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RESEARCH PAPER

A Novel Hybrid MCDM Method for Optimal Location Selection of Free Trade Zones, Case Study: Mazandaran Province

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Abstract

The free trade zone has attracted significant attention, especially in developing countries. It facilitates attracting foreign capital and skilled workforce and experts to achieve economic development, which is its ultimate goal. An efficient free trade zone has different features which most of which are related to its location. Therefore, location selection has an important role in its success. Facility location planning is a strategic decision that is very expensive, but it can decrease future costs. This paper aims to find the optimal location for establishing a free trade zone. The current paper applies Multi-Criteria Decision-Making (MCDM) to capture all the features and essentials of a thriving free trade zone. To this end, a novel hybrid MCDM method is developed to obtain the optimal solution with fewer paired comparisons and less reliance on estimations. Then, to assess the applicability of the developed method, a real case study has been conducted in Mazandaran, Iran. Finally, the proposed method's results are evaluated by comparing them to the results of the AHP method.

Keywords:
Multi Criteria Decision Making;
Free Trade Zone;
Best-Worst Method;
Location Problem;
Hybrid MCDM Method

Introduction

The World Bank defines a free trade zone (FTZ) as "a geographic area where goods are imported, manufactured, stocked, cleared, or shipped under certain conditions and regulations, and generally without customs fees." FTZs are generally located near ports, airports, and a country's borders to take advantage of these areas[†]. The first FTZ, with its current definition, was built in the 12^{th} century AD, the Hanseatic League in northern Europe. The most famous of these is the Hamburg Free Zone and London Steel Yard Zone. The Shannon Free Zone opened in Ireland in 1959, which is referred to as the first modern FTZ and is one of the most successful free zones that are still in operation [1]. Establishing FTZ is a well-agreed solution to increase non-oil exports and reduce dependence on the revenue from crude oil exports, based on objectives such as attracting foreign capital, technology transfer, employment creation, economic prosperity, domestic industry strengthening, increase in export earnings, and economic welfare. FTZs have somehow been able to tackle anti-development barriers and gain significant new knowledge and skills. With the entrance of technology, management, and investment into developing countries, domestic production factors are moving along the path of development and alignment with the global economy. The main effect of these areas for developing countries is to change economic thinking and alignment with the global economy.

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As is known, economics is a global science and it cannot be expected to grow economic indicators with the country's isolation. One of the best ways to build links and exchanges with other countries is to establish FTZs.

Inappropriate location of economic areas resulting from ignoring the standards significantly reduces the efficiency of the industrial system and, consequently, leads to an unfavorable industrial environment. In location selection planning, the knowledge about the natural and human resources of the regions, estimation of demand, and recognition of the spatial factors must be considered. Different places have different cost structures; as the result of the ultimate effort to make profits in production and trade, close attention should be paid to the cost structures of the candidate locations. Therefore, achieving maximum profits involves optimally selecting the locations, in which the production factors are combined with the least cost and most efficient form. Notably, the related literature shows that one of the main reasons for failure in FTZs and industrial parks is their unsuitable location. To select the optimal location, the associated criteria and their importance should be recognized firstly. The number and variety of these criteria make it hard to find the optimal location. Therefore, we utilize multi-criteria decision-making (MCDM) methods to present a holistic and precise framework for FTZ location selection.

MCDM is a well-known branch of the decision making theory. Its general concept is to choose the most desired alternative among other available alternatives based on decision-makers' opinions [2]. There are usually several criteria for choosing the optimal alternative. The interrelations among these criteria make it a complicated process. MCDM problems are divided into two distinct categories based on their solution space. Multi-objective decision-making (MODM) is used for continuous issues and multi-attribute decision-making (MADM) is used for discrete issues. The current study aims to present a holistic framework for finding the optimal location of FTZ among available alternatives, considering various criteria. Hence, we deal with an MADM problem. Prior studies have developed various methods to derive the importance of each criterion and alternative (e.g., analytical hierarchy process (AHP), analytical network process (ANP), technique for order of preference by similarity to ideal solution (TOPSIS), elimination et choix traduisant la realité (ELECTRE), viekriterijumsko kompromisno rangiranje (VIKOR), and best worst method (BWM)). Interested readers can refer to Zavadskas et al. [3]. BWM is one of the most recent methods for solving a multi-criteria decision problem. Compared to other MCDM methods, BWM is much easier to use. This is because it needs fewer comparisons [4]. Moreover, it provides more consistent results (according to the consistency rate). Another recent MCDM method is the basic point approach which is based on the experts' opinions. This method is best used when there is much information about the criteria and alternatives. This method leads to more consistent results due to its independence from the paired comparisons [5]. However, this can reduce its accuracy if the information used is not reliable. It needs considerable information in the first step. Depending too much on experts' preferences may lead to more estimation errors.

On the other hand, BWM is a novel method for obtaining the criteria's weights, but it cannot determine alternative's weights and select the best option. To overcome the above deficiencies, we combine the BWM method and basic point. In other words, we present a hybrid method, consisting of BWM and basic point methods to use their strengths and cover their weaknesses. This study contributes to the literature by introducing a novel hybrid method based on the best-worst and basic point methods to cover their deficiencies and achieve better results.

The remainder of this paper is presented as follows. The related investigations and papers are reviewed in Section 2. The provided methodology is explained in Section 3. Section 4 shows the applicability of the novel hybrid model with a case study, and discussions are presented in Section 5. Finally, Section 6 concludes the paper.

Literature Review

Facility location selection is a crucial decision in strategic planning for a range of private and public facilities. Retailers who want to build a new branch, a manufacturer who wants to add new storage to the existing warehouses, or a city planner looking for the best location for the fire department are faced with the challenge of location selection [6]. Besides, relocating the facilities is important, since population, customer tastes, environmental factors, and market fluctuations are changing in a dynamic market of unpredictable changes. The high cost of buying land and building facilities has led to many articles and projects in this area. As a strategic decision, most of the facilities are intended to be used for a long time. Therefore, decision-makers should focus not only on the current situation but also on future trends throughout the facility's lifetime [6].

Constructing or developing a facility is a time-consuming and expensive activity. Before purchasing and constructing, an appropriate location should be identified, and its strengths and weaknesses be properly evaluated. The process of locating the facility is a long-term investment, which despite the high initial costs, leads to huge longevity in the facility lifetime. In this regard, the location of the facility can be considered an important strategic decision. The first person who officially worked on locating the facility was Weber; in 1909, he found the location of a warehouse to minimize trips [7].

Afterwards, researchers have worked on location selection until 1964, when the location selection of police stations was presented [8]. To do so, a more general model is developed that takes several places on the network to minimize the total distance between customers and facilities. In the 1960s, the focus on locating increased and several papers were published under deterministic and stochastic scenarios. Uncapacitated location problem [9], p-median problem [10], and covering problem [11] are important location selection problems. It is argued that location selection inherently contains several criteria [12]. Most of the studies have aimed to minimize cost or distance. However, considering other criteria could provide a better result. Problems with point goal function, the problem of minimizing sum in a continuous state, and multi-criteria median in the network are among these issues [13]. In the following, we review some important papers that have addressed the location selection problem through MCDM methods.

Various MCDM methods have been used for location selection problems. Shapira and Goldenberg used the AHP technique to determine the optimal place to build mansions concerning the facilities of the area [14]. Badri used a combination of AHP and goal programming methods to find the optimal location of facilities [15]. In many cases, AHP combined with other techniques is used for the location selection problem. Shang and Sueyoshi used AHP and DEA to find a flexible production system [16]. They used AHP to obtain the inputs of the DEA method. More recently, Yang and Kuo applied the combination of AHP and DEA to solve the multi-objective location problem [17]. They used AHP to achieve the weight functions. Rezaei (2016) presented the best-worst method (BWM) as an efficient and effective MCDM method [4]. Afterwards, Rezaei et al. used this method to select the best supplier with a lifetime approach [18]. Motevali Haghighi and Torabi conducted this method to evaluate the hospital information system and select the best unit [19]. They also used the DEA method to measure the performance of each unit. Despite the significant body of literature on optimal location selection for different facilities, locating industrial centers such as free and special trade zones, industrial parks, and logistics centers are hardly addressed.

Kilkenny and Thisse investigated the factors that majorly affect the location selection problem and finally reached the population, labor force, and economic strategies [20]. Li et al. obtained the optimal location of the logistics center using fuzzy and TOPSIS techniques [21]. They illustrated the validity of their model by a case study with 15 candidate locations and 13 criteria. Government pressures, customer expectations, and competitive advantage have led to sustainable location problems. In this regard, Pellenbarg argued that sustainability issues must be taken into account while selecting the location of industrial parks [22]. He also indicated the effects of environmental issues in location problems. Moreover, Fernández and Ruiz considered socio-economic, planning, infrastructure, and environmental factors affecting the location of industrial towns [23]. Using the AHP method, they showed that environmental and economic factors are the most critical factors in locating industrial parks.

As shown, previous studies have been focused on FTZ development with qualitative approaches. In the scope of facility planning, most of the studies have tried to find the optimal location for industrial parks, logistic centers, warehouses, etc.; but FTZ location selection has been neglected. In this paper, we developed a hybrid MCDM method to find the optimal location of FTZ more reliably and consistently.

Methodology

The problem that we consider in this paper is to develop an MCDM framework for selecting the optimal FTZ location. First, the most effective factors and criteria regarding FTZ location are obtained through a comprehensive literature review and confirmed by experts. Afterwards, the associated weights of each criterion and alternative are achieved based on MCDM methods.

Best-worst method

In the next step, using the BWM method, we obtain each criterion's upper and lower bounds, which resembles its importance. In the following, BWM is explained:

Rezaei showed that the main reason for the inconsistency of the AHP method was the large comparison between the criteria and alternatives [4]. He also claimed that each comparison consisted of two parts: the first part is to select a stronger criterion (direction) and the second part is to determine the degree of strength. Decision-makers usually have no problem with the first part and can easily recognize it. But they often find it difficult to determine the degree of superiority, which leads to inconsistency. To assign a number between 1 and 9 for comparing the two criteria, if both are not the best and worst (in terms of the decision-maker), the decision-maker usually first compares the best criterion to the criterion on his mind. With respect to their preference, he/she makes the original comparison. In order to understand the distance between the two criteria, the decision-maker first compares them to the best or worst. To reduce this complexity, BWM provides a model based on minimizing the maximum distance between preferences of the best and worst criteria and other criteria, which only requires the comparison between the best criterion and the others, and other criteria with the worst criterion. This method has five steps:

Step 1: Identify the criteria.

Step 2: Determine the best and worst criteria.

Step 3: Conduct a paired comparison between the best criterion and the other criteria.

Step 4: Conduct a paired comparison between the other criteria and the worst criterion.

Step 5: Obtain the weight of each criterion by solving the model.

The advantage of this method over others is the requirement of less information (fewer comparisons), which leads to more consistent results. In the following, we present the notations used in the paper and formulation of BWM:

i	Index of criteria, $i = 1,2,\dots,m$
j	Index of alternatives, $j = 1,2,\dots,n$
${w_i}^{min}$	Lower range of criterion i

w_i^{max}	Upper range of criterion i
r_{ij}	Membership degree of ith criterion and jth alternative
E_{j^*}	Comprehensive evaluation value
W_b	Weigh of best criterion
W_w	Weight of worst criterion
w_i	Weight of criterion i
a_{bi}	Preference of best criterion to criterion i
a_{iw}	Preference of criterion i to worst criterion
y	An auxiliary variable

$$MinW_i \tag{1}$$

S.t.

$$\left[\frac{W_b}{W_i} - a_{bi}\right] \le y \qquad \text{For all } i\text{s} \tag{2}$$

$$\left[\frac{W_i}{W_w} - a_{iw}\right] \le y \qquad \text{For all } i\text{s} \tag{3}$$

$$\sum_i W_i = 1 \tag{4}$$

$$w_i \ge 0 \qquad \text{For all } i\text{s} \tag{5}$$

The above model obtains the lower bound for the weight of each criterion. The following model obtains the upper bound.

$$MaxW_i \tag{6}$$

S.t.

$$\left[\frac{W_b}{W_i} - a_{bi}\right] \le y \qquad \text{For all } i\text{s} \tag{7}$$

$$\left[\frac{W_i}{W_w} - a_{iw}\right] \le y \qquad \text{For all } i\text{s} \tag{8}$$

$$\sum_i W_i = 1 \tag{9}$$

$$w_i \ge 0 \qquad \text{For all } i\text{s} \tag{10}$$

Aiming to determine the lower and upper bounds of each criterion's weight, the above models minimize the distance between the weights and the related preferences. After deriving the weights of the criteria, we use them as the inputs of the basic point method to determine weights for each alternative based on the experts' opinions.

Basic Point

First, the best alternative among the existing options should be estimated, and a score between zero and one should be assigned to it (E_{j^*}). E_{j^*} is called a comprehensive evaluation value. Then, experts are asked to give a score to each alternative considering each criterion (X_{ij}). A normalization method is employed to comprise the scheme indexes because of the criteria' different scores (r_{ij}).

$$r_{ij} = \begin{cases} \dfrac{(x_{ij} - x_{imin})}{(x_{imax} - x_{imin})} & ; x_{imax} \neq x_{imax} \\ 1 & ; x_{imax} = x_{imax} \end{cases} \tag{11}$$

Eq. 11 shows the normalizing formulation. In many cases, it is hard to estimate the weights of each criterion, but its range can be estimated easily. Accordingly, we assumed H_i and K_i as the ranges of criterion i. We have:

$$E_j = \sum_{i=1}^{m} r_{ij} w_i \qquad \square j \tag{12}$$

where, r_{ij} is the membership degree of the ith criterion and the jth alternative.

With Eq. 13, the weighted distance between each membership degree and degree of the best and worst alternative are calculated.

$$\xi_j(w) = \sqrt{\sum_{i=1}^{m} {w_i}^2 (1 - r_{ij})^2 + \sum_{i=1}^{m} {w_i}^2 (r_{ij} - 0)^2} \tag{13}$$

Basic point method aims to minimize the weighted distance based on the following model:

$$Minz = \sum_{i=1}^{m} {w_i}^2 \sum_{j=1}^{n} \left[(1 - r_{ij})^2 + (r_{ij} - 0)^2 \right] \tag{14}$$

$$H_i \leq w_i \leq K_i \qquad \square i \tag{15}$$

$$\sum_{i=1}^{m} w_i \, r_{ij} = E_{j^*} \qquad \square j \tag{16}$$

$$\sum_{i=1}^{m} w_i = 1 \tag{17}$$

$$w_i \geq 0, i = 1,2, \ldots, m \tag{18}$$

As discussed earlier, H_i and K_i are the range of criterion i, estimated by the experts. Evidently, relying too much on the experts' opinions decreases the validity of the method and leads to imprecise results due to biased opinions. To tackle this issue, we develop a more scientifically sound MCDM method to delve into rigorous results. In the next section, we explain the novel hybrid MCDM method.

Proposed hybrid method

The developed MCDM method is able to provide the weights of both criteria and alternatives. Using fewer paired compares, it shows high consistency. Unlike the basic point method, the developed model does not require much information and estimation in the first step. In fact, instead of directly using the experts' subjective estimations, it provides more precise upper and lower ranges for each alternative. The developed method has nine steps:
Step 1: Select the best and worst criteria based on experts' opinions.
Step 2: Conduct paired comparisons between the best criterion and other criteria.
Step 3: Conduct paired comparisons between the other criteria and the worst criterion.
Step 4: Obtain the upper and lower limits for the weight of each criterion by solving the BWM model (${w_i}^{min}$ & ${w_i}^{max}$).
Step 5: Choose one alternative as the best one and assign a weight (comprehensive evaluation value) to it based on the experts' opinions (E_{j^*}).
Step 6: Ask experts to rate each alternative in each criterion and normalize it (r_{ij}).
Step 7: Run the novel model (with BWM's upper and lower bounds) to get the weight of each criteria.

$$Minz = \sum_{i=1}^{m} {w_i}^2 \sum_{j=1}^{n} \left[(1 - r_{ij})^2 + (r_{ij} - 0)^2\right] \tag{19}$$

$${w_i}^{min} \leq w_i \leq {w_i}^{max} \tag{20}$$

$$\sum_{i=1}^{m} w_i \, r_{ij} = E_{j^*} \qquad \forall j \tag{21}$$

$$\sum_{i=1}^{m} w_i = 1 \tag{22}$$

$$w_i \geq 0, i = 1,2, \dots, m, j = 1,2, \dots, n \tag{23}$$

Step 8: Based on Eq. 12, calculate the comprehensive evaluation value for each alternative. Rank the alternatives based on their comprehensive value (E_j). The higher value, the more desirable it is.
Step 9: Validate the answer. The comprehensive evaluation value of the selected alternative as the basic point should be more than other alternatives' comprehensive evaluation value; otherwise, return to step five and choose a new basic point.
The pseudo-code of this method is as follows:

```
Strat
        C= Input set of criteria;
        A= Input set of alternatives;
```

```
        W_b = Input and Select the best criterion;
        W_w = Input and Select the worst criterion;
        W_max = 0;
        W_min = 0;
        Define Array w(i) = size i: {1,2,3 …, C}
        ii=0;
        While  ii < C + 1
                w(ii) =Optimize BWM model;
                W_max(ii) = Max(w(ii));
                W_min(ii) = Min (w(ii));
                ii = ii + 1;
        End While
        Define set J: {1,2,3 …, A};
        Array x_{i,j} =Input the score of alternative j according to criterion i;
        r_{i,j} =Normalize Function (Array x_{i,j} );
        jj = 1;
        While  jj < A
                Select EJ* = E(jj)
                For ii = 1: C
                        Array W_ii = Calculated by NHM(EJ*, W_max(ii), W_min(ii))
                End For
                Array EJ_jj = ∑_{i=1}^{C} r_ijj w_i
                For k = 1: A
                        IF  EJ_k ≥ EJ*
                                BS = k;
                        End IF
                End For
                jj = jj + 1;
        End While
        Array W*_i = Calculated by NHM(BS, W_max, W_min);
        Array EJ*_j = ∑_{i=1}^{C} r_ij w_i ;
        Print W*_i And EJ*_j;
Finish
```

Fig. 1. The pseudo-code of the proposed method

Case Study

In this section, we apply the proposed method for a real case study. At first, we briefly describe each alternative. Mazandaran Province is located in the north of Iran and on the southern coast of the Caspian Sea. This province is one of the most populous provinces in Iran. Regarding its unique geography, Mazandaran Province has four ports. Despite the experts' opinions about the tremendous economic development opportunity, there is no FTZ here. However, the Parliament of Iran has ratified the establishment of one FTZ in this province. Therefore, finding the optimal location for the FTZ in Mazandaran Province is of special interest. Accordingly, we applied our hybrid MCDM method to find the optimal location. Table 1 presents a brief description of each port (alternatives).

Table 1. The most important advantages of each alternative

Nowshahr	Easy access to the consumer market in central and eastern Europe Access to airport within 2 kilometers of the port

	Direct connection through pipelines to Chalous oil reservoirs with a storage capacity of 65 million liters
Fereydunkenar	700000 tons per year capacity of loading and unloading General cargo with multipurpose usage Having warehouses and special facilities for export and transition of goods
Babolsar	Ability to launch sea trips and develop the tourism industry One of the scientific centers of the Province with a prestigious university
Amirabad	Linked to Iran's rail network Largest port of the Caspian sea and third-largest port of the country Already being a special economic zone

Fig 2. The the case study in the map

The purpose of this study is to find the optimal location of the FTZ in Mazandaran Province among the available options (Amirabad, Babolsar, Nowshahr, and Fereydunkenar). As discussed earlier, one of the main reasons for the failure of free zones is their inappropriate locations. In this paper, the best alternative is chosen without any prejudice and merely relying on scientific principles and MCDM techniques. To this end, first, the criteria that are necessary for a free zone and their success are introduced. These criteria are obtained by reviewing the existing literature in this domain and the experts' views. Moreover, several international indicators like Legatum, LPI (logistics performance index), and CPI (consumer price index) are used to gather a holistic list of important factors and criteria. Table 2 indicates the most critical recognized factors.

Table 2. The identified criteria and their sub-criteria

Criteria	**Description**	**Sub-criteria**
Economic	In general, the main objective of a free zone is to accelerate economic development, which requires considering the criteria and economic advantages of the candidate countries.	1. Land price 2. The presence of skilled labor force 3. The structure of the economy
Social	Sustainable development cannot be reached unless we take social dimensions into account. Particular attention should be paid	1. Unemployment rate 2. Tourist attraction 3. Access to social and welfare services

	to the legacy of candidate regions in order to attract foreign capital and specialists.	
Environmental	Sustainable development cannot be achieved unless we consider environmental dimensions. The candidate's locations must have the necessary environmental capacity (water, soil, etc.) to establish a free zone. Ignoring these dimensions can lead to ecosystem destruction.	1. Contaminations (water, soil, sound, etc.) 2. The status of sanitary and industrial wastewater 3. Protection of forests and pastures 4. Conservation of agricultural principles
Infrastructure	The alternative to be selected should have the least infrastructure. The experience of the previous free zones indicates that selecting a region without the necessary infrastructure while hoping for future development could result in significant failure over a short period.	1. The status of infrastructures (water, electricity, gas, energy, etc.) 2. Transport and communications 3. Information technology 4. Political stability 5. The existence of scientific and technical institutions 6. Import and export capacity
Geographical	The importance of geographic factors is that other criteria do not compensate for them. Some of these criteria have a direct impact on the FTZ economy.	1. Access to international waters 2. Access to port facilities (blue port and dry port) 3. Height and slope 4. The vulnerability of the area (natural and man-made disasters) 5. Proximity to regional and international markets 6. Climate condition (average temperature, average humidity, annual rainfall, etc.)

After identifying essential criteria, we apply the novel hybrid method to derive the weight of each criterion and alternative.

According to step 1, geographical and social criteria were chosen as the best and worst criterion, respectively. After that, paired comparisons were conducted between the best and worst criteria and others. For step 5, Amirabad port is assumed as the basic point with a comprehensive evaluation of 0.75.

Running the proposed model, the weight of each criterion is achieved (Table 3).

Table 3. The obtained weight of each criterion

Criteria	Geographical	Environmental	Structure	Economic	social
Weight	0.442	0.286	0.184	0.064	0.042

By using Eq. 12, the comprehensive evaluation values of each alternative are shown in Table 4.

Table 4. The obtained weight of each alternative

Alternative	Amirabad	Babolsar	Nowshahr	Fereydunkenar
Comprehensive value	0.9	0.31	0.25	0.42

As expected, Amirabad was selected as the optimal location for establishing FTZ in Mazandaran Province. Since Amirabad obtained the highest weight and all the other alternatives' weights are lower than the estimated comprehensive evaluation value (0.75), the developed method achieved the optimal location in the first irritation.

To assess the proposed method's validity, we applied the widely-used AHP method to see if the results are consistent. Table 5 and Fig. 3 indicate the results of the AHP method using Expert choice software.

Table 5. The obtained weight of each alternative based on AHP

Alternative	Amirabad	Babolsar	Nowshahr	Fereydunkenar
weight	0.301	0.230	0.224	0.245

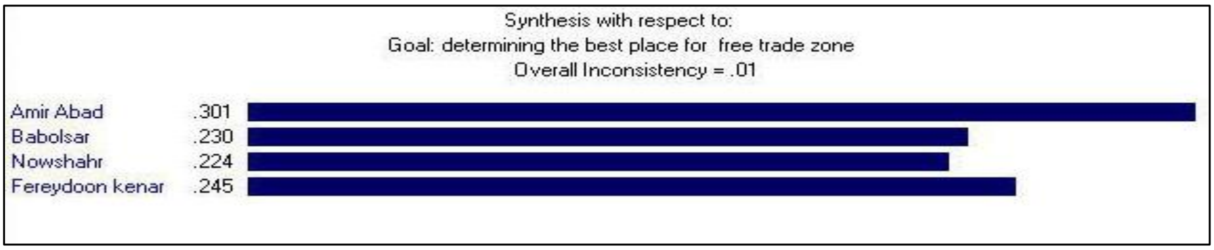

Fig. 3. The obtained weight of each alternative based on AHP

To facilitate the evaluation, a comparison has been applied between the results of the AHP and the novel hybrid method (Fig. 4).

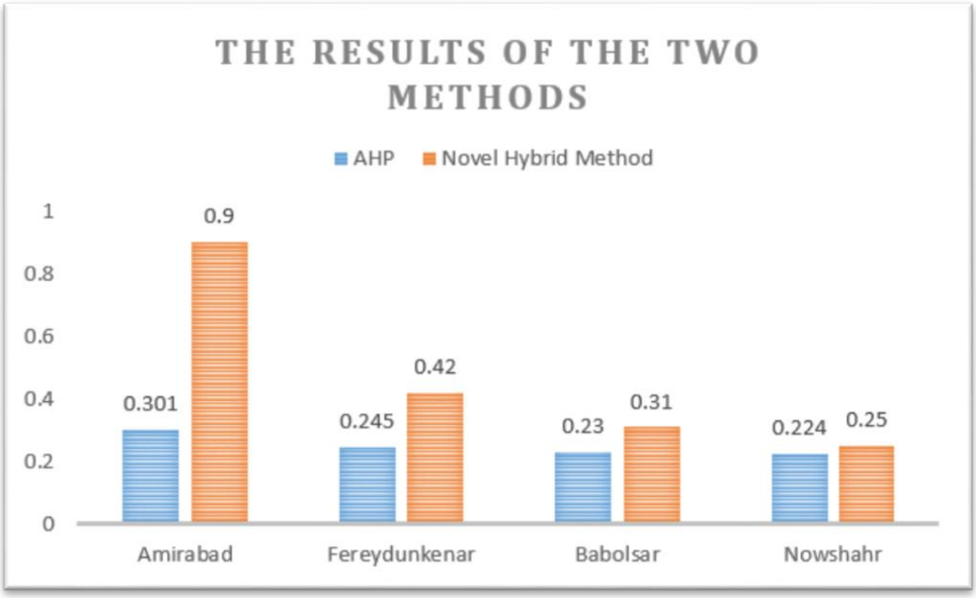

Fig. 4. The results of the two methods

As expected, there is a negligible difference between the results of the two methods, but the alternatives' rankings is the same. In both methods, Amirabad was chosen as the best alternative (optimal location).

Discussions

In this section, we discuss the implications derived from the results of the MCDM method. Table 6 indicates the pertinent weight of each sub-criterion.

Table 6. The weight of each sub-criterion

Criteria	**Sub-criteria**	**Weight**
Economic	Land prices	0.2
	The presence of a specialized labor force	0.39
	The structure and economic power	0.41
Social	Unemployment rate	0.32

	Tourist Attractions	0.23
	Access to social and welfare services	0.45
Environmental	Types of contamination	0.18
	The status of sanitary and industrial wastewater	0.27
	Protection of forests and pastures	0.3
	Conservation of agricultural fertile land	0.25
Infrastructure	The status of infrastructures	0.2
	Transport and communications	0.2
	Information technology	0.19
	Political stability	0.12
	The existence of a suitable scientific and technical structure	0.1
	Import and export capacity	0.19
Geographical	Access to international waters	0.29
	Access to port facilities	0.24
	Height and slope	0.1
	The vulnerability of the area	0.1
	Nearness to regional and international markets	0.17
	Climate condition	0.1

Table 3 shows that geography is the main influential criterion. Environmental, structural, economic and social criteria are the less important factors in establishing an FTZ. There are several important implications in this result.

The geographical criterion obtained the highest weight. It means that geography is the most important factor for economic development in Mazandaran Province. With a closer look at its sub-criteria (Table 6), access to international waters and port facilities are unique advantages for the free zone's transportation system. Hence, it is majorly important to establish free zones in the places where there is access to international water and/or port facilities. It also provides the opportunity of marine transportation mode, identified as the facilitating factor for the transportation of free zones by the literature. Mazandaran has the geographical advantages of neighboring the Caspian sea (the world's largest inland water) and Tehran Province (Capital of Iran). Furthermore, it has a historical background for foreign trade with neighboring countries. Therefore, the province has great potential for attracting foreign investment, gaining geopolitical advantages, and enhancing community welfare. Establishing an FTZ, indeed, can facilitate the above measures.

As the second most important index, the environmental criterion is very valuable for FFTZs. Generally, scholars have unanimously confirmed that sustainable development cannot be achieved without observing environmental factors [24]. Besides, the unique climate condition of Mazandaran makes environmental organizations more sensitive to any constructions there. Taking environmental issues into account can ensure them no environmental damage would be imposed.

It is worth mentioning that the results of the current study are consistent with those of the previous papers in terms of the importance of criteria, and even sub-criteria. For example, according to Table 6, the structure and economic power are of special importance, since investors often receive the minimum wage rates and costs. This is highlighted by several previous studies [25]. Moreover, the related literature confirms that export and import capacity is a critical factor for FTZs since a low capacity can be the bottleneck of a free zone, paralyzing the other parts [26].

The results show that Amirabad Port performs better than other alternatives. Being already a port, it offers both hardware- and software-related advantages. Compared to the other candidates, this port exhibits several advantages, e.g., a broad planning area, multi-transportation modes, and port support. Notwithstanding these benefits, land price is relatively high in this region. However, the low weight assigned to this sub-criterion (see Table 6) would compensate for this expense.

Conclusion

Establishing FTZs plays a significant role in economic development. It can lead to technology transfer, capital attraction, connecting to the world markets, and economic and social growth. Regarding government policies and Mazandaran's particular potential, establishing FTZ in this province was approved in 2015, but political problems postponed it. In this paper, we conducted a novel MCDM method to find the optimal location fairly and scientifically. At first, we obtained the related criteria by making a literature review and collecting experts' opinions. According to the experts' opinions, access to the ports, contamination, transportation and communication, infrastructure, and import and export capacity were the most important criteria. Then, by applying the developed method, the weights of the criteria as well as alternatives were obtained. The alternative with the most weight (Amirabad) was identified as the optimal location. We introduced a novel hybrid MCDM method to determine the best alternative. Furthermore, we supposed the results of the AHP as a benchmark and evaluated the qualifications of the developed method. We hope the governments and decision-makers consider academic works and do not sacrifice national interests for the local ones.

Despite the proposed contributions, the current work is not without limitations. Considering uncertainties and unpredictable changes of the market, an interesting avenue for extending this work is capturing uncertainties based, for example, on fuzzy logic.

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