{oj}\rvert<\lvert\underline{G}_{oj}-G_j^{min}\rvert\end{cases}$	
$\begin{cases}u_2=\underline{G}_j^{max} & if\ \lvert G_j^{max}-\underline{G}_{oj}\rvert\geq\lvert\underline{G}_{oj}-G_j^{min}\rvert\\ u_2=\underline{G}_j^{max} & if\ \lvert G_j^{max}-\underline{G}_{oj}\rvert<\lvert\underline{G}_{oj}-G_j^{min}\rvert\end{cases}$	

Decision-making normalizing relations

Optimal and Qualitative criteria

$$\underline{G}_j^{\max} = \max 1 \le i \le m \;\; G_{ij} \quad , \quad G_{\min}^{\min} = \min_{1\le i\le m} \;\; G_{ij}$$

$$\underline{G}_j^{\max} = \max 1 \le i \le m \;\; G_{ij} \quad , \quad G^{\min} = \min_{1\le i\le m} \;\; G_{ij} \tag{15}$$

In Table 4, $\otimes G_{\text{oj}}$ and R_{oj} were predetermined optimal values for *j*th quantitative and qualitative criterion and also $\otimes G_{\text{oj}} = [\underline{G}_{oj}, \overline{G}_{oj}]$

Step 3. Referential Sequence Definition

To evaluate the comparative sequence considering the normalized matrix alternatives, a referential sequence was used to determine it as an optimal criterion by Relation (16) as follows:

$$A_0 = \{[max_{1\le i\le m} \underline{G_{i1}}^*, max_{(1\le i\le m)} G_{i1}^*], \ldots, [max_{1\le i\le m)} \underline{G_{ik}}^*, max_{(1\le i\le m)} \overline{G_{ik}}^*], max_{(1\le i\le m)} R^*_{(i,k+1)}, \ldots, max_{\le i\le m)} R_{in}^*\} \tag{16}$$

Step 4. Gray Relation Coefficient Calculation

Deng proposed a mathematical equation for the gray relation coefficient using Equation 17 as follows(21)

$$\gamma \;\; x_0 \;\; k \;\; , x_i \;\; k \;\; = \frac{\min_i \min_k \Delta_i \;\; k \;\; + \iota \max \max_k \Delta_i \;\; k}{\Delta_i \;\; k \;\; + \zeta \max_i \max_k \Delta_i \;\; k} \tag{17}$$

Where $\Delta_i(k) = |x_0(k) - x_i(k)|$ is the distance between A_1 alternative and the referential alternative according to *jth* criteria. In the current study, Minkowski distance was used to determine this distance. ζ is the distinguished coefficient $(æ\in[0,1])$ and it is commonly equal to 0.5 [48], [51], [56].

Step 5. Grade (degree) of Gray Relation Calculation

The grade (degree) of the gray relation between alternative the A_1 and the referential alternative can be calculated by Relation (18) as follows. (21)

$$\gamma(x_0, x_i) = \Sigma_{(k=1)}^{n} w_k \gamma(x_0(k), x_i(k)) \tag{18}$$

Where w_k denotes the weights of the *kth* criterion.

The criteria weights $w = (w_1, \ldots, w_k, \ldots, w_n)$ can be determined using the Analytic Hierarchy Process (AHP) method (if criteria are independent of feedback) or the Analytic Network Process (ANP) method (if criteria are dependent on feedback)

Note, that the grade (degree) of the gray relation (larger is better) can be determined using Relation 20.

4- Results

The results of the developed decision-making process approaches were presented in this section

4- 1- First Matrix

To reflect logistic center location selection factors, 17 criteria, which were defined in Section 3, were proposed. The ultimate goal of logistic and engineering center selection is achievable based on 17 evaluation functions in 4 groups and 3 alternatives, as shown in Figure 5.

4- 2- Second Matrix

Based on the 17 grouped criteria, as presented in Table 3, the decision matrix was designed to rank the relationship among functions and the importance of each function in each group.

We utilized pairwise questionnaires to get the total weight corresponding to criteria using the AHP method which was developed by Saaty. The results for each criterion have been presented in Table 4.

4- 3- Determining Normalized Decision-Making Matrix

To compare the alternatives on each attribute, the normalized process was made using Relation 10 to 15 corresponding to the best alternative A_0 as presented in Table 5.

4- 4- Gray Relation Coefficient

Considering the results of Table 5, the distance between the A_i alternative and the referential alternative according to *jth* criteria were determined by Minkowski distance as presented in Table 6.

The results of the AHP and the gray relational model were presented in this section. All questionnaires were filled out by experts in the domain of maritime transportation, logistics, and port management.

In conclusion in the explanation of the results, firstly, we begin with a general question which is how to select a logistic center location then we do narrow down the question to ports

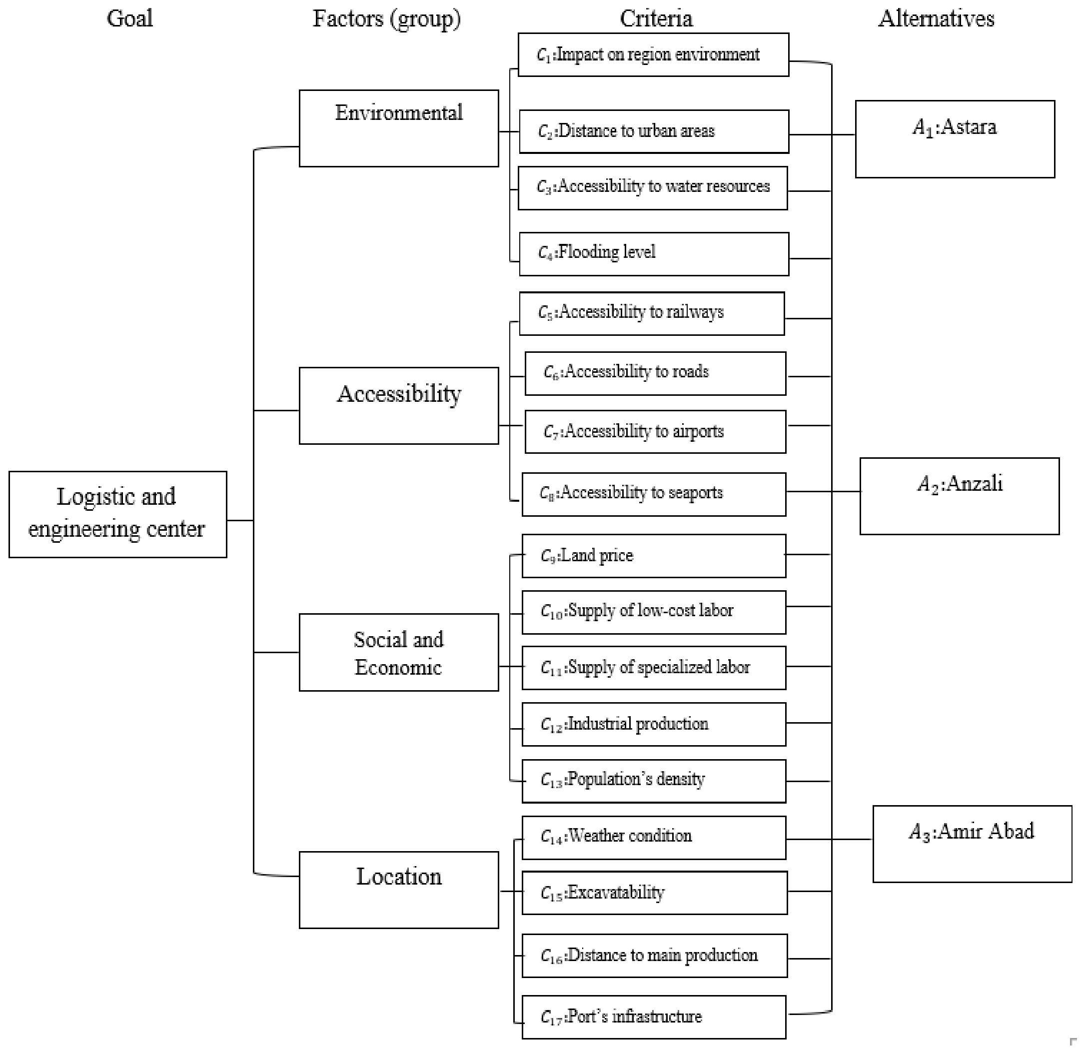

Fig. 5. Analytic hierarchy process for the design of 1st matrix.

Table 3. Original responses to the 2nd matrix in scores and linguistic terms.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
A_1	[6,9]	1	1	5	[9,10]	[6,9]	[4,5]	[1,3]	50	547	208	641	222	15.4	[4,5]	488	[5,6]
A_2	[3,4]	40	2	3	[3,4]	[3,4]	[5,6]	[4,5]	150	194	61	842	441	19.2	[3,4]	358	[4,5]
A_3	[1,3]	60	5	4	[4,5]	[4,5]	[6,9]	[6,9]	100	641	225	1131	87	17.6	[6,9]	347	[6,9]

Table 4. Total weights for each criterion using analytic hierarchy process (AHP)..

First level Factors (weight = G)	Second level Criteria	Second-level Criteria (Weight = G)
Environmental (0.1333)	C_1: Impact on regional environment	0.2971
	C_2: Distance to urban areas	0.2908
	C_3: Accessibility to water resources	0.1956
	C_4: Flooding level	0.2161
Accessibility (0.2688)	C_5: Accessibility to railways	0.4303
	C_6: Accessibility to roads	0.2383
	C_7: Accessibility to airports	0.0802
	C_8: Accessibility to seaports	0.2509
Social and Economic (0.3233)	C_9: Land price	0.1399
	C_{10}: Supply of low-cost labor	0.1749
	C_{11}: Supply of specialized labor	0.3040
	C_{12}: Industrial production	0.2873
	C_{13}: Population's density	0.0935
Location (0.2742)	C_{14}: Weather condition	0.1300
	C_{15}: Excavatability	0.1575
	C_{16}: Distance to main production	0.498
	C_{17}: Port's infrastructure	0.2151

Table 5. Normalized decision-making matrix.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
A_1	[0.66,1]	0.01	1	1	[0.9,1]	[0.66,1]	[0.44,0.55]	[0.11,0.33]	1	0.85	0.92	0.56	0.39	0.70	[0.25,0.20]	0.71	[0.44,0.66]
A_2	[0.33,0.44]	0.66	0.5	0.6	[0.3,0.4]	[0.33,0.44]	[0.66,1]	[0.44,0.55]	0.33	0.30	0.27	0.74	0.19	0.94	[0.50,0.66]	0.96	[0.44,0.55]
A_3	[0.11,0.33]	1	0.2	0.8	[0.4,0.5]	[0.44,0.55]	[0.55,0.66]	[0.66,1]	0.5	1	1	1	1	0.84	[0.16,0.11]	1	[0.66,1]
A_0	[0.66,1]	1	1	1	[0.9,1]	[0.66,1]	[0.66,1]	[0.66,1]	1	1	1	1	1	0.94	[0.16,0.111]	1	[0.66,1]

Table 6. Gray relation coefficient.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
A_1	1	0.32	1	1	1	1	0.65	0.39	1	0.72	0.83	0.47	0.39	0.57	0.53	0.52	1
A_2	0.51	0.58	0.48	0.33	0.43	0.53	1	0.65	0.37	0.36	0.35	0.60	0.33	1	1	0.88	0.37
A_3	0.43	1	0.37	0.33	0.54	0.65	0.75	1	0.44	1	1	1	1	0.76	0.41	1	0.33

Table 7. Grade of the Gray model.

Factors/Alternatives	Alternative 1	Alternative 2	Alternative 3	Preferred ranking
Environmental	0.8018	0.4853	0.5622	$A_1 \succ A_3 \succ A_2$
Accessibility	0.8184	0.5542	0.6973	$A_1 \succ A_3 \succ A_2$
Social and Economic	0.6896	0.4243	0.9212	$A_3 \succ A_1 \succ A_2$
Location	0.6316	0.8053	0.7323	$A_2 \succ A_3 \succ A_1$

in the northern region of Iran and focus on 3 major northern ports of Iran. Then, we went through a systematic method using AHP and gray relational that produces appropriate decisions for logistic and engineering locations. Thus, the gray relation model was used to determine the preferred ranking of alternatives with respect to the criteria.

The results of the model corresponding environmental, accessibility, social and economic, and location factors for alternatives 1, 2, and 3 have been presented in Table 7.

As can be seen, alternative 1 was the best option in terms of the environmental factor to construct a logistic center. This can be addressed in a situation in which Astara port compared to Anzali and Amir Abad ports was less sensitive to an industrial project establishment due to its nature. So, it would impose not too much damage on its surrounding nature, if Astara port was selected as a main logistic location concerning environmental factors. Moreover, Astara had better water resources as this port is located in a less populated area than the other two investigated places.

The accessibility factor also is another important case for the success of the logistic center and minimizing its costs. The calculations with respect to the accessibility to transportation mode factors showed that Astara port considering its access to INTSC's railway and the international road had the best connectivity compared to other ports while its access to the airport was far away than others. This implies that the establishment of the logistic center in Astara decreases the cargo handling cost which was in line with the results of gray relational model outcomes.

Investigating the social and economic factors is also critical to consider the sustainability criteria according to the most influential impactor on the analyzed model. In that sense, the outcome of the study showed that Amir Abad port concerning the land price, supply of human resources, and industrial production indexes had an ideal situation for its competitor in facilitating the flow of work needed to be done in the logistic center. This founding was due to the number of companies active in the province of Mazandaran where Amir Abad port is located and a better supply of human resources both specialized and low-skilled ones.

Depending on the availability of information for the port's infrastructure, weather conditions, excavatability, and distance to the main production center of Iran, Anzali port was ranked as the best one. It can be discussed that this port was the nearest port to Tehran, the capital city of Iran, and had better infrastructure in cargo handling thanks to investment in this port.

This research examined the location of the logistic and engineering center using a theoretical AHP and gray relational model. It evaluated the impacting factor for the establishment of an industrial project by taking into account 4 main and 17 sub-criteria. Logistics has gained an excessive capacity during the past decades. However, logistic flow always deals with unpredictable challenges, uncertainty, and risk that are the main affecting factors for its efficiency. Any logistic companies should be constructed in a location that minimizes their cost while they have to take into account other variables such as demand, supply, regulations, and information.

Thus, due to these challenges this study aimed to propose a model to construct a logistic and engineering center in which, the most important factors of environmental, accessibility, social and economic, and location. Therefore, we first developed questionnaires to get the weight of factors. Then, in the next step, the research model using data from the different locations was collected and entered into the study's model.

5- Discussion and Implications

Investigating the impact of four main factors of environmental, accessibility, social and economic, and location on the establishment of a logistic and engineering center and its bond with the logistic center's effectiveness draws a lot of attention to the sphere of supply chain management research. It is also significant to look at the sustainability factor based on the greatest impacting indicators on the analyzed model. In order to infer sustainability calculation, the environmental impact of the logistic center was determined from the outcomes of the analyzed model.

Depending on the logistic center adjacent place's conditions, Astara port's environmental and accessibility factors were calculated as the best alternative. However, the grade of two factors of socio-economic and location belonged to other alternatives which should be taken into account in the construction of the proposed logistic center. It is more evident from the previous studies that the decision to determine location is very useful in the long-term strategic planning of a logistics company and optimizing transportation costs by determining the right logistics company location (Onstein et al., 2020).

This research examined the location selection of the logistic and engineering center by incorporating the AHP method into the gray relational approach to get the final decision. It evaluated four main factors corresponding to three alternatives to investigate the impact of criteria on the selection of the best alternative. Supply chain management, particularly logistic management, makes an important part of the product cost. However, logistic centers, often time, deal with various unpredictable challenges, which is the main affecting factor for the efficiency of the logistic center services. Every logistic center should be constructed in a location to maximize its profit while considering other variables such as environment, transportation, socio-economic, and location costs should be minimized.

6- Conclusions and Future Research

Incorporating the AHP method into the gray relational model can contribute to understanding logistic center location selection. This research mainly provided answers to the initially identified question considering the objective determined in section 3. The main line of the question was to identify the best location for the establishment of a logistic center for a Russia-Iran logistic center when we derived the data of the criteria.

Establishing a logistic center in Astara port has been found to be the most promising option. In this method, we show that four main factors can influence the logistic center's operations.

From the criteria evaluating standpoint, the designed approach represented not all aspects of the real situation. Thus, this approach only coped with the location selection for the alternatives. Then, to establish a logistic center and multi-disciplinary systems, logistics company's managers need an evaluation method that allows them to systematically detect this complex system into similar sub-problems. Thus, it would be interesting to evaluate information exchange systems and add more factors to the model regarding, demand and supply information.

Therefore, the overall cost, benefit, and related economic studies of the developed model would provide a broader view of the cost and benefits of this industrial project. It is also recommended to investigate existing factors for integrating logistic-related information. Next to that, it is proposed to take into account CO_2 equivalent emissions for the different alternatives as sustainability indicators.

All these concerns need to be addressed in future research to minimize the related costs of a logistics and engineering center. Thus, it is of particular concern for other academics to propound appropriate answers to these discussions and questions.

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