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Optimizing location selection for foreign trade intelligence centres using spherical fuzzy methods

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ABSTRACT

This investigation focuses on a vital research topic that has significant research gaps in the literature, such as the selection of locations for foreign trade intelligence centres, which have a critical role in a country's development, a country's development and export capabilities. Previous studies have primarily addressed site selection in the context of manufacturing industries and retail outlets, focusing on strategies, and often ignored the unique requirements of foreign trade intelligence operations. This study solves the problem by considering the requirements of an innovative and integrated decision-making approach developed in the context of foreign trade intelligence centres, while at the same time filling the relevant research gap. The proposed model provides a mathematical form by extending Delphi management with spherical fuzzy sets to highlight influential evaluation criteria, as well as providing an integrated decision-making model extended with spherical fuzzy numbers to assess alternatives and determine rankings. Ten primary evaluation criteria are established to present a set of criteria for the authorities. The importance level of the criteria and assessments of alternatives for these criteria are aggregated spherical fuzzy numbers. A mixed integer non-linear multi-objective mathematical model is developed for the previous stages' outputs and different parameters. The results of the empirical application in Turkey show that Mersin is the most suitable alternative due to its attractive government incentives and strong commercial vitality compared to other options. The robustness checks verified the model's validity and reliability, proving a consistent decision-making tool for decision-makers and policymakers in the context of systematic decision-making.

1. Introduction

Since exports are essential to economic growth, every country and area prioritises optimizing its export plans (Cinar et al., 2021). A wide range of intricate elements, such as changes in global economic trends, market demand variations, and geopolitical events, affect the number of exports (Yu and Lee, 2010). Furthermore, global commerce agreements, logistics networks, and regional and global connections substantially influence a country's capacity and capability to export. Hence, the market dynamics of global trade are significantly affected by strategic factors that also affect the global actors of international trade. To better understand global trade's operational complexity and risks, decision-makers need solid and reliable insights into these aspects. For example, the political crisis and war in Syria in 2011 caused Gaziantep's export revenue, which was 1.8 billion dollars in the previous period, to decrease to 500 million dollars the following year and approximately 270 million dollars in 2013 (İçen and Günay, 2019). In this context, the Syrian crisis reduced the region's export revenue by 72 %, leading to significant losses (Wee and Leow, 1994).

At the same time, in addition to being a transit country between Turkey and Middle Eastern countries, Syria is also a major exporter. Gaziantep's exports to Middle Eastern countries and Syria have severely declined. Accordingly, export companies have started looking for new customers and markets to improve the region's export volume. As a result, establishing a foreign trade intelligence centre tailored explicitly for the Gaziantep province became imperative.

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Exporting companies can effectively identify international target markets and potential customers by employing a comprehensive set of research methods known as foreign trade intelligence. Export companies can increase their market share within export nations and add new customers to their portfolio. Information and data gathered, sifted through, and analysed from the corporate world form business intelligence.

Accurate information can yield significant benefits when acquired, appropriately interpreted, and effectively utilised through business intelligence approaches. Accordingly, a business intelligence application necessitates expert knowledge and skills. For this reason, firms prefer to get support from business intelligence service-providing firms instead of employing an in-house professional. For this reason, establishing business intelligence centres has become widespread, and their numbers are constantly rising (Lönnqvist and Pirttimäki, 2006). For exporters, FTICs significantly facilitate reaching new markets and customers abroad. They make it possible to sell goods quickly and reliably to customers in terms of their specifications and requirements. These organizations aim to establish healthy and long-term relationships between exporters and their customers by providing them with intelligence and information about their customers in foreign countries. The centres also strive to offer organizations formulating regional foreign trade policies information and resources.

Emerging market companies suffer greatly from late entry into international markets. Moreover, factors such as the inability of enterprises to acquire new customers or the fact that customers have different preferences for buyers, the lack of sufficient knowledge and experience in the markets of foreign countries, and the loss of existing customers for various reasons, hurt the achievement of export targets of enterprises. Business intelligence centres aim to connect with these businesses and grow their market share based on this idea. Besides, the location of international trade intelligence centres is significant in this context because of its closeness to exporting businesses, installation costs, and access to marketplaces. International trade intelligence centres should be located in the right places so that the companies do not lack knowledge during the export process. Therefore, the foreign trade intelligence centre location selection problem has been identified as one that should be discussed in the literature. Choosing the most suitable locations for foreign trade intelligence centres directly affects the number of buyers (customers) in foreign countries that exporters can access. In that regard, an optimal choice regarding site selection enables the most effective use of exporters' potential, increasing profitability rates and reaching the country's annual export targets, thus positively improving the foreign trade balance. In addition, it contributes to achieving sustainability goals in the context of green exports. Opening these institutions in the wrong place has negative consequences for the exporting companies, the experts who invest in the institution, and the nations.

This study arises because no location could be determined for the foreign trade intelligence centre planned to be opened in Turkey. Scientific techniques have been researched to select the most suitable location, and the background of the study has developed within the specified framework. The selection of the most appropriate locations has been addressed as a problem in the literature. There is currently no foreign trade intelligence centre location selection study in the literature. In addition, Multi-Criteria Decision-Making (MCDM) and Fuzzy MCDM methods have generally been preferred in the literature regarding location selection. The location selection problem acquires qualitative criteria that depend on the humans' preferences and quantitative criteria that arise from the nature of the problem. However, the solution to the problem with MCDM, fuzzy MCDM methods, and multi-objective optimisation methods - by developing mathematical modelling - has not been found in the literature. Thus, this study aims to fill these two critical gaps in the literature. In the suggested decision model, qualitative criteria, such as expert opinions on commercial vitality and business climate, are integrated using the Spherical Delphi Method to eliminate experts' subjectivity. On the other hand, quantitative criteria, including cost factors, export volume, and infrastructure availability, are assessed through Spherical Fuzzy Numbers, ensuring a structured evaluation. By combining these two dimensions, the model provides a balanced decision-making process where subjective insights are systematically quantified and objective factors are incorporated with expert-driven assessments.

This study addresses the problem of foreign trade intelligence centre location selection. The analysis considers existing centres and new regions that are anticipated to open. By applying the location selection problem to these locations specifically, it has attempted to determine which areas or regions would be most profitable to build a foreign trade intelligence centre. Although there are many studies on location selection for various facilities (i.e., manufacturing plants, warehouses, logistics centres, hospitals, shopping malls, and so on) in diverse industries (Akyol and Akehurst, 2003), location selection for foreign trade intelligence centres is a complex decision-making issue neglected by the members of the research society (Lotfi and Naami, 2015). Intricate situations and uncertainties considerably influence evaluation processes concerning location selection for foreign trade intelligence centres, and they require considering different and special criteria and factors compared to classical site selection problems. Besides, many contradictory evaluation criteria make it difficult to produce efficient solutions concerning location selection for foreign trade intelligence centres.

In conclusion, numerous studies on site selection consider the location selection problem an intricate decision-making issue that can only be addressed with the help of an expert system (Eidizadeh et al., 2017). The piece-based regression model developed by Yu and Lee (Quaye et al., 2017) integrates the quadratic programming approach with automatic point-of-change detection to address fuzzy input-output data with significant variations. It inspired us to develop a more consistent, innovative, and optimized decision-making framework for modelling and managing critical and intricate uncertainties and ambiguities. In addition, İçen and Günay (Neubert and Van der Krogt, 2018) presented an innovative solution to uncertainty management by using the fuzzy expert system (FES) for parameter estimation in the Monte Carlo method. This method provides accurate and reliable estimates even with small sample sizes. Similarly, our study used optimisation and uncertainty techniques to manage extensive variance data and fuzzy media.

Consequently, it is required to successfully design a fuzzy expert system handling existing ambiguities to select the best location for foreign trade intelligence centres. In that regard, multi-criteria decision-making (MCDM) methods were used to analyse this determination because there are not many experts in the field of international trade intelligence, and their recommendations impact the industry. The study first examined the criteria for creating a foreign trade intelligence centre. The criteria were developed by academics, industry experts, and studies in the literature. Then, these criteria were founded on their weight using the Spherical Fuzzy sets (SFSs). This approach enabled the decision-makers to reveal their views with the slightest deviation. Then, a new mixed integer non-linear programming model was developed because MCDM methods were insufficient due to problems like the setup costs necessary for creating the establishments. The model has been designed to reduce setup costs while attempting to increase the criteria weights. Therefore, multi-objective optimisation algorithms can be used to solve the relevant model. The weighted Sum Scalarization Method has been applied at this stage to solve the problem, and the best location 4 for international trade intelligence centres has been determined with the help of experimental design.

This study continues as follows: In the second section, the literature is reviewed. Reviewing the literature on the decision-making problem, the existing research gaps and theoretical evaluation deficiencies in the literature are determined, and the information collected from the literature is presented. The third chapter details the mathematical notion and implementation steps of the decision-making approach proposed in this study. The fourth section examines a case study, presenting criteria established for the location selection of the trade intelligence centre and information about experts evaluating the criteria. The fifth section presents findings from applying the method to the case study. In the sixth section, information about the managerial implications of this study is given. In the final section, general conclusions of the study are provided, along with recommendations for future research.

2. Literature review

This section investigates studies that contribute to the analysis of selecting the location of the foreign trade intelligence centre. Studies involving business intelligence and export potential are examined in the first section, and location selection is investigated in the second section. The literature search of the survey is conducted with the keywords "commercial intelligence", "export performance", and "location selection" from the Web of Science and Scopus databases. The most critical studies on the subject are included in the literature section and Table 1.

2.1. Business intelligence and export performance

Nowadays, business intelligence is a crucial concept for the sustainability of companies. This concept's root in the literature is based on earlier industrial periods. Any industrial, scientific, or governmental institution has been developing an automated system to distribute information to its many departments. For the automatic abstraction and encoding of documents and the creation of interest profiles for each " action point" in an organisation, this intelligence system will use data processing devices. Business intelligence is a disorganized, uncollated, and unevaluated input that must be considered and evaluated. Business intelligence is the labour performed to obtain this information. Competitive information is defined as material collected, arranged, and analysed to gain insight into the competitor. Wee and Leow (Malca et al., 2021) conducted an application on competitive intelligence with a survey study of 97 companies in Singapore. The findings indicated that there were not many variations across organizations in corporate intelligence compared to the numerous criteria employed. However, it was discovered that competitive intelligence affected business performance. The importance of business intelligence was further understood between 1997 and 2006.

Over the years, the number of articles in the field has increased significantly, with studies including artificial intelligence, data mining, and modelling. For example, Lönnqvist et al. (Kolbe et al., 2021) propose a 4-step BI (business intelligence) performance measurement model: stakeholders' satisfaction and contribution, BI Strategy, BI process, and capabilities. With a similar approach, the market trends for export operations of the Turkish textile and clothing industry were investigated by Akyol and Akehurst (Tarek and Adel, 2016). The findings obtained in the research show that there is a significant relationship between export market orientation and export performance. In this context, it is underlined that the direct concentration and prioritization of the focus markets of textile enterprises greatly improves the business performance related to exports. In addition to this study, Lotfi et al. (Yang and Lee, 1997) tried to identify BI parameters that are the main drivers of increasing and developing export potential in the context of exporters in Tehran with the help of an empirical analysis. They suggested identifying and focusing on key customers in a correct and rational context are the most critical factors, along with efficiency-based system design and competitive positioning.

Furthermore, Eidizadeh et al. (Yong, 2006) demonstrated that BI significantly boosts knowledge sharing, organisational innovation, and competitive advantage, as evidenced by evaluations from 213 experts. Quaye et al. (Kheybari et al., 2019) further contribute by employing multiple regression to link export promotional activities with export success in Ghanaian manufacturing enterprises, suggesting that tailored promotion programs are crucial for enhancing competitiveness. Neubert and Krogt (Athawale and Chakraborty, 2010) summarised expert opinions on Paraguayan software companies, showing that BI systems effectively increase the capacity for globalisation, while Malca et al. (Ertuğrul and Karakaşoğlu, 2008) underscored the mediating role of export proactivity and coordinating ability between export market orientation and export performance. Findings demonstrated the impact of export persistence on export performance and the mediator role of export proactivity among export market orientation and export performance.

Additionally, it demonstrates how relationship norms affect export market orientation as a precursor. Kolbe et al. (Sennaroglu and Celebi, 2018) examined how well small and medium-sized businesses performed in exporting to the Mexican market. General, marketing, sales, and export managers of 155 Mexican SMEs completed a survey to provide the information. According to the study, Mexican SMEs' export performance is driven by innovation capacity and proactive market orientation. Tarek et al. (Emeç and Akkaya, 2018) analysed the impact of 300 North African SMEs on their international competitiveness. Data were collected by the questionnaire method. The findings indicate a substantial relationship between the entrepreneurial competitive intelligence method and the competitive position of North African SMEs because this strategy contains fundamental extra steps that might also allude to an entrepreneurial orientation and a defensive attitude. Although several authors have investigated the importance of business intelligence, the location selection of intelligence centres has not been explored via MCDM methods and mathematical models.

2.2. Location selection

There are studies on site selection for installing and constructing many facilities in the literature. Yang and Lee (Kumar and Anbanandam, 2019) implemented an application for facility location selection using the AHP method. Among the criteria are market, transportation, labour, and communication. Yong (Chien et al., 2020) designed a system implementing the fuzzy TOPSIS method to select the study's plant location. Skilled labour, growth potential, the accessibility of acquisition materials, and investment costs are some criteria. The study's findings led to selecting area 3 as the best option. Kheybari et al. (Yazdani et al., 2020a) implemented a plant site selection application to apply bioethanol using the BWM technique. The study has three central, twelve Middle, and twenty-five sub-criteria. The study's economic criteria are given the highest level of significance. Considering the study's findings, the Khezustan region is ideal for bioethanol production. Athawale (Yücenur and Ipekçi, 2021) has implemented a survey of facility location selection by applying the Promethee II method. Some criteria are air transportation, labour cost, availability, community education, and business climate. As a result of the application, p2 was determined as the most suitable region for selection. Using geographic information systems, Cheng et al. (Oztaysi et al., 2022) designed a shopping centre placement selection application. The study's application is carried out in Hong Kong. In the study results, Tsimshatsui was the most accurate location. Ertuğrul and Karakaşoğlu (Karaşan et al., 2020) applied fuzzy AHP and fuzzy TOPSIS methods to address the facility location problem of a textile company in Turkey. They considered criteria such as a favourable labour climate, community considerations, and quality of life. Their analysis identified an optimal alternative among the options considered.

Sennaroğlu and Çelebi (Lee and Ter Chang, 2018) applied a study on the military airport location problem. There are nine central and 33 sub-criteria among the selection criteria. Some criteria include cost, climatic conditions, geographical features, and land. AHP, PROMETHEE, and VIKOR methods are employed for analysis. In the results, the most important criteria are military and climate conditions, and the most suitable region is the C location. Emeç and Akkaya (Oztaysi et al., 2022) employed stochastic AHP and fuzzy VIKOR methods to solve the storage location problem in a stochastic environment with uncertain conditions. According to the study results, Gaziantep is the most suitable

Table 1
The preceding studies deal with facility location (site) selection and their details.

				Number of		Results: Most important					
Author(s) year	OM	Methodology	Fuzzy sets	Criteria	Options	Criteria	Alternatives	Industry	SA	Case	Id.Cr
Yang and Lee (Kumar and Anbanandam, 2019)	No	AHP	No	12	4	Market, labour, and business climate	–	Manufacturing	No	No	Unclear
Yong (Chien et al., 2020)	No	TOPSIS	Classical FS	4	3	Investment cost	–	Manufacturing	No	No	Unclear
Kheybari (Yazdani et al., 2020a)	No	Best worst method	No	9	–	Provincial finance subsidies	–	Chemical	No	Yes	EV
Chakraborty & Athawale (Seker and Aydin, 2020)	No	PROMETHEE II	No	8	3	Business climate	–	Service	No	No	Unclear
Cheng et al. (Biswas and Pamucar, 2020)	No	GIS	No	4	8	Minimum distance	Aberdeen	Retail	No	No	Unclear
Ertuğrul & Karakaşoğlu (Karaşan et al., 2020)	No	AHP & TOPSIS	Classical FS	5	3	Labour climate	–	Textile	No	No	LR
Sennaroglu & Celebi (Lee and Ter Chang, 2018)	No	AHP & VIKOR	No	32	4	Frost, fog, storm, and flood risk	–	Military	Yes	No	LR
Emeç & Akkaya (Oztaysi et al., 2022)	No	AHP & VIKOR	Classical FS	17	4	Cost of land	Gaziantep	Logistics	Yes	Yes	EV
Kumar & Anbanandam (Chakraborty and Zavadskas, 2014)	No	AHP & TOPSIS	Intuitionistic FS	25	4	Special economic zone development	–	Logistics	No	No	LR
Chien (Cheng et al., 2007)	No	ANP & TOPSIS	Classical FS	14	10	Protected fauna	Nghe An	Energy	No	Yes	LR
Yazdani (Suman et al., 2021)	No	DEA & FUCOM & CoCoSo	Rough FS	11	5	Connectivity to multimodal transport	Murcia	Logistics	Yes	Yes	LR
Yücenur & Ipekçi (Lin and Chen, 2022)	No	SWARA & WASPAS	No	12	3	Proximity to town	Bosphorus	Energy	No	No	EV
Karaşan et al. (Saha et al., 2023)	No	DEMATEL & AHP & TOPSIS	Intuitionistic FS	21	9	Size of traffic conditions	Kadiköy	Energy	Yes	Yes	EV
Lin & Chen (Çebi and Otay, 2015)	No	VIKOR	Classical FS	9	5	Reliability	–	Health	No	Yes	EV
Oztaysi et al. (Chithambaranathan et al., 2022)	No	REGIME	Pythagorean FS	5	3	Unclear	Unclear	Health	Yes	Yes	EV
Saha et al. (Alkafaas et al., 2020)	No	DN-MARCOS	Fermatean FS	9	5	Energy availability & and cost	Ankara	Logistics	Yes	Yes	FF-Delphi
Sekerci Aydın (Şahin, 2020)	Yes	AHP	Classical FS	6	4	Closeness to the market	–	Logistics	No	Yes	Unclear
Chithambaranathan et al. (Huang et al., 2020)	No	VIKOR	Classical FS	6	4	Infrastructure facilities	–	Service	No	Yes	EV
Seker and Sukran (Bait et al., 2021)	No	TOPSIS	IV Pythagorean FS	12	4	Policy and legal support	Sinop	Energy	Yes	Yes	LR
Biswas and Pamucar (Ulutaş et al., 2020)	No	LBWA & PIPRECIA	No	12	3	Convenience in Travelling	–	Education	Yes	Yes	EV
Suman et al. (Mohammadi et al., 2013)	No	AHP & FAHP	Classical FS	7	5	Energy availability	Chattogram	Furniture	Yes	Yes	LR
Çebi and Otay (Mohammadi et al., 2019)	No	TOPSIS	Type-2 FS	6	3	Energy	–	Cement	No	Yes	Unclear
Alkafaas et al. (Chang, 2024)	No	VIKOR	Intuitionistic FS	5	6	Cost of energy	–	Manufacturing	Yes	Yes	LR
Şahin (Akram et al., 2023)	No	AHP & TOPSIS & VIKOR	Classical FS	32	25	Low initial price	–	Offshore	No	Yes	Unclear
Huang and Weng (Kutlu Gundogdu and Kahraman, 2019)	No	DANP & VIKOR	No	16	5	ICT adoption	Taiwan	Manufacturing	No	Yes	EV
Bait et al. (Sharaf, 2023)	No	AHP & TOPSIS	No	7	2	Supply and sales logistics	Ghana	Health	No	Yes	Unclear
Ulutaş and Karakuş (Kutlu Gündoğdu, 2020)	No	PIV & FUCOM	Classical FS	8	6	Proximity to the railway	–	Textile	No	Yes	EV
Our model	Yes	WSSM	Spherical FS	12	7	Incentives	Mersin	Foreign trade	Yes	Yes	SF-Delphi

AHP: Analytic Hierarchy Process, **TOPSIS**: Technique for Order Preference by Similarity to Ideal. Solution, **PROMETHEE**: Preference ranking organisation method for enrichment evaluation, **VIKOR**: Vise Kriterijumska Optimizacija I Kompromisno Resenje, **ANP**: Analytic Network Process, **GIS**: Geographic Information System, **DEA**: Data Envelopment Analysis, **FUCOM**: Full Consistency Method, **CoCoSo**: Combined Compromise Solution, **SWARA**: Step-wise Weight. Assessment Ratio Analysis, **WASPAS**: Weighted Aggregated Sum Product Assessment, **DEMATEL**: The Decision-Making Trial and Evaluation Laboratory, **MARCOS**: Measurement of alternatives and ranking according to COmpromise solution, **PIPRECIA**: Pivot Pairwise RElative Criteria Importance Assessment Extended, **PIV**: Proximity Index Value, **MADGM**: Multi-Attribute Decision Group Making, **FS**: Fuzzy Sets, **IV**: Interval-Valued, **OM**: Optimisation Model, **SA**: Sensitivity Analysis, **Id. Cr**: Identification of the criteria, **EV**: Experts' views, **LR**: Literature Review, **SF**: Spherical Fuzzy, **FF**: Fermatean Fuzzy, **WSSM**: The weighted Sum Scalarization Method.

location for warehouse selection. Kumar and Anbanandam (Chakraborty and Zavadskas, 2014) applied AHP and TOPSIS methods in freight terminal selection. There are five central and 25 sub-criteria in the application. Technical criteria are determined to be the most essential main criteria. A3 is the most suitable location for the highest freight terminal. Chien et al. (Cheng et al., 2007) applied fuzzy ANP and TOPSIS methods for Vietnam's hydroelectric facility location selection. There are 14 criteria and 10 locations in the application part. Location 5 is selected as the most suitable region for installation. In the autonomous communities of Spain, Yazdani et al. (2020b) aim to create a two-stage decision-making methodology to determine the most appropriate area for constructing logistics facilities. The location selection application employs FUCOM, CoCoSo, and Data Envelopment Analysis.

In the study results, A4 is selected as the most suitable location for selection. Yücenur and İpekçi (Lin and Chen, 2022) employed a location selection problem for the first Turkish marine current energy production plant planned to be established. The application has four main criteria, 12 criteria, and three alternatives. SWARA and WASPAS methods are employed in this study. Proximity to the city is determined as the most crucial criterion, and A2 is selected as the most suitable location for installation. Karaşan et al. (Saha et al., 2023) performed an application with MCDM methods for the selection of charging station locations for electric vehicles. There are four main 21 Sub-criteria and nine alternative locations in the application. The outcome of the IVIF-AHP method demonstrates that the power system security and traffic convenience sub-criteria are the essential criteria for this selection process (Guneri et al., 2009) Implemented an application to select COVID-19 vaccination sites using the VIKOR method. Oztaysı et al. (Chithambaranathan et al., 2022) applied the Pythagorean Fuzzy regime method for waste disposal site selection.

In addition to the studies mentioned above, numerous studies dealing with location selection in the relevant literature have been encountered in a comprehensive literature survey. A significant part of these studies focused on the problem of location selection concerning industrial activities such as production, logistics, transportation, storage, etc. In this context, according to the authors' information, no study focused on location selection directly related to foreign trade intelligence centres. Hence, when investigating the relevant literature, the authors used keywords such as location selection, site selection, facility location selection, and their combinations. In conclusion, the authors collected indirectly relevant studies, even if they are not directly related to the focal point of the current work. They listed these studies by considering their details, and with the help of this list, the proposed model and the studies in the literature were compared. Table 1 exhibits the previous studies on site selection problems with/without MCDM methods and their details.

When studies dealing with facility location selection problems in the literature are evaluated in general, the AHP Analytical Hierarchy Process method is the most used method to calculate the weight values of the criteria. This method was preferred in 11 (50 %) of the 22 studies considered in the literature investigation process. While the FUCOM was used in two works, one of the other weighting methods shown in Table 1 was employed in each study. However, there is no explanation of how the limitations and disadvantages of the AHP method were overcome in these studies. Besides, considering the methods used to rank the alternatives, TOPSIS (40 %) and VIKOR (28 %) are the most preferred sorting methods. However, both methods are the most criticised in the literature for their resistance to the rank reversal problem, and no substantial evidence has been presented by the studies available in the relevant literature on how this problem has been overcome. The spherical fuzzy sets-based approach proposed in this study determines the criteria weights directly, without being dependent on the need to use a weighting method, and provides a reliable, easy-to-implement, and time-saving evaluation environment for decision-makers. In addition, multi-objective optimisation problems, such as plant location, may not always be solved with classical decision-making approaches. Mohammadi et al. (Donyatalab et al., 2022) developed the spectrum sensing method with a central decision mechanism to reduce the effects of noise strength uncertainty by using fuzzy hypothesis testing (FHT) within the Neyman–Pearson lemma framework. This study reveals the effectiveness of fuzzy set theory in modelling uncertainties. Our proposed model, with its potential to significantly enhance the accuracy and effectiveness, inspires future research. Depending on the nature of the problem, the solutions can be infinite, which makes it very difficult to solve the problem with current decision-making methods. In this respect, the weighted Sum Scalarization Method proposed to determine the most appropriate location in this study provides precious advantages in solving problems by transforming multi-purpose optimisation problems into single-purpose optimisation problems.

The proposed method manages uncertainty in the decision-making process using advanced fuzzy set-based approaches. The spherical fuzzy sets provide a framework for modelling ambiguity and variability in the input data, ensuring robust results under uncertain conditions. Mohammadi et al. (Gass and Saaty, 1955) improved the event detection performance in wireless sensor networks using the Bayesian Fuzzy Hypothesis Test (BFHT) method to model noise strength uncertainty. Such approaches reveal that accurate modelling of uncertainties increases the accuracy of decision-making processes. Our proposed model, similarly, is designed to provide satisfaction by delivering reliable and optimized solutions that effectively reduce the impact of uncertainties.

When the studies on facility location selection are evaluated concerning handling uncertainties, classical fuzzy set theory has been preferred in eleven studies (37.93 %). In contrast, nine studies use classical subjective or objective decision-making methods (31.03 %). In this respect, almost one-third of the studies ignored the existing uncertainties, while many used the traditional fuzzy set theory. However, due to several limitations, triangular fuzzy sets may not be able to produce satisfactory solutions in highly intricate decision-making environments.

On the other hand, while only three studies used Intuitionistic fuzzy sets, which can deal with complex uncertainties much more successfully than traditional fuzzy sets, Rough, Pythagorean, Interval-Valued Pythagorean, Fermatean, and Type-2 fuzzy sets were used once. It is necessary to use advanced fuzzy sets that can better handle uncertainties to successfully address highly complex decision-making issues influenced by uncertainties. The facility location selection problem is one of the most complicated decision-making issues due to its considerably dynamic nature and structure. Hence, the spherical fuzzy set theory proposed in this study is one of the newest approaches that can successfully handle highly intricate ambiguities compared to the prior fuzzy sets used in the literature and is quite successful in dealing with highly complex uncertainties influencing facility location selection problems.

The industries where site selection problems arise are highly decisive in determining the criteria for solving the problem, the weights of these criteria, and the alternatives to be evaluated. Accordingly, no consensus exists on effective criteria influencing the facility location selection problem in the literature, yet among the members of the research society. In almost every study dealing with this current decision-making issue, the authors used different numbers of criteria with diverse characteristics. Similarly, since the alternatives directly depend on the case study under consideration, many studies do not mention the direct names of other options. Many studies employ a varied set of criteria with distinct characteristics, and the alternatives are often represented by codes (e.g., A1, alternative-1) rather than explicit names. Few studies in the literature have used decision alternatives derived from real-life problems. In addition, the authors often consulted literature reviews or expert opinions to determine effective criteria for the evaluation process. Apart from this, only one study proposes a framework by extending the classical Delphi approach with the Fermatean fuzzy sets to determine effective criteria in the relevant literature (Alkafaas et al., 2020). In this context, the Delphi approach based on spherical fuzzy sets proposed in this study may be a framework that can produce more reliable and effective solutions in determining the criteria for decision-makers.

In addition, much of the work focused on plant location selection has attempted to solve this decision-making problem for specific industries. In this direction, the problem of facility location in sectors such as Logistics (5), Manufacturing (4), Energy (4), Health (3), Service (2), and Textile (2) attracted significant attention from the members of the research community. Besides, the researchers attempted to address the facility location selection problem in several industries, such as chemical, retail, military, maritime, education, furniture, cement, and offshore. In contrast, a study on the choice of the location of foreign trade intelligence centres in the literature is not available to the authors' knowledge. Finally, most studies in the literature (62.07 %) did not provide a sensitivity analysis to test the validity and suitability of their proposed model. Further, in more than seventy per cent (72.41 %) of the studies, the authors preferred to perform their proposed model with the help of a case study.

2.3. Research gaps

In the related literature, there are two critical gaps. The first concerns the foreign trade intelligence centre, while the second concerns location selection. Researchers have argued about business intelligence (Kolbe et al., 2021; Yang and Lee, 1997; Yong, 2006; Athawale and Chakraborty, 2010; Emeç and Akkaya, 2018) and export performance (Kheybari et al., 2019; Athawale and Chakraborty, 2010; Ertuğrul and Karakaşoğlu, 2008; Sennaroglu and Celebi, 2018). However, these studies did not specify business intelligence centres and their locations. The first critical gap in the literature is thus this one. Similarly, some studies in the literature focus on location selection. These studies include airport location selection (Lee and Ter Chang, 2018), shopping mall centre location selection (Biswas and Pamucar, 2020), energy plant location selection (Lin and Chen, 2022), warehouse location selection (Oztaysi et al., 2022), facility location selection (Yazdani et al., 2020a; Yücenur and Ipekçi, 2021; Karaşan et al., 2020), waste disposal location selection (Chithambaranathan et al., 2022). However, these studies did not specify location selection for business intelligence centres. The current literature indicates that both theoretical and practical studies point to the importance of business intelligence for companies. Furthermore, studies on location selection in the literature use MCDM and fuzzy MCDM methods for different industries. However, the selection of foreign trade intelligence centres has not been studied in the literature.

Furthermore, no studies have integrated the relevant MCDM and mathematical programming model for location selection. These are the research gaps as a result. These lead to the study. This study includes a location selection application for foreign trade intelligence centres to improve export performance. The study's application section applies MCDM techniques and mathematical models in an integrated approach. The location of the foreign trade intelligence centre jointly applying MCDM methods and mathematical programming model is selected for the first time in this study.

This study deals with two main issues lacking in the literature: the concept of the Foreign Trade Intelligence Center and the choice of location of these centres. Current studies have focused on business intelligence and export performance and do not provide comprehensive research on the positioning of commercial intelligence centres. To address this shortcoming, this study will: *i*) For the first time, it integrates multi-criteria decision-making (MCDM) and mathematical modelling approaches for the location selection of a commercial intelligence centre. Although MCDM methods used in different industries have been applied in the existing literature, no specific modelling study exists for commercial intelligence centres. *ii*) Optimizes decision makers' evaluations by applying the "Spherical Fuzzy Delphi" method to manage uncertainties better. Existing studies have generally used classical Delphi or fuzzy MCDM techniques, and no methodology has been developed that offers a more advanced level of uncertainty management. *iii*) The methodology presented by this study provides a more reliable and applicable decision-making model for policymakers and decision-makers. While no standard selection criteria have been established for commercial intelligence centres, this study presents a comprehensive set of criteria supported by sectoral expert opinions. In this context, the present study fills a critical gap in the literature and proposes a new methodological framework for the location selection of commercial intelligence centres.

2.4. The motivation for the study

The current paper aims to fill the research gaps discussed above. First, it helps decision-makers identify the influential criteria for adequately structuring the decision problem. As discussed in the literature survey section, there is no consensus on the selection criteria that influence facility location selection, except for site selection for trade information centres. The current study provides a set of criteria identified based on comprehensive fieldwork performed with exceptionally experienced professionals in the relevant field. Secondly, selecting an appropriate location for trade intelligence centres is difficult for practitioners and policymakers. Therefore, this study offers a methodological framework that practitioners can easily implement without needing advanced mathematical information to determine the optimal location. Finally, the current paper aims to assist the research society's members in dealing with the MCDM frameworks and decision-making models by providing a robust and stable optimisation model strengthened with the help of the SFSs.

3. The proposed model

In the study, we recommend a procedure with four stages to select the location of the foreign trade intelligence centre. The basic steps of the suggested model are illustrated and summarised in Fig. 1.

The proposed model consists of four stages, which are provided below:

Stage 1: First, we examine the qualities, standards, and guidelines needed to establish foreign trade intelligence centres. To tackle this, extensive theoretical research, the experiences of prior specialists, and the examination of pertinent theories and technical reports are used.

Stage 2: Following the conclusion of the first stage, we evaluated the process with the experts to determine the evaluation criteria. The reports crea8ted by numerous public agencies and organizations, as well as the papers in the literature review section, combine the criteria established for the case study. The goal is to develop a criteria pool to direct the expert group in the following step.

Stage 3: To determine the ideal location for Turkey's foreign trade intelligence centre, we assembled a committee of individuals with experience in management, foreign trade, and academia. To get their feedback on these criteria and alternatives, we gave the lists to the experts. We asked them to evaluate the importance of the criteria and assess the options by considering the spherical fuzzy numbers. By adhering to the fundamental steps of the Spherical Delphi technique, it is possible to determine the relative significance of the criteria and assessments of the assessment scores of the options.

Stage 4: A new mixed integer non-linear multi-objective mathematical model considers the parameters and the previous phases' outputs. The most appropriate location among all potential locations is selected in this way. Through the use of multi-objective optimisation techniques, the final decision is made.

To facilitate comprehension of this paper, we will introduce the concepts related to several components, including SFSs, the developed mixed integer non-linear multi-objective mathematical model, and the

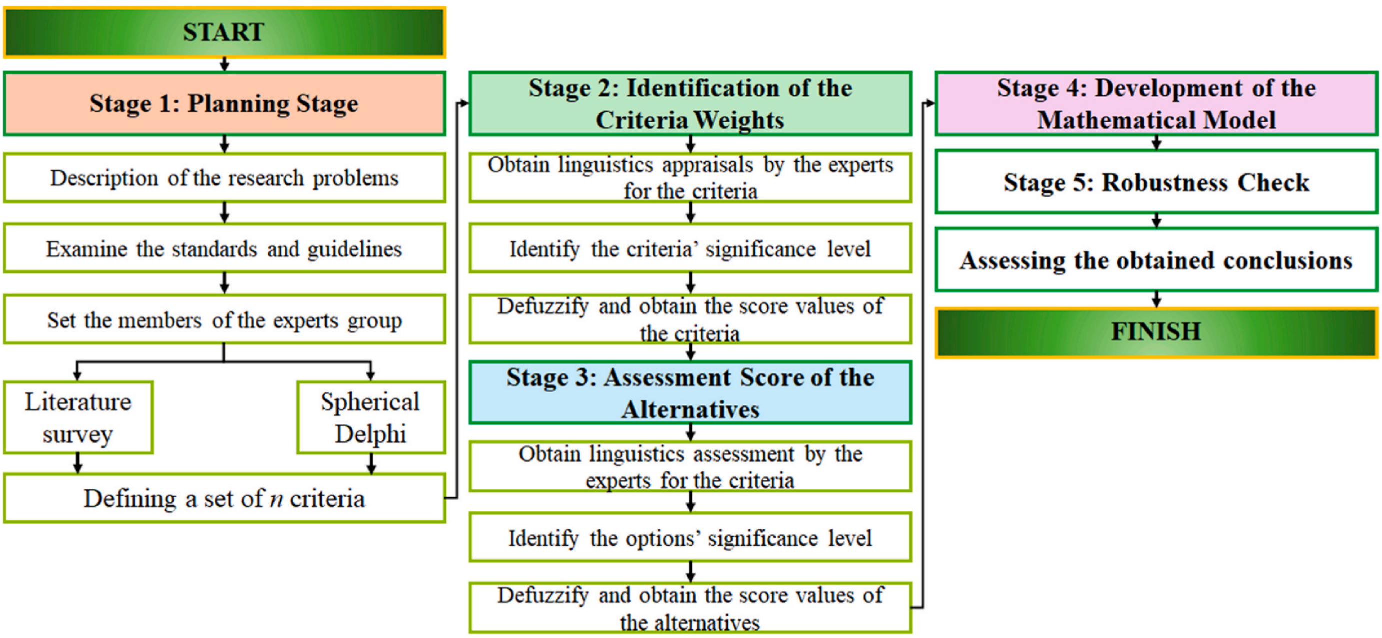

Fig. 1. The flowchart of the developed model and its basic procedure.

WSSM method.

3.1. Preliminaries for SFSs

SFSs represent an extension of traditional fuzzy sets, incorporating a third dimension to capture the degree of hesitancy and membership and non-membership degrees (Cicek and Ozturk, 2020). It makes it possible to depict uncertainty and insufficient information more comprehensively. The following explanations provide an overview of SFS operations and basic principles (Demirel et al., 2010):

Definition 1. (Tsygankova and Ishchenko, 2017) Consider a universe of discourse denoted by X. A spherical fuzzy set Bs defined on X can be represented in the following manner

$$\widetilde{A}_s=\left\{\langle x,\left(\mu_{\tilde{A}_s}(x),\nu_{\tilde{A}_s}(x)\pi_{\tilde{A}_s}(x)\right)\rangle | x\in X\right\}, \tag{1}$$

Here, $\mu_{\tilde{A}_s}(x): X\rightarrow[0,1]$ denotes the membership degree, $\nu_{\tilde{A}_s}(x): X\rightarrow[0,1]$ symbolizes the non-membership degree, and $\pi_{\tilde{A}_s}(x): X\rightarrow[0,1]$ represents the hesitancy degree, and $0\leq\mu^2_{\tilde{A}_s}(x)+\nu^2_{\tilde{A}_s}(x)+\pi^2_{\tilde{A}_s}(x)\leq 1, \forall x\in X$ is met for all $x\in X$. The degree of refusal membership is denoted by $\varphi_{\tilde{A}_s}=\sqrt{1-\mu^2_{\tilde{A}_s}-\nu^2_{\tilde{A}_s}-\pi^2_{\tilde{A}_s}}$ (Rao et al., 2015).

Definition 2. (Zolfani et al., 2023) For the purpose of clarity, $\widetilde{A}_s=\left(\mu_{\tilde{A}_s},\nu_{\tilde{A}_s},\pi_{\tilde{A}_s}\right)$ and $\widetilde{B}_s=\left(\mu_{\tilde{B}_s},\nu_{\tilde{B}_s},\pi_{\tilde{B}_s}\right)$ are two SF numbers. Fundamental operations such as addition, multiplication, multiplication by a scalar for real, λ^{th} power of $\widetilde{A}_s$, and exponentiation, along with the score and accuracy functions, are defined in Eq (2) through (7).

$$\widetilde{A}_s\oplus\widetilde{B}_s=\sqrt{\left(\mu^2_{\tilde{A}_s}+\mu^2_{\tilde{B}_s}-\mu^2_{\tilde{A}_s}\mu^2_{\tilde{B}_s}\right)},\nu_{\tilde{A}_s}\nu_{\tilde{B}_s},\sqrt{\left(1-\mu^2_{\tilde{B}_s}\right)\pi^2_{\tilde{A}_s}+\left(1-\mu^2_{\tilde{A}_s}\right)\pi_{\tilde{B}_s2}-\pi^2_{\tilde{A}_s}\pi_{\tilde{B}_s2}} \tag{2}$$

$$\widetilde{A}_s\otimes\widetilde{B}_s=\left(\mu_{\tilde{A}_s}\mu_{\tilde{B}_{ss}},\sqrt{\left(\nu^2_{\tilde{A}_s}+\nu^2_{\tilde{B}_s}-\nu^2_{\tilde{A}_s}\nu^2_{\tilde{B}_s}\right)},\sqrt{\left(1-\nu^2_{\tilde{B}_s}\right)\pi^2_{\tilde{A}_s}+\left(1-\nu^2_{\tilde{A}_s}\right)\pi_{\tilde{B}_s2}-\pi^2_{\tilde{A}_s}\pi_{\tilde{B}_s2}}\right) \tag{3}$$

$$\lambda\widetilde{A}_s=\sqrt{1-\left(1-\mu^2_{\tilde{A}_s}\right)^{\lambda}},\nu^{\lambda}_{\tilde{A}_s},\sqrt{\left(1-\mu^2_{\tilde{A}_s}\right)^{\lambda}-\left(1-\mu^2_{\tilde{A}_s}-\pi^2_{\tilde{A}_s}\right)^{\lambda}} \tag{4}$$

$$\widetilde{A}_s^{\lambda}=\langle\mu^{\lambda}_{\tilde{A}_s},\left(1-\left(1-\nu^2_{\tilde{A}_s}\right)^{\lambda}\right)^{1/2},\left(\left(1-\nu^2_{\tilde{A}_s}\right)^{\lambda}-\left(1-\nu^2_{\tilde{A}_s}-\pi^2_{\tilde{A}_s}\right)^{\lambda}\right)^{1/2}\rangle \tag{5}$$

$$S(\widetilde{A}_s)=\frac{\mu_{\tilde{A}_s}+1-\nu_{\tilde{A}_s}+1-\pi_{\tilde{A}_s}}{3} \tag{6}$$

$$A(\widetilde{A}_s)=\mu_{\tilde{A}_s}-\nu_{\tilde{A}_s} \tag{7}$$

An order relationship between a pair of SFSs $\widetilde{A}_s$ and $\widetilde{B}_s$ is noted as

$\widetilde{A}_s<\widetilde{B}_s$ *if* $S(\widetilde{A}_s)<S(\widetilde{B}_s)$ or $S(\widetilde{A}_s)=S(\widetilde{B}_s)$ and $A(\widetilde{A}_s)<A(\widetilde{B}_s)$

Definition 3. (Rao et al., 2015) To combine a set of spherical fuzzy numbers denoted as $\widetilde{A}_j=\left(\mu_{\tilde{A}_j},\nu_{\tilde{A}_j},\pi_{\tilde{A}_j}\right)$, $(j=1,..,n)$, The Spherical Weighted Arithmetic Mean (SWAM) and the Spherical Weighted Geometric Mean (SWGM) are constructed using Eqs (8) and (9). Here, the weight vector is denoted as $w=(w_1,w_2,\ldots,w_n,)$, where each $w_j\in[0,1]$ and $\sum_{i=1}^{n}w_j=1$ (Rao et al., 2015).

$$SWAM_w(\widetilde{A}_{s1},\widetilde{A}_{s1},\ldots,\widetilde{A}_{sn})=w_1\widetilde{A}_{s1}\oplus w_2\widetilde{A}_{s2}\oplus\ldots\oplus w_n\widetilde{A}_{sn}$$
$$=\left(\sqrt{1-\prod_{i=1}^{n}\left(1-\mu^2_{\tilde{A}_{si}}\right)^{w_j}},\prod_{i=1}^{n}\nu^{w_j}_{\tilde{A}_{si}},\sqrt{\prod_{i=1}^{n}\left(1-\mu^2_{\tilde{A}_{si}}\right)^{w_j}-\prod_{i=1}^{n}\left(1-\mu^2_{\tilde{A}_{si}}-\pi^2_{\tilde{A}_{si}}\right)^{w_j}}\right) \tag{8}$$

Where $w_j\in[0,1]$; $\sum_{i=1}^{n}w_j=1$

$$SWGM_w(\widetilde{A}_{s1},\widetilde{A}_{s1},\ldots,\widetilde{A}_{sn})=\widetilde{A}_{s1}^{w_1}\otimes\widetilde{A}_{s2}^{w_2}\otimes\ldots\otimes\widetilde{A}_{sn}^{w_n}$$
$$=\left(\prod_{i=1}^{n}\mu^{w_j}_{\tilde{A}_{si}},\sqrt{1-\prod_{i=1}^{n}\left(1-\nu^2_{\tilde{A}_{si}}\right)^{w_j}},\sqrt{\prod_{i=1}^{n}\left(1-\nu^2_{\tilde{A}_{si}}\right)^{w_j}-\prod_{i=1}^{n}\left(1-\nu^2_{\tilde{A}_{si}}-\pi^2_{\tilde{A}_{si}}\right)^{w_j}}\right) \tag{9}$$

Where $w_j\in[0,1]$; $\sum_{i=1}^{n}w_j=1$

Definition 4. (Toker and Görener, 2023) A weighted Minkowski distance measure for spherical fuzzy sets (SFSs) was introduced by Donyatalab et al. (Toker and Görener, 2023) and w_j denotes the weight vector. The weighted Minkowski distance between $\widetilde{A}_s$ and $\widetilde{B}_s$ is identified with the help of Eq. (10).

$$Md_{SFS}(\widetilde{A}_s\widetilde{B}_s) = \sqrt[p]{\frac{1}{2}\sum_{j=1}^{n} w_j\left[|\mu_{\widetilde{A}_s}(x) - \mu_{\widetilde{B}_s}(x)|^p + |\nu_{\widetilde{A}_s}(x) - \nu_{\widetilde{B}_s}(x)|^p + |\pi_{\widetilde{A}_s}(x) - \pi_{\widetilde{B}_s}(x)|^p\right]} \quad (10)$$

If p = 1, the spherical fuzzy Minkowski distance becomes a spherical fuzzy Hamming distance, and if p = 2, it becomes a spherical fuzzy Euclidean distance (Toker and Görener, 2023).

Definition 5. [64] In the Spherical Weighted Arithmetic Mean (SWAM), the values of the initial weights of the criteria are obtained by applying the weighted sum method. The calculation is given below:

The Euclidean distance between the pair of SFSs is demonstrated as follows:

$$d_E(\widetilde{A}_s, \widetilde{B}_s) = \sqrt{(\mu_{\widetilde{A}_s} - \mu_{\widetilde{B}_s})^2 + (\upsilon_{\widetilde{A}_s} - \upsilon_{\widetilde{B}_s})^2 + (\pi_{\widetilde{A}_s} - \pi_{\widetilde{B}_s})^2} \quad (11)$$

The spherical distance is exhibited as follows:

$$dis_{Sp}(\widetilde{A}_s, \widetilde{B}_s) = \frac{2}{\pi}\left(\arccos\left(\mu_{\widetilde{A}_s}\mu_{\widetilde{B}_s} + \upsilon_{\widetilde{A}_s}\upsilon_{\widetilde{B}_s} + \pi_{\widetilde{A}_s}\pi_{\widetilde{B}_s}\right)\right) \quad (12)$$

3.2. Recognition of criteria by the Spherical Delphi Method

Building upon the Delphi procedure and spherical fuzzy numbers, we developed an enhanced process for determining evaluation criteria. The Spherical Delphi Method synergizes the iterative consensus-building of the traditional Delphi method with the advanced uncertainty-handling capabilities of SFSs. First, a panel of experts is selected based on their knowledge of the subject matter. These experts evaluate various criteria using linguistic scales expressed as spherical fuzzy numbers, where each linguistic term is represented by membership, non-membership, and hesitancy degrees. After collecting all the necessary evaluations, we proceed with aggregating all responses. In aggregating expert responses, first, linguistic evaluations are converted to corresponding SFNs in the linguistics scale, and then we employ the SWAM operator to form a composite spherical fuzzy number for each criterion, representing the group's overall opinion. Following the aggregation, the composite spherical fuzzy numbers are defuzzified by dividing the sum of the aggregated values for each criterion by its corresponding normalized importance value (w_j). Finally, the relative score for each criterion is obtained by dividing its defuzzified score by the maximum defuzzified score, as defined by Eq. (13).

$$c_j = \frac{w_j}{\max(w_j)} \quad (13)$$

Finally, criteria are classified as "Uncritical" if the c_j value is between $0.000 \le c_j \le 0.499$, "Moderate" if it is between $0.500 \le c_j \le 0.599$, and "Critical" if it is between $0.600 \le c_j \le 1.000$. This process ensures a balanced determination of criteria weights while accommodating the influence of extreme values within the linguistic scale.

Once the criteria weights have been identified, the experts assess each option according to each criterion, considering the linguistic evaluation scale. Next, these evaluations are transformed into spherical fuzzy numbers. The initial assessments are aggregated as in the previous stage, and the combined evaluations are defuzzied. Finally, the final scores are derived using the weighted sum method.

The weights of the three experts (ω_1, ω_2, ω_3) were set equally as (1/3, 1/3, 1/3), following a consensus-based approach, as all experts had comparable experience and influence in the decision process. If unequal weights had been used, their values would have been explicitly reported.

3.3. Mathematical model

In the earlier stages, the criteria and their weights are determined by considering the experts' assessments via SFSs. However, using the MCDM methods in selecting a location is insufficient since each location has investment costs that must be considered when making a choice. As a result, a new mixed integer non-linear multi-objective mathematical model is developed that considers both the investment costs and the criterion weights. The notation of the model is given in Table 2.

$$\min \alpha f_1^{norm} + (1-\alpha) f_2^{norm} \quad (14)$$

$$\sum_j x_{ij} = 1, \forall i \quad (15)$$

$$n_j y_j \le b_j \quad \forall j \quad (16)$$

$$\sum_j n_j = T \quad (17)$$

$$\sum_j y_j \ge 1 \quad (18)$$

$$x_{ij} \le y_i \quad \forall i, j \quad (19)$$

$$f_1 = \sum_j s_j y_j \quad (20)$$

$$f_2 = \sum_m \sum_j w_{mj} y_j \quad (21)$$

$$f_1^{norm} = \frac{f_1 - f_1^{min}}{f_1^{max} - f_1^{min}} \quad (22)$$

$$f_2^{norm} = \frac{f_2^{max} - f_2}{f_2^{max} - f_2^{min}} \quad (23)$$

$$x_{ij} y_i \in \{0, 1\} \quad (24)$$

$$n_j \ge 0 \quad (25)$$

The objective function is given by Eq. (14). It consists of two terms: the investment costs of the intelligence centres and the weights of the criteria of the intelligence centres. The investment costs should be minimized, and the criteria weights should be maximized. Therefore, the model is given as a multi-objective optimisation problem and achieves the balance between cost-effectiveness and strategic importance. Eq. (15): Ensures that each customer is mapped to a unique intelligence center. Thus, no customer remains unassigned; all customers are directed to a specific centre. Eq. (16): Ensures that the number of customers mapped to a centre does not exceed the centre's capacity. It ensures efficiency in operations by preventing any centre from becoming overloaded. Eq. (17) specifies that the number of customers to be allocated should equal the number of customers available. Thus, it is assumed that all the customers will be considered for the model. Eq. (18): Guarantees that at least one intelligence center must be opened. Without this constraint, the model can be such that no centres must be

Table 2
Notations.

Indices	
I	set of customers ($i \in$ I)
J	set of centres ($j \in$ J)
M	set of criteria (m $\in$ M)
Decision variables	
x_{ij}	If the customer *i* assigned to *j* centre is 1, otherwise 0
y_j	If j centre is open 1, otherwise 0
n_i	The number of customers that j centre has been given
Parameters	
s_j	The setup cost of *j* centre.
w_{mj}	The weight of the *m* criteria for *j* centre
b_j	The customer capacity of the centre j
T	The total number of customers
α	The weight of the objective function

opened, which is an invalid scenario for actual conditions. Eq. (19): Ensures a customer is assigned to the open intelligence center. It prevents assigning a customer to a closed or non-existent centre. Eqs. (20) and (23): Define the objective functions. Eqs. (24) and (25): Define that the decision variables must be positive and binary (0–1). This means that the decisions of the assignment and opening of centres possess only 0 or 1 values, and the number of customers cannot be negative.

3.4. Weighted sum scalarization method

The weighted Sum Scalarization Method (WSSM) was introduced by Gass et al. (Kutlu Gündoğdu and Yörükoğlu, 2021). This method is used more commonly than other methods to solve multi-objective problems. In the WSSM, the decision-maker determines a weighting value for each objective, and then the objectives are connected to this weighting value. Thus, a scalar objective function is achieved, and an attempt is made to maximize the function produced by the weighted sum of the objectives in the form of a single objective.

If the weights $(w_j, j = 1, \ldots, p)$ are positive, the minimum of the following WSSM is Pareto optimal (Menekşe and Camgöz Akdağ, 2022):

$$min_{x\in X}\sum_{i=1}^{p} wf(x) \tag{26}$$

4. Case study

The developed MCDM model, which merges the MCDM methods and mathematical programming model, is used to specify the foreign trade intelligence centre. The steps of the model are given as follows:

4.1. Description of the case study

Exports have become a requirement for every business worldwide due to the escalation of the highly competitive global trade climate and the shift in strategic goals. Investigating new market potential, obtaining necessary information about domestic and foreign companies, and getting suitable targets before entering new markets are growing concerns, especially for developing countries like Turkey. Exporting may be challenging for companies selling their products to domestic customers. They may struggle to analyse and discover available export potential and specify the new potential customers. Foreign Trade Intelligence Centres may be considered a bridge for businesses without experience or knowledge that are not brave enough to open up to their commercial activities and new markets.

Furthermore, managers need these centres as a vital tool to remain in the fiercely competitive corporate environment of the near and distant future; because of this, domestic and international businesses must enhance their capacities in areas like target markets, potential customers, and information collecting and management to carry out critical commercial and operational operations. Above all, the vital matter is where to open such a foreign trade intelligence centre in a large country like Turkey. Determining the optimal location of the foreign trade intelligence centre and identifying the criteria set will positively contribute to the country's economic growth. That will give countries a competitive advantage and enable them to strengthen their position at the global level.

We assembled an expert committee of qualified managers, foreign trade professionals, and academics to find the best location for Turkey's foreign trade intelligence centre. The preliminary expert interviews suggested that the matter is crucial for boosting Turkey's export potential and merits investigation. Our research team read publications and scholarly articles to compile facts and figures about the work done with the International Trade Centre before the second meeting. The researchers combined the preliminary data gleaned from the accessible sources with the thoughts and assessments of the experts during the second meeting to identify the critical research issues.

For the final assessment of the criteria in the application portion of the study, the views of three top experts in the field were consulted. The following are the areas of expertise of the decision-makers:

- The first expert has been providing consultancy services to exporting companies under the auspices of foreign trade intelligence for 26 years. On the topic of foreign trade intelligence, he lectures at universities. He has the manager in charge of establishing four centres for foreign trade intelligence.
- The second expert has counselled businesses on international trade for 23 years. In foreign trade intelligence, he also has his own company. This company provides consultancy services to companies that want to export.
- The third expert has 21 years of experience working in government agencies related to international business. Then, it offers companies consulting so they can export to potential companies.

Researchers concluded that a new centre could provide information and technical support to businesses to increase Turkey's export potential. Location selection is a critical and fundamental decision-making issue. The location of the foreign trade centre is a crucial issue for businesses that want to increase their export potential, and it is a very complex decision-making problem.

4.2. Identifying the criteria set

After completing the preliminary planning, we initiated an extensive evaluation process to identify a comprehensive and unbiased set of evaluation criteria. Initially, a pool of 62 potential criteria was compiled from reports by public institutions, organizational documents, and the literature review. This pool guided the expert group, which included experts from diverse stakeholder groups such as academia, government agencies, non-governmental organizations, and the private sector. Then we assessed each criterion, narrowing the list to a more manageable 25 key evaluation criteria.

Table 3 presents these evaluation criteria for analysing the location selection of a foreign trade intelligence centre, which serves as a critical foundation for strategic decision-making in this area. The selection of an optimal location is essential to maximize operational efficiency, accessibility, and economic viability, and directly impacts the centre's effectiveness in collecting, processing, and disseminating business intelligence. By systematically evaluating multiple criteria, such as infrastructure, market proximity, security, and regulatory environment, this analysis provides a comprehensive and data-driven approach to site selection. The insights from this table contribute to the literature by providing a structured framework that improves decision-making processes in business intelligence management and ultimately promotes competitive advantage and economic sustainability. Therefore, in terms of application and the results to be acquired, the criteria established in Table 3 form the backbone of the study. To ensure comprehensiveness and mitigate any potential bias, we implemented a Spherical Delphi technique. In the first round, each expert was asked to review the criteria pool, suggest additional criteria they believed were influential, and recommend removing any insignificant criteria. Their linguistic evaluations were provided using the spherical fuzzy numbers detailed in Table 4. During subsequent rounds, the process focused on eliminating repetitive criteria and merging similar ones, which reduced the list to 10 criteria. The influential criteria were identified, as demonstrated in Table 5 at the end of the evaluation process.

Table 5 contains the decision-makers' evaluations. As a result of the Spherical Delphi method, incentives are the most crucial factor in the identifying criteria, as shown by Table 5's findings. This instance highlights the importance of considering the state or local government's financial assistance or incentives when deciding where to locate the foreign trade intelligence centre.

Table 3
Foreign Trade Intelligence Centre location selection criteria.

Criteria	Sub-Criteria	Apply Meaning	Foreign Trade Intelligence Center Selection Outcomes	Reference
C_1 **Economic**	Commercial Vitality (C_{1-1})	Commercial dynamism in the targeted area	Increasing the number of exports with the analysis of the foreign trade intelligence centre for exporters	(Kumar and Anbanandam, 2019)
	Service Radius (C_{1-2})	Distance of the area it can serve	Presence of commercial production in the region: It is easier than setting up the export system from zero.	[61]
	Operating and maintenance cost (C_{1-3})	All operational costs in the target region	The easier it is for the foreign trade intelligence centre to provide services, the lower the expenses.	(Şahin, 2020); (Yazdani et al., 2020a)
	Export Quantity (C_{1-4})	Export amount of the city in the target region	Exporting, even if limited in the region, makes it easier to establish an export infrastructure.	**Expert Opinion**
	Incentives (C_{1-5})	Local government's economic incentives for export	Regional government incentives reduce firms' export costs.	(Şahin, 2020); (Yazdani et al., 2020a)
	Competitiveness of Companies (C_{1-6})	Decreased ability of local companies to compete successfully with international companies	Reducing exports in the region necessitates the establishment of a foreign trade intelligence centre.	[62]
	Decrease Tendency of Export Rates (C_{1-7})	Decrease in export figures in the target region.	The decrease in current export figures causes exporters to panic. The necessity of a business intelligence centre arises in this area.	**Expert Opinion**
C_2 **Social**	Legal Arrangement (C_{2-1})	Presence of legal regulations in the region	Investment is secured in a potential area	Yücenur and Ipekçi (2021)
	Layout (C_{2-2})	Providing the legal framework required for trade and export	Producers tend to export with the legal arrangement	Şahin (2020)
	Consciousness of Businesspeople (C_{2-3})	Businessmen need to understand the importance of exporting	Businessmen make an effort to export	**Expert Opinion**
	Businessmen's Desire to Increase Their Exports/ Business Climate (C_{2-4})	Businessmen's efforts to increase their current export rate	Accelerating export growth	Kumar and Anbanandam (2019)
	Export Perception (C_{2-5})	The perspective of businessmen and the region on exports	Understanding the importance of the foreign trade intelligence centre	**Expert Opinion**
C_3 **Labour Characteristics**	Skilled Labor Population (C_{3-1})	Availability of skilled labour in the region	Acceleration of production in the region	(Yazdani et al., 2020a); (Kumar and Anbanandam, 2019); (Yücenur and Ipekçi, 2021); (Şahin, 2020)
	Existence of Trained Foreign Trade Personnel (C_{3-2})	Availability of personnel trained in business intelligence	Foreign trade intelligence centre to start work quickly	Yücenur and Ipekçi (2021)
C_4 **Geographical Conditions**	Environmental Consideration (C_{4-1})	Opportunities in the region and factors that will facilitate foreign trade	Diversification of business and opportunities of the commercial intelligence centre	Yazdani et al. (2020a)
	Location (C_{4-2})	Location of the foreign trade centre to be established	Logistics and supply chain opportunities are more advantageous in the port city	(Yazdani et al., 2020a); (Kumar and Anbanandam, 2019)
	Inland or Port City (C_{4-3})	Being in the port city or inland affects the activities.	Being in a port city increases the economic potential.	(Yazdani et al., 2020a); (Kumar and Anbanandam, 2019)
	Existence of Exporters' Associations (C_{4-4})	Unions to which exporters must be members	Indicates the export readiness of producers	[63]
	Available Transportation Modes (C_{4-5})	Availability of modes of transport to the regions	Ease of access to the intelligence centre	Yücenur and Ipekçi (2021)
	Safety and Security (C_{1-6})	The target region's technology infrastructure will support production, logistics, and supply chain operations.	Facilitates the activities of the foreign trade intelligence centre in the region.	Yücenur and Ipekçi (2021)
C_5 **Infrastructure Services**	The closeness of the industry area (C_{5-1})	Air, land, railroad, and seaway possibilities	Facilitates the export of products	Karaşan et al. (2020)
	Cooperation with logistics agent (C_{5-2})	Supply chain capacity and possibilities	Acceleration of production, market, and sales processes	Karaşan et al. (2020)
	Availability of Terminals (C_{5-3})	The existence and development of terminals	Facilitating export processes	Şahin (2020)
	Movement Flexibility (C_{5-4})	The centre's ability to provide flexible service	Speeding up the activities of the centre	**Expert Opinion**
	Transportation Infrastructure (C_{5-5})	Transportation opportunities in the area	Facilitating the transfer of export and import products	Yücenur and Ipekçi (2021)

4.3. Identifying the assessment score of the alternatives

Spherical Delphi determines the criteria set for foreign trade intelligence centres. Experts then used the linguistic terms mentioned in Table 4 to undertake linguistic importance level assessments for these criteria. Table 6 lists the evaluation outcomes, score function values, and the weights for the criteria.

Three experts evaluate the seven alternatives (Table 7) according to each criterion on the scale provided in Table 4. The linguistic evaluations of the alternatives are shown in Table 7. The linguistic variables are afterwards converted into spherical fuzzy numbers. Finally, the score values for each alternative for the ten criteria were determined by aggregating experts' opinions with the weighted sum method and presented in Table 8.

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Table 4
Spherical fuzzy linguistic scale.

Qualitative terms	Spherical Fuzzy Number		
	μ	ν	π
Absolutely more importance (AMI)	1.00	0.00	0.00
Relatively more importance (RMI)	0.90	0.10	0.10
Very high importance (VHI)	0.80	0.20	0.20
High importance (HI)	0.70	0.30	0.30
Slightly more importance (SMI)	0.60	0.40	0.40
Equally importance (EI)	0.50	0.50	0.50
Slight low importance (SLI)	0.40	0.60	0.40
Low importance (LI)	0.30	0.70	0.30
Very low importance (VLI)	0.20	0.80	0.20
Relatively less importance (RLI)	0.10	0.90	0.10
Absolutely less importance (ALI)	0.00	1.00	0.00

5. Findings

We developed a new mathematical model following Equations (14)–(25) to address the foreign trade intelligence centre location selection problem. However, to solve this mathematical model, we need some parameters. These parameters include setup costs, customer capacities, the number of customers, and weights. Except for weights, we can reach all parameters. As a result, we used MCDM techniques to determine the weights. The mathematical model was then solved using the BARON solver. We used a computer with an Intel Core i5, 2 GHz, and 16 GB of RAM for the experiments.

10 foreign trade intelligence centres in Turkey have been established, with three additional centres, as shown in Fig. 2. For this study, we have focused on seven potential centres, namely Bursa, İzmir, Ankara, Trabzon, Mersin, Mardin, and Zonguldak, as indicated in Fig. 3. Identifying these potential centres has been based on expert opinions, which considered various factors, some of which are outlined in Table 3. As a result, different parameters—including setup costs, customer capacities, customer numbers, and weights—were created for each prospective location, as given in Table 9. Because every potential centre has different parameters. For example, every setup cost differs since each city (potential centre) has a different price structure.

As a result, Mersin has found using these parameters. The experts claim that the result is logical. However, in the experiment, the total number of customers and the customer capacity are equal. Because only one centre is what the people who will fund the opening of the foreign trade intelligence centre want to open, by altering these parameters, users can discover a solution if they want to open more than one. According to these parameters, Mersin province is found as a result. This result is not a surprise because the setup cost of Mersin is average, and the weights of Mersin are at the forefront.

Table 3 provides a comparative assessment of alternative locations based on predefined decision-making parameters. The advantage of Mersin, as highlighted in the table, was measured through a weighted scoring system that evaluates factors such as infrastructure, logistics efficiency, and economic feasibility. Each parameter was assigned a

Table 5
Classification and identification of criteria.

Code	Name of Criterion	DM1	DM2	DM3	Spherical Fuzzy Number	Score	w_j	Value	Category
C01	Commercial Vitality	VHI	RMI	RMI	(0.867, 0.141, 0.141)	0.861	0.059	0.933	Critical
C05	Incentives	RMI	AMI	RMI	(0.933, 0.081, 0.081)	0.923	0.064	1.000	Critical
C06	Competitiveness of Companies	VHI	VHI	RMI	(0.834, 0.173, 0.173)	0.829	0.057	0.898	Critical
C13	Skilled Labor Population	SLI	LI	SLI	(0.367, 0.635, 0.369)	0.454	0.031	0.492	Uncritical
C08	Legal Arrangement	EI	VHI	RMI	(0.714, 0.325, 0.325)	0.688	0.047	0.745	Critical
C11	Businessmen's Desire to Increase Their Exports	HI	VHI	RMI	(0.798, 0.216, 0.216)	0.788	0.054	0.854	Critical
C14	Existence of Trained Foreign Trade Personnel	VHI	RMI	VHI	(0.834, 0.173, 0.173)	0.829	0.057	0.898	Critical
C18	Existence of Exporters' Associations	VHI	HI	RMI	(0.798, 0.216, 0.216)	0.788	0.054	0.854	Critical
C23	Availability of Terminals	SLI	LI	LI	(0.334, 0.668, 0.336)	0.443	0.031	0.480	Uncritical
C09	Layout	SLI	RLI	SLI	(0.255, 0.755, 0.334)	0.389	0.027	0.421	Uncritical
C24	Movement flexibility	EI	VLI	SMI	(0.395, 0.622, 0.391)	0.461	0.032	0.499	Uncritical
C19	Available Transportation Modes	SMI	SLI	RLI	(0.292, 0.727, 0.334)	0.410	0.028	0.444	Uncritical
C16	Location	LI	SLI	LI	(0.334, 0.668, 0.336)	0.443	0.031	0.480	Uncritical
C17	Inland or Port City	SMI	RLI	LI	(0.266, 0.750, 0.296)	0.406	0.028	0.440	Uncritical
C25	Transportation Infrastructure	VLI	LI	SMI	(0.334, 0.679, 0.312)	0.448	0.031	0.485	Uncritical
C21	Closeness of the industry area	HI	VHI	RMI	(0.798, 0.216, 0.216)	0.788	0.054	0.854	Critical
C22	Cooperation with logistics agent	LI	VLI	SMI	(0.334, 0.679, 0.312)	0.448	0.031	0.485	Uncritical
C03	Operating and maintenance costs	SLI	LI	LI	(0.334, 0.668, 0.336)	0.443	0.031	0.480	Uncritical
C20	Safety and Security	LI	VLI	SLI	(0.292, 0.712, 0.312)	0.423	0.029	0.458	Uncritical
C15	Environmental considerations	SLI	ALI	VLI	(0.000, 1.000, 0.262)	0.246	0.017	0.266	Uncritical
C02	Service radius	LI	RLI	VHI	(0.292, 0.737, 0.216)	0.446	0.031	0.483	Uncritical
C04	Export Quantity	LI	RLI	RMI	(0.304, 0.734, 0.192)	0.459	0.032	0.497	Uncritical
C07	Decrease the Tendency of Export Rate	VHI	SMI	AMI	(0.785, 0.262, 0.262)	0.754	0.052	0.816	Critical
C10	Consciousness of Businesspeople	HI	VLI	VLI	(0.307, 0.711, 0.238)	0.453	0.031	0.490	Uncritical
C12	Export Perception	VHI	RMI	RMI	(0.867, 0.141, 0.141)	0.861	0.059	0.933	Critical

Table 6
The assessments of the criteria and their importance.

		DM1	DM2	DM3	Spherical Fuzzy Number	Score	w_j
C01	Commercial Vitality	VHI	RMI	RMI	(0.875, 0.126, 0.131)	0.5535	0.1008
C05	Incentives	RMI	AMI	RMI	(1.000, 0.000, 0.000)	1.0000	0.1820
C06	Competitiveness of Companies	VHI	VHI	RMI	(0.842, 0.159, 0.164)	0.4603	0.0838
C08	Legal Arrangement	EI	VHI	RMI	(0.793, 0.215, 0.255)	0.2876	0.0523
C11	Businessmen's Desire to Increase Exports/Business Climate	HI	VHI	RMI	(0.821, 0.182, 0.194)	0.3927	0.0715
C14	Existence of Trained Foreign Trade Personnel	VHI	RMI	VHI	(0.842, 0.159, 0.164)	0.4603	0.0838
C18	Existence of Exporters' Associations	VHI	HI	RMI	(0.821, 0.182, 0.194)	0.3927	0.0715
C21	Closeness of the industry area	HI	VHI	RMI	(0.821, 0.182, 0.194)	0.3927	0.0715
C07	Decrease the Tendency of Export Rate	VHI	SMI	AMI	(1.000, 0.000, 0.000)	1.0000	0.1820
C12	Export Perception	VHI	RMI	RMI	(0.875, 0.126, 0.131)	0.5535	0.1008

Table 7
The assessments of alternatives.

Cr.	Alt.	C01	C05	C06	C08	C11
IC1	Bursa	AMI, VHI, AMI	HI, RMI, VHI	AMI, VHI, AMI	LI, SMI, EI	RMI, VHI, RMI
IC2	İzmir	VHI, VHI, AMI	AMI, VHI, VHI	HI, RMI, RMI	SLI, VHI, RMI	VHI, RMI, RMI
IC3	Ankara	HI, RMI, RMI	HI, AMI, SMI	HI, AMI, RMI	SLI, EI, SMI	HI, AMI, RMI
IC4	Trabzon	VLI, EI, VHI	HI, SMI, EI	VHI, SMI, EI	HI, VLI, LI	HI, EI, AMI
IC5	Mersin	AMI, AMI, AMI	VHI, VHI, RMI	RMI, VHI, AMI	SLI, RMI, RMI	RMI, VHI, VHI
IC6	Mardin	RLI, RLI, SLI	SLI, RLI, VLI	LI, VLI, RLI	HI, RLI, RLI	LI, RLI, AMI
IC7	Zonguldak	RLI, EI, SMI	SLI, SLI, SLI	SLI, LI, SLI	HI, VLI, LI	VLI, LI, VHI
Cr.	Alt.	C14	C18	C21	C07	C12
IC1	Bursa	VHI, VHI, VHI	VHI, AMI, AMI	AMI, RMI, AMI	HI, AMI, VHI	VHI, RMI, HI
IC2	İzmir	AMI, RMI, VHI	VHI, RMI, AMI	RMI, AMI, AMI	SMI, RMI, HI	AMI, HI, RMI
IC3	Ankara	VHI, AMI, AMI	HI, VHI, RMI	VHI, AMI, VHI	HI, VHI, VHI	RMI, SMI, AMI
IC4	Trabzon	HI, EI, AMI	LI, HI, RMI	VHI, VHI, RMI	VHI, HI, SMI	RMI, VHI, HI
IC5	Mersin	VHI, VHI, RMI	HI, VHI, VHI	HI, HI, VHI	RMI, AMI, AMI	HI, RMI, VHI
IC6	Mardin	LI, RLI, AMI	LI, RLI, AMI	LI, RLI, AMI	HI, SMI, HI	VHI, HI, HI
IC7	Zonguldak	RLI, SLI, AMI	VLI, VHI, AMI	LI, RLI, AMI	SMI, HI, HI	HI, EI, VHI

weight based on expert evaluations and validated using sensitivity analysis.

An additional comparison was conducted to further enhance the study by incorporating alternative parameters such as environmental sustainability, proximity to international markets, and trade volume potential. The results indicate that while Mersin scored the highest in logistical efficiency, Bursa performed better in terms of economic incentives and industrial development potential. These findings suggest that decision-makers may prioritize different factors depending on strategic goals, highlighting the flexibility of the proposed evaluation model.

In the problem examined in this study, the commercial intelligence centre's capacity is not exceeded by the number of consumers. However, the case of a condition that exceeded the capacity has also been examined. The problem was resolved by setting the customer capacity to "1000″ and finding that two centres—Mersin and Bursa—were open.

5.1. Sensitivity analysis

Expert opinion provided the basis for determining the relative importance of the criteria, and the method applied ensured systematic weighting. Since decision situations are rarely stationary, it was required to test the robustness of the results under different conditions. For this purpose, a comprehensive sensitivity analysis was conducted, wherein the weights of each criterion were systematically reduced in 10 % steps to zero. This process generated 100 different scenarios in all, allowing the system to be tested under different circumstances and ensuring that the findings would remain valid even if the weighting structure were significantly changed [64]. As can be understood from Fig. 4, the results unequivocally indicate that Mersin remains the preferred alternative in 87 out of 100 scenarios, while Bursa emerges as the top-ranked alternative in only 13 scenarios. This spread indicates that Mersin's superiority is indifferent to broad changes in criteria weighting, thereby validating the robustness and stability of the decision model. Therefore, the findings strongly support the establishment of a commercial intelligence centre in Mersin because the city performs better across a wide range of possible conditions.

While Mersin is clearly the first preference, the study goes on to indicate that there are certain circumstances under which Bursa can be a second preference. A glance at the scenario-based graph seems to indicate that both cities function at varying levels of capability depending on the weight adjustments made to the criteria. Mersin is indicated to have supremacy in a vast majority of the scenarios, which immensely testifies to its position as the ideal choice. Still, Bursa, even though not the best in general, always ends up being the second choice. This is evidence that, even as Mersin surpasses Bursa in almost all aspects, Bursa possesses qualities making it a worth-considered option in the sensitivity context. Such a finding reveals the importance of embracing other possibilities even when one possibility proves absolute superiority.

Sensitivity analysis likewise supports these findings through the evidence that Mersin's superior position is stable and firm in virtually all the cases that have been run, hence proving overall potency as the best option. Bursa's continued listing as second-best signifies that it remains strategically important and can be considered plausible in some cases where some of the criteria are given differently, or when conditions locally deviate. On the academic side, the findings highlight that though the selected criteria and approach properly complement Mersin, Bursa remains a valuable alternative choice.

5.2. Comparative analysis

In this section, we applied five different SF-based decision-making approaches to compare the results obtained with the application of the model proposed in the study, and compared the overall results obtained by applying these methods. In this context, we used SF-TOPSIS [65], SF-WASPAS (Tsygankova and Ishchenko, 2017), SF-WPM [66], SF-MULTIMOORA (Zolfani et al., 2023), and SF-ARAS [67] methods. However, since the primary purpose of this study is to determine the most appropriate alternative with the optimisation model used, the criteria are not listed due to the nature of the application. On the other hand, we repeated the analysis for the remaining alternatives, excluding the Mersin option, which is the most suitable alternative for comparing the results. The results obtained during the evaluation process without Mersin pointed to Bursa as the best alternative. Then, the alternatives were ranked using the popular decision-making tools mentioned above.

Table 8
The assessment scores of alternatives.

	C01	C05	C06	C08	C11	C14	C18	C21	C07	C12
IC1	3.007	2.674	2.829	1.265	2.446	2.346	2.659	2.811	2.304	2.431
IC2	2.699	3.014	2.431	1.649	2.446	2.699	2.546	2.811	2.000	2.668
IC3	2.554	2.426	2.532	1.350	2.399	2.829	2.215	2.425	2.143	2.467
IC4	1.301	1.852	1.760	1.058	1.894	1.970	1.563	2.336	1.933	2.431
IC5	1.365	2.537	2.322	1.235	2.336	2.457	2.128	2.031	1.471	2.431
IC6	0.733	0.821	0.769	0.768	0.963	0.974	0.963	0.963	1.857	2.202
IC7	1.061	1.296	1.156	1.058	1.104	1.044	1.449	0.963	1.857	1.913

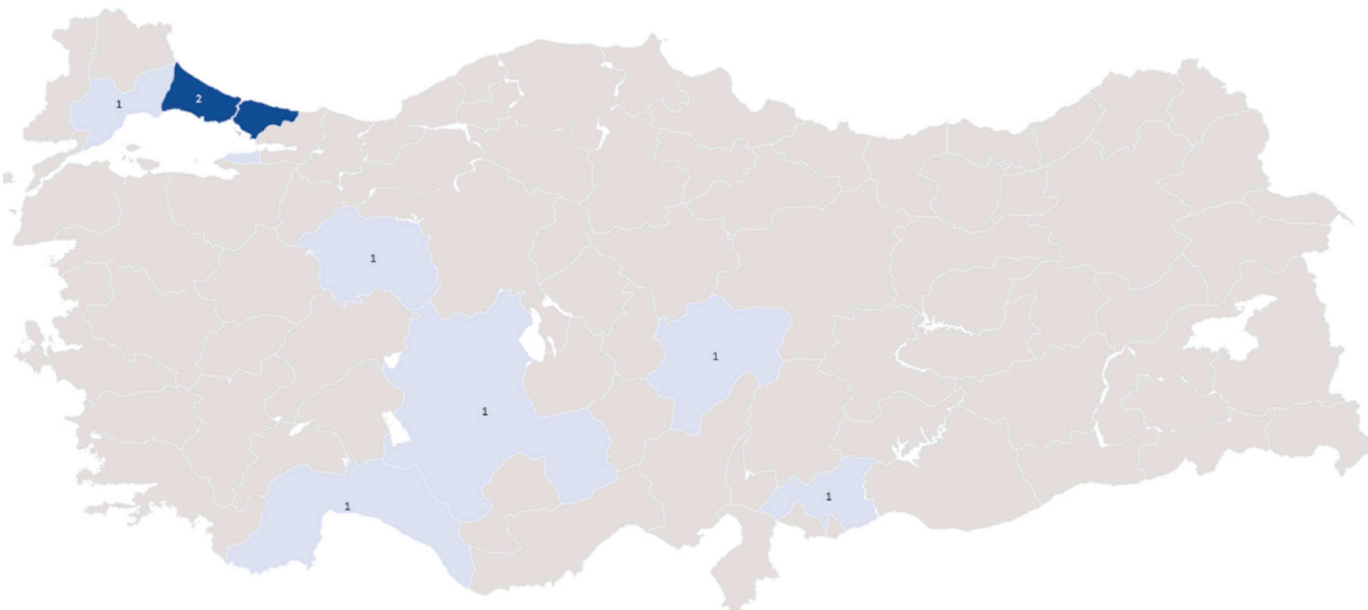

Fig. 2. Existing foreign trade intelligence centres in Turkey.

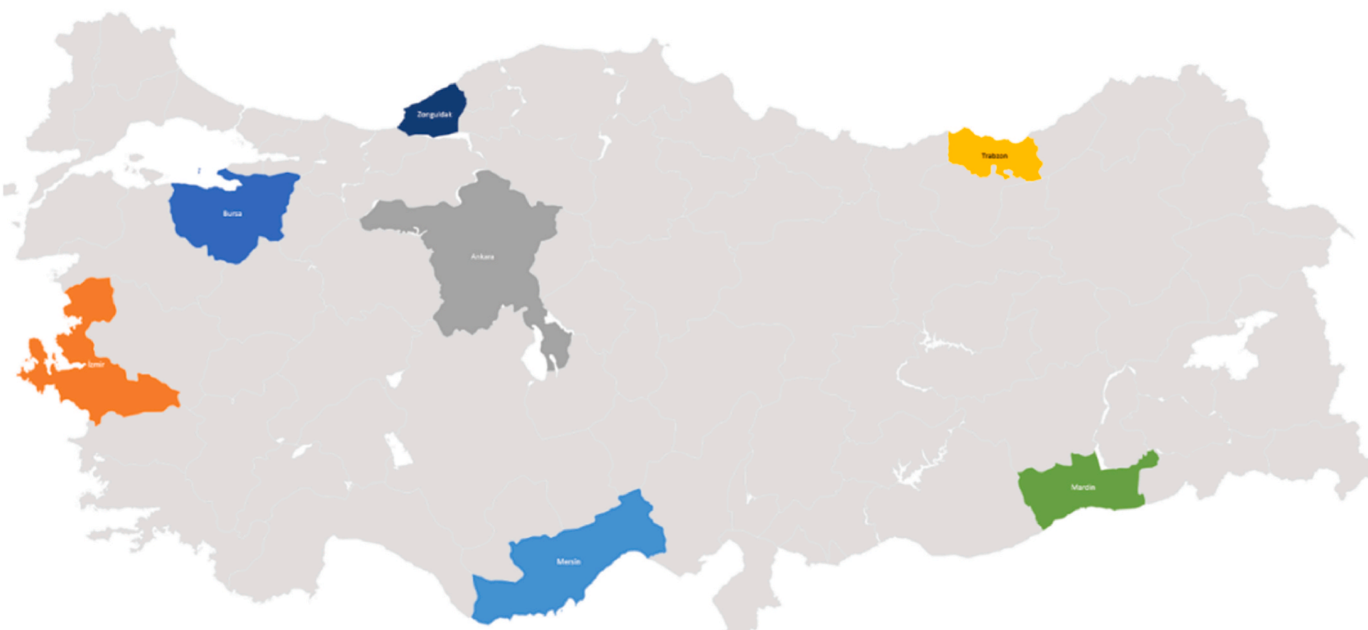

Fig. 3. Potential foreign trade intelligence centres selection map.

Table 9
Potential trade intelligence centres.

Potential center	Set up cost	Customer capacity	Total number of customers
Bursa	100	1200	1200
İzmir	120	1200	1200
Ankara	150	1200	1200
Trabzon	85	1200	1200
Mersin	78	1200	1200
Mardin	50	1200	1200
Zonguldak	60	1200	1200

Fig. 5 presents the overall ranking results of the methods used.

As can be seen from Fig. 5, the IC5 Mersin alternative has been determined as the most suitable and optimum alternative for each SF-based model used. In this context, the model proposed in the study and five other applied calculation tools point to the same result. However, the IC1 Bursa alternative has been determined as the second-best option according to the results of the other approaches, except the SF-WASPAS and SF-WPM methods. In addition, there is a correlation between the results of the applied methods, which can be considered extremely high on average, of 0.988. Table 10 shows the correlation values between the applied methods.

As a result, the results of the comparative analysis confirm the stability, validity, and robustness of the model proposed in this study, as well as the results obtained. Accordingly, the mathematical tool

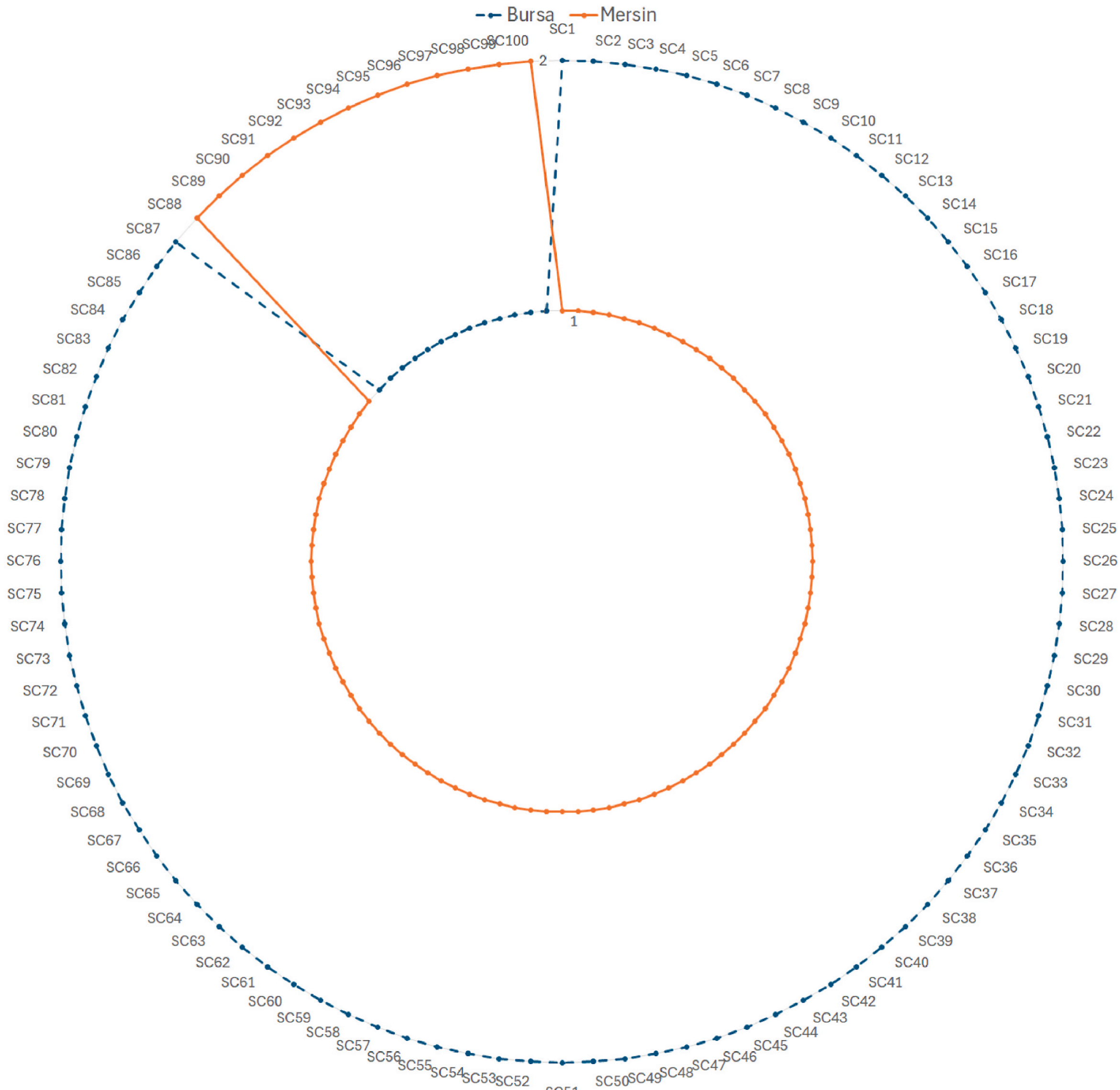

Fig. 4. Result of sensitivity analysis.

proposed in this study can be reliably used by decision-makers.

6. Managerial implications

The paper offers numerous priceless benefits to critical players in the international trade actors, including exporters, importers, and policymakers of countries familiar with trade privileges. The need for trustworthy, up-to-date, in-depth information and analysis to support strategic planning and decision-making in international trade has become increasingly critical to society. Foreign Trade Intelligence centres have become essential companies for understanding the advantages of these centres. For policymakers charged with boosting export rates, choosing the best location for a foreign trade intelligence center can be difficult because numerous subjective and objective variables must be considered. Selecting the ideal location is also difficult due to the many uncertainties of the evaluation methods. We began our research project to find a solution to the issue of location selection for a foreign trade intelligence center. After gathering the initial information, we realized that professionals with sufficient industry experience should handle this issue. We overlooked how difficult it would be to choose a location for a foreign trade intelligence center, and the literature lacks any useful decision-making tools to assist decision-makers.

By integrating MCDM approaches and a mathematical programming model, the current research suggests a reliable and practical decision-making model. This model has numerous critical managerial applications as well as theoretical contributions. The benefits of the MCDM and the mathematical programming model are integrated to develop a new decision-making model first. While the traditional Delphi procedure is a practical, inclusive, systematic, and structured method for addressing complicated topics by lessening the influence of respondents' social pressures, it has the drawback of missing crucial information because of time-consuming exploration. Spherical fuzzy sets may capture and analyse more complex ambiguities than traditional crisp or fuzzy sets. They have been implemented to improve the traditional Delphi approach to deal with more complex uncertainties. We have expanded the conventional Delphi technique by using spherical fuzzy numbers to reflect the decision-makers' linguistic judgments of the alternatives. By integrating the benefits of the MCDM and optimisation, the proposed model reinforced the Spherical fuzzy sets, which answer expert linguistic assessments. The mathematical model will provide the decision-makers with the optimal location to open a new facility based on the decision-makers' evaluation and weights of criteria acquired by Spherical numbers.

It can provide decision-makers and policymakers with a valuable and

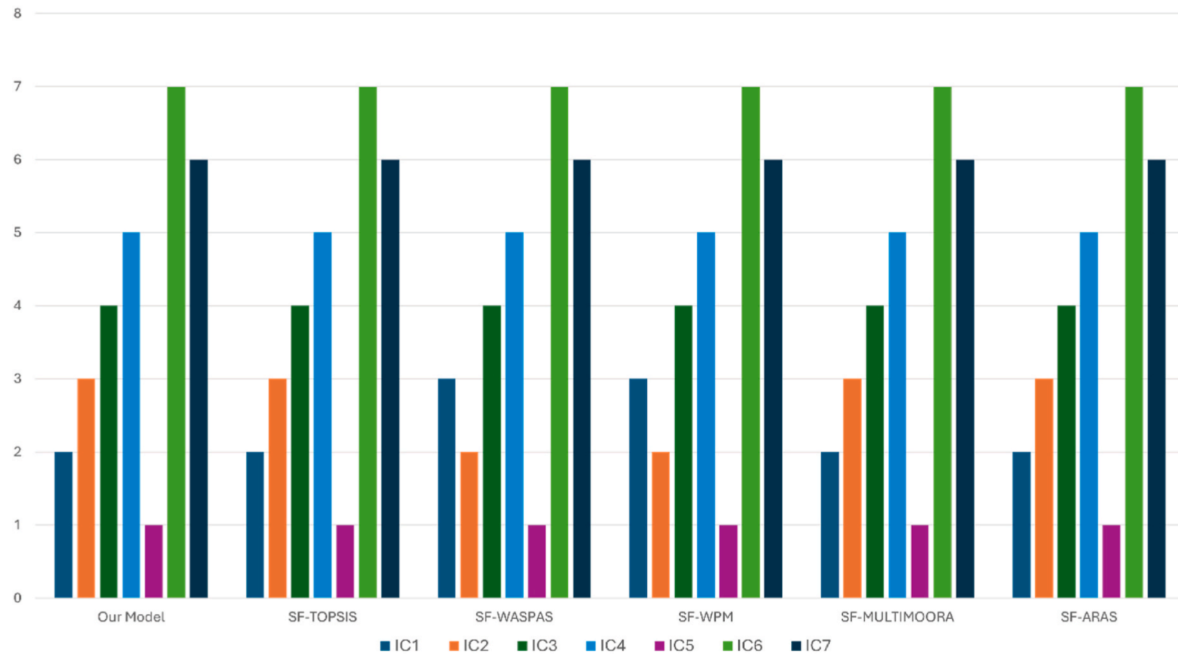

Fig. 5. Result of comparative analysis.

Table 10
Correlation coefficient between the implemented SF-based models.

		SPHERICAL FUZZY					
SPHERICAL FUZZY		TOPSIS	WASPAS	WPM	MULTIMOORA	ARAS	Our Model
	TOPSIS	1.000	0.964	0.964	1.000	1.000	1.000
	WASPAS	0.964	1.000	1.000	0.964	0.964	1.000
	WPM	0.964	1.000	1.000	0.964	0.964	1.000
	MULTIMOORA	1.000	0.964	0.964	1.000	1.000	1.000
	ARAS	1.000	0.964	0.964	1.000	1.000	1.000
	Our Model	1.000	1.000	1.000	1.000	1.000	1.000

effective decision-making tool for choosing suitable locations to produce more reliable, efficient, and applicable results. No widely accepted criteria are adequately reliable and appropriate for selecting a foreign trade intelligence center location. There are no established or widely accepted selection criteria in the academic community and international trade. It is more challenging for practitioners to evaluate since so many competing criteria and options in real-life circumstances influence the evaluation process. Additionally, because global trade intelligence centres are still in their early stages, decision-makers lack expertise and knowledge of this technology and its widespread application in other industries. Consequently, establishing the appropriate and fitting criteria can aid in effectively structuring the decision-making challenges. This paper can help motivate professionals from various industries to choose a site for the foreign trade intelligence center.

The major conclusions of the paper state that incentives are the most critical criterion because they deal with maintaining domestic products' competitiveness in the international market. Incentives are intended to promote companies without enough knowledge about their global trade activities, offer strategic resources, and facilitate the distribution of supplies and raw materials. According to the weight given to incentives, attractive incentives, like tax breaks or subsidies, are the most well-known strategies for promoting investments. These are essential for drawing international trade intelligence centres, especially export-led growth countries like Turkey. export promotion, attracting foreign direct investment, and economic growth can all be enhanced by incentives. Incentives can also motivate companies to expand, which is essential for maintaining their competitiveness on a worldwide scale. This finding is consistent with the body of research on location selection, which emphasizes the significance of incentives and support from the government.

One of the most essential considerations in selecting a location is another crucial indicator of commercial vitality. Making investment decisions and identifying the regional growth pattern can be aided by predicting commercial vitality. A wide range of business applications depends critically on precise location data. Strong commercial vitality increases a company's chances of long-term success, which makes it a more desirable investment opportunity. That suggests that locations for foreign trade intelligence centres are more likely to be found in cities with a robust and active economic environment.

Export perception demonstrates the importance of considering a region's reputation and view of its export potential. Perceived competitive advantages and export commitment directly impact export performance. Thus, success between companies in international trade may be considered a facilitator of export performance.

That implies that locations with a good reputation and a perceived potential to export are more likely to be picked for the construction of international trade intelligence centres.

Mersin has been chosen as the ideal location for the foreign trade intelligence center because it offers favourable conditions and satisfies the essential requirements for successful operations. More so than its rivals, this city meets many requirements for developing international trade intelligence centres. Mersin obtained a higher score for most of the very influential criteria. This knowledge can be used by managers and decision-makers to strategically plan and allocate funds for opening and running the Mersin Center.

To further enhance Mersin's attractiveness and ensure the effective operation of foreign trade intelligence centres, policymakers and managers should implement targeted incentive schemes. These may include tax reductions for businesses operating in Mersin, streamlined administrative procedures to expedite foreign investment approvals, and infrastructure improvements such as upgraded logistics hubs and digital trade platforms. Additionally, fostering collaboration between government institutions and private stakeholders can create a more dynamic trade environment, while establishing specialized support units for exporters can facilitate smoother market entry and expansion. Implementing these strategies will reinforce Mersin's commercial vitality and position it as a competitive hub for international trade intelligence activities.

The outcomes emphasize the importance of an effective commercial environment when selecting a location. Managers should, therefore, concentrate on increasing Mersin's commercial vitality by encouraging business growth, enabling trade operations, and encouraging corporate collaboration to draw in foreign trade intelligence and boost competitiveness. In addition, due to Mersin's favourable conditions, such as labour characteristics and geographical conditions, the results of the study are supported by the results in the literature (Yazdani et al., 2020a; Kutlu Gündoğdu, 2020).

Given the importance of incentives in decision-making, policymakers and local authorities should consider providing attractive incentives and support measures to stimulate the construction of international trade intelligence centres in Mersin. Tax breaks, faster administrative processes, and specialized help might all be used to entice industry and foster economic development. The results highlight the significance of favourable export perception in luring foreign trade intelligence facilities. Through targeted marketing initiatives, participation in trade events, and forging close bonds with foreign trading partners, managers and stakeholders in Mersin can seek to improve the city's brand and perception as a booming export hub. Decision-makers may select wisely and take the right actions to maximize the advantages of putting the foreign trade intelligence center in Mersin by considering these theoretical and managerial implications.

In addition, the city of Mersin received a high evaluation score in terms of criteria such as commercial vitality, incentives, competitiveness of companies, and export perception in the literature (Kumar and Anbanandam, 2019; Şahin, 2020). For this reason, prioritizing the City of Mersin primarily in selecting foreign trade intelligence center locations will positively affect its export potential.

7. Conclusions

This study evaluates the degrees of preference of foreign trade intelligence centres regarding the location selection of countries to increase their export potential. Where foreign trade intelligence centres should be located is an unanswered research question because a specific research community has not yet participated in this area. As a result, it has been realized that there is a critical research gap in the literature. This study proposes a highly functional and practical decision-making method. The results have proven to be a very applicable, powerful, and robust technique. This paper proposes a new integration of linguistic evaluations of experts with the help of Spherical fuzzy numbers and mathematical models. This integration method overcomes many disadvantages of current MCDM techniques implemented in the literature.

This study's criteria are obtained through a detailed literature review, field research, and Spherical fuzzy Delphi results. The decision-makers using the spherical fuzzy Delphi method first evaluate the obtained results and are pre-selected for the application. Then, the criteria weights are calculated with spherical fuzzy numbers for the final criteria. After calculating the criteria weights, it is determined by the Weighted Sum Scalarization Method, in which cities in Turkey's foreign trade centres would be set up with a mathematical model.

The location of the projected foreign trade intelligence center in Turkey is the study's main research topic. A four-stage approach has been implemented to find a solution. The province of Mersin has been determined to be the most appropriate location because of the application. Based on this result, establishing a foreign trade intelligence center in Mersin is the most advantageous scenario. Because of its location and the possibility of job growth, the Mersin region is most likely to be chosen among the options.

The application of the study is carried out in Turkey, which has borders in Europe and Asia. It is in the status of developing countries whose export potential is increasing daily. With its application part, this study is one of the first studies in the literature that combines fuzzy MCDM and mathematical models. In addition, it is an essential resource for developing countries in terms of increasing export potential.

The study's main objective will be to introduce foreign trade intelligence centres, which are growing more significantly in the export industry, for the first time in the literature. Consequently, a topic of sectoral importance would be included in the literature and emerge as a fundamental source in this area.

The Foreign Trade Intelligence Centre has launched threats regarding utilising the research findings on location selection. Some of these threats are that businesspeople and bureaucracy do not sufficiently understand the economic importance of the export concept in the country where the foreign trade centre will be established. In addition, economic inadequacies, infrastructure problems, and instability in the country where the application will be carried out constitute significant obstacles to establishing a foreign trade intelligence centre.

Different fuzzy set methods can be implemented in future foreign trade intelligence centre location selection studies. In addition, this study creates an infrastructure for all applications related to export potential and foreign trade intelligence centre keywords. For this reason, it is anticipated that the application part and the methods used in the article will be an indispensable resource for researchers. In addition, in future studies, the multi-objective optimisation solution techniques implemented as a solution method in this study can be differentiated, developed, and employed as a solution method. In addition, in future studies, based on this study, innovative solutions can be offered to enable commercial intelligence centres to function functionally by integrating different multi-objective optimisation solution techniques and MCDM techniques.

The study has relatively few restrictions. The application has been subjected to an area classified as a developing country to influence and boost the export potential. Consequently, the study must be revised for implementation for applications in nations classified as developed. However, this circumstance is not seen as a significant constraint because the issue of export growth is not encountered frequently in industrialized nations.

The theoretical and policy implications of the study are important for understanding its application areas. This study makes a novel contribution by integrating multi-criteria decision-making (MCDM) methods with spherical fuzzy logic to address the location selection problem for foreign trade intelligence centres. Unlike previous studies focusing on industrial facility selection or logistics centres, our research explicitly evaluates trade intelligence hubs, which remain underexplored in the literature. Additionally, our approach provides a structured methodology that policymakers and practitioners can readily apply without requiring advanced mathematical expertise. It is challenging to immediately extrapolate the study's findings to industrialized nations because it was conducted in a developing nation. The methodology has been enhanced for emerging nations since their demand for export growth is more noticeable there. The model must be updated further to be implemented in industrialized nations because their trade policy and economic dynamics differ. However, the study's flaws are less significant in this context because the issue of export growth is less prevalent in industrialized nations.

The spherical fuzzy logic technique is beneficial for handling uncertainty in developing nations. Previous studies on facility location selection, such as Yang and Lee (Kumar and Anbanandam, 2019) and

Kumar and Anbanandam (Chakraborty and Zavadskas, 2014), primarily employed classical fuzzy and intuitionistic fuzzy approaches. However, our research extends these models by leveraging spherical fuzzy logic, which enhances decision-making under high uncertainty. Additionally, unlike the work of Sennaroğlu and Çelebi (Lee and Ter Chang, 2018) on military facility location selection, our study applies a trade-specific framework, ensuring that economic and commercial factors are adequately considered. These comparisons highlight the robustness and applicability of our proposed method. The research aids in the composition of plans to place foreign trade intelligence facilities in emerging nations. Increasing the efficiency of trade intelligence centres in developing nations should be a policy priority. Policymakers should consider implementing targeted tax incentives, streamlined administrative procedures, and investment grants to attract foreign trade intelligence centres.

Additionally, fostering public-private partnerships can enhance operational efficiency and sustainability. By aligning these policy measures with technological advancements, such as AI-driven trade analytics, decision-makers can ensure that trade intelligence centres remain competitive and effective. The model must be changed again to implement policy changes in industrialized countries. The distinct demands of industrialized and developing nations should be considered while creating global export growth plans.

CRediT authorship contribution statement

Ömer Faruk Görçün: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Formal analysis. **Sinan Çizmecioğlu:** Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Esra Boz:** Writing – original draft, Validation, Methodology, Investigation. **Ahmet Çalık:** Writing – original draft, Validation, Project administration, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The research presented in this study, “Optimizing Location Selection for Foreign Trade Intelligence Centres Using Spherical Fuzzy Methods,” was conducted solely for academic and scientific purposes. The authors confirm that there are no conflicts of interest regarding financial support, institutional involvement, or personal affiliations that might be perceived as influencing the results or interpretation of the findings.

All authors have contributed equally to this manuscript’s conception, design, analysis, and writing, and they collectively take responsibility for its content and integrity.

Data availability

Data will be made available on request.

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