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Developing an uncertainty-proof **E**xpert **D**ecision **S**upport **S**ystem for making **R**eal **E**state **L**ocation **D**ecision in FREM organizations, a case of **I**nvestor-**D**eveloper-**U**ser organization.

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SUMMARY

This study tackles the problem of locations analysis and decision making in FREM organizations using a technological tool named expert decision support system (EDSS) that **enhances** the procedure of real estate **location analysis and decision making** in an **objective** form.

On the one hand, **deciding on the location** of the real estate is one of the most **critical** issues in **FREM organizations** and has a significant impact on the performance of the core business under which the FREM organizations operates. On the other hand, utilizing the **technological tools** for decision making and analysis is turning into a **top trend** in many businesses, supporting the organization's activities for more efficiency and effectiveness. Consequently, employing such systems seems to be **essential** to support the procedure of real estate location decision making in FREM organizations for keeping the business **prosperous** and **flourishing**. Nevertheless, the application of such modern tech-tools in the realm of FREM has been very limited so far.

This study proposes an expert decision support system (EDSS) for performing location analysis and **making real estate location decisions** in FREM organizations, which is particularly useful for making **strategic decisions** in **portfolio management**, **investment appraisal**, **development project** evaluations, and deciding on **usage possibilities**. This EDSS is designed to handle the uncertainties that affect the effectiveness and accuracy of the decisions in decision-making environments using **fuzzy logic** and **uncertainty theory** as two of the most useful tools for this purpose.

This system is designed and developed based on the objectives, aspirations, and insights of the organization's strategic decision makers, in a typical **case of an investor-developer-user organization**, that is initiating an expansion project of investing in several real estates to develop new properties and expand its market coverage. The EDSS takes the **information** provided by the **experts** in **the field** (through **qualitative** and **quantitative data collecting** from them) as the inputs and operates as an objective decision-making tool based on logical, and mathematical programming. It performs an unbiased analysis based on the input data and the outlined objectives by the organization's decision-makers and delivers the best possible solutions to the organization.

The locations of the mentioned real estates must possess specific attributes that form the company's **decision criteria**. The potential locations need to score sufficiently in all decision criteria before they can be considered for selection. The company has already determined **fifty-nine** locations with **minimum required scores** in each decision criterion. However, not all locations are selectable since the project **budget is limited**. Therefore, the company aims to make a smart selection of the locations within its budget with the best achievable score in each and every decision criterion **simultaneously**.

The most difficult part of dealing with this problem is the multi-objectivity of the problem which means the solution must satisfy five different aspects of the problem that might be even contradictory to one another. Making such decisions is at the stake of compromising between the objectives which might be highly inaccurate and subjective in traditional ways. Therefore, having an objective expert system that works based on the inputs of several resources may help to improve the quality of the decisions significantly.

The proposed EDSS utilized the input data from the expert, executed a combination of several modeling and problem-solving approaches, determined a suitable compromise level between the objectives, and delivered a set comprised of **11 locations** of which attributes **comply with the outlined desires of the company as the final solution**.

FOREWORD

Having a background in industrial engineering and process optimization, I have always been wanting to carry out intraciliary research topics on the existing real-life problems and find them creative, modern solutions. However, over the time I noticed that finding comprehensive solutions requires a certain level of competency in business, management, and dealing with people which I lacked. This shortcoming motivated me to study facility and real estate management which was a discipline that could provide me the combination for which I was looking.

The master thesis in this program not only provided me the opportunity to work on a project on which I always wanted to work, but also was an exciting experience of dealing with a real-life problem using a combination of several bodies of knowledge.

However, conducting this research would not be possible if it wasn't for the support of the master facility and real estate management program directors who granted me enough flexibilities to work on my proposed unconventional research topic.

Particularly, I would like to thank my dear tutor, **Mrs. Adrienn Eros**, who is one of the kindest people that I have known, for her friendly and sincere support during this challenging path, always making time for me, and continuously orienting my path keeping me in line with the principles of the FREM program. This study would not be as it is without her comments, insights, and, corrective advice.

I would also like to thank dear **Mr. Jan van den Hogen**, with whom I started the program. He not only provided me with very invaluable insights on my topic but also spent lots of his personal time answering my related and unrelated questions to the program.

Moreover, I would like to thank dear **Mrs. Hester van Sprang** not only for her helps and supports and help during the program, but also for her friendly and genuine personality, cheerful attitude, and motivating style. She unquestionably is one of the reasons why I enjoyed this education.

Last but not the least, I would like to thank dear **Mr. Joris Verwijmeren** for his valuable bits of advice that benefited me a lot in initiating my thesis topic.

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Declaration: This research and thesis is entirely my own work. Where other sources have used, they are referenced and acknowledged.

16 August 2018

Sam M. Pour

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CHAPTER 1

INTRODUCTION

Among all managerial decisions, choosing the location of the organization's real estates is of most importance due to its both tangible and intangible influence on the core business. In other words, location decisions have a significant strategic impact on the organizations' achieving their objectives. This importance explains the enormous attention paid to solve the real estate location selection problems in the past two decades in both academic and business environments (Chou, Hsu, & Chen, 2008; Heragu, 2008). It concludes that the location of an establishment must well serve the objectives and purposes of the organization and provide added value to stakeholders (Droj & Droj, 2015; Lindholm, Gibler, & Levainen, 2006).

Interestingly, the location decisions are not solely about the real estate department and selection of a potential prospect for further investment, development, or private use. This issue can, in fact, be viewed from macro levels such as spotting the best location for having the next Amazon warehouse constructed (which is in global scale and similar to this study), and micro levels that can be down to dealing with facility services' layout problems in the organizations (Atkin & Brooks, 2014; "Beyond Commercial Real Estate: Megatrends to Watch | CBRE," n.d.; Owen & Daskin, 1998).

On the other hand, the current trend of the facility management (FM) services within organizations is towards a more integrated approach with the corporate real estate management (CREM) activities. This development has resulted in the emergence of an integrated unit in the most organizations referred to as FREM (facility and real estate management) in which dealing with the location decisions is an integral task (Barrett & Baldry, 2009; Hoendervanger, Bergsma, van der Voordt, & Jensen, 2016; Laning, 2016; O'mara, 1999; Pfnur, 2011). In other words, location analysis as a chief concern of the originations is a vital FREM task in modern organizations not only because good locations are considered as the investment magnet by the investors and developers but also, because they are highly attractive and influential for the users of a facility (Dorian, 2014; Lannon, 2016). Figure 1, shows the variation of the location analysis problems in different disciplines of FREM organizations.

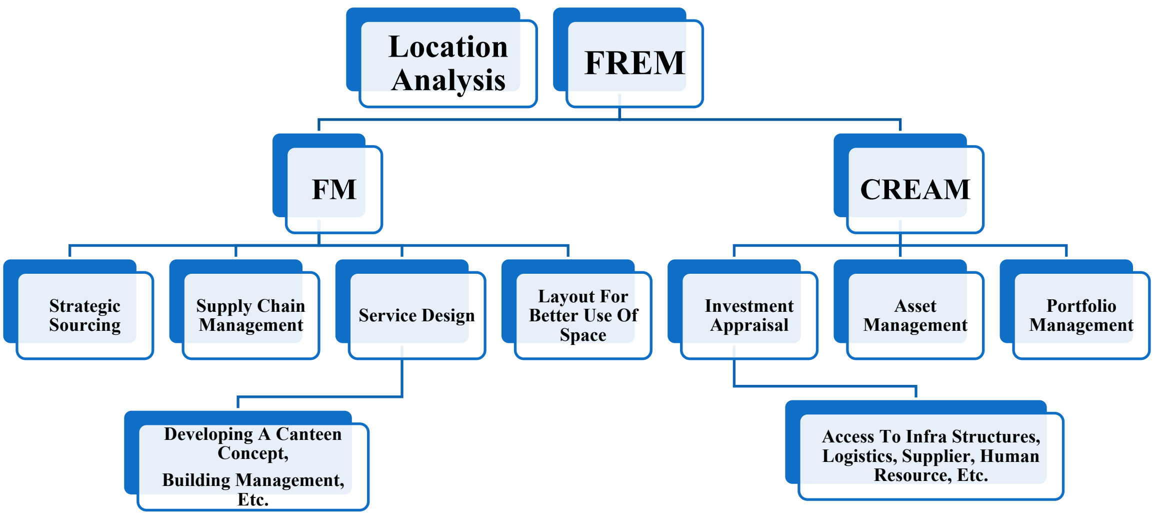

FIGURE 1. APPLICATION OF LOCATION ANALYSIS IN FM AND CREAM, MICRO AND MACRO LEVEL (AUTHOR, 2018)

As shown by figure 1, location analysis in macro level is more of a real estate activity whereas in micro level it is more of a facility management activity.

Correspondingly, the location decision must be made respecting different decision criteria proportional to requisites of the authorities and the strategic prospect of the organization. It is important to note that the relevant trends and developments in the business environment may significantly polarize the stated expectations and decision criteria. For instance, the rapid change in shopping behaviors makes location selection the biggest challenge for investors which is why they intend to determine a guaranteed approach to locate investment opportunities and evaluate the property values (Laning, 2016). Furthermore, the characteristics of the business impose specific conditions on the location of a business. For instance, the logistics and transportation state are the most important decision criteria for the locations of distribution centers: locations with better access to high-quality infrastructure serve the business' core objectives more adequately. Similarly, in case of choosing the location of a business' headquarter, the locations and the internal layout and designs are vital for brand's visibility acting as a flagship to showcase goods and to offer a pleasurable experience to customers (Chou et al., 2008; Laning, 2016; Yang & Lee, 1997).

Ergo, it is no wonder that making proper real estate location decisions (RELDs) is among the main concerns in various public and private sectors at both national and international level (Farahani, SteadieSeifi, & Asgari, 2010). They may lead to increase the organization's market share, productivity, cost reduction, delivering performance, improved brand reputation, etc. It also enhances the customer satisfaction, sourcing strategies, and market penetration (Ayhan, 2013; Kuo, Chi, & Kao, 2002; Yang & Lee, 1997).

As a consequence, the decision maker must consider multiple criteria such as value for money, risk factors, potential turnover, the extent of possibility to have other uses in future, and similar issues according to the organizations' objectives, business model, and preferences when searching for a location for investment, development, or usage. This matter is a decision-making process in which multiple decision criteria should be considered; by definition, this procedure is solving a "multi-criteria decision-making problem" (MCDM) in the realm of FREM (Abdollahi, Arvan, & Razmi, 2015; Farahani, SteadieSeifi, & Asgari, 2010; Mardani et al., 2015).

As mentioned formerly, the real estate location decisions (particularly in macro levels) either address the problem of locating at least one new real estate among the existing alternatives or, selecting a location for a new real estate from a set of available options. Such problems correspond to multi/single objective optimization problems in the literature by solving which several decision criteria can be satisfied simultaneously (Abdollahi et al., 2015; Chen, Olhager, & Tang, 2014; Ehrgott & Gandibleux, 2000; Golabi, Shavarani, & Izbirak, 2017; Malczewski, 2006; Ozgen & Gulsun, 2014; Szidarovszky, Gershon, & Duckstein, 1986; Wen & Iwamura, 2008).

As an essential part of the FREM functions, providing a satisfying solution to RELD problems depends on a proper and realistic formulation of the problems corresponding to the objectives; expectations, and aspiration of the problem owners, as well as utilizing a suitable problem-solving strategy (Badri, Mortagy, & Alsayed, 1998; Krol, Lasota, Trawinski, & Trawinski, 2008; Mark & Asieh, 2005; Mosallaeipour, Mahmoodirad, Niroomand, & Vizvari, 2017).

Given the diversity of the influencing factors, complying with the mentioned requirements needs a varied set of knowledge and skills in business management, portfolio management, asset management, and property management as well as modeling, optimization, multi-criteria decision-making (MCDM), and problem-solving techniques at the FREM department (Abdollahi et al., 2015; Camacho-Vallejo et al., 2014; Ghadiri Nejad, Guden, Vizvari, Vatankhah Barenji, 2017; Ozgen & Gulsun, 2014; ReVelle & Eiselt, 2005; Ulungu & Teghem, 1994).

On the one hand, finding the required expertise and foundations within an organization and coherently administering them is not easy; on the other hand, the trends and developments in the business environment introduce new prospects regarding such problems.

In this regard, one of the most influential developments that might be a game changer is utilizing the technological tools (tech-tools) and scientific approach for dealing with the problem that used to be handled traditionally and based on the gut feelings in the realm of FREM (Lecamus, 2017; Sittler, 2017). Emerging the tech-tools developed based on the scientific problem-solving approach facilitate the FREM activities to an extent which was not imaginable five years ago. The increasing popularity of employing artificial intelligence and using big data in developing the data centered intelligent software for managing daily activities are some of the most obvious examples of the work fashion in the new world (CBRE, 2017; Finkenzeller, Dechant, & Schafers, 2010; Lecamus, 2017). This trend directly initiates an inclination for attracting the talented professional with multi-disciplinary skills to design, implement, and operate such advanced tools in FREM (CoreNet Global, 2012). Hence, adopting such new developments and benefiting from them can significantly contribute to the FREM departments for **better strategic choices, more integrated approaches, and enhanced operationalization**.

Back to the decision making procedure, one of the best tools for problem-solving in this field are the expert decision support system (EDSS) designed by qualified experts (Droj & Droj, 2015; Kuo et al., 2002; Turban, 1993). The early versions of EDSS found their way to industrial applications nearly three decades ago; ever since these systems have been evolving for more capability and complexity and utilized in various disciplines and fields of work (Power, 2007). Nevertheless, the application of tech-tools (particularly expert decision support systems) in FREM industries is very young and has been very limited so far.

The expert decision support systems can significantly enhance the decision-making procedures and save a massive amount of time, energy and effort within FREM organizations. An accurate determination of the decision criteria and key stakeholder' objectives; alternative options; constraints, and restrictions as well as proper data collection and interpretations are the essential inputs to design a functional EDSS (Shuai & Wu, 2011).

The fundamental part of any practical decision support system that must be created very carefully is a mathematical model that **represents** the state of the problem including the requested result(s) defined by the key stakeholders and the constraints associated with satisfying the requested objectives. The ultimate task of such models is to provide a platform for solving the problem and getting a proper answer. For this purpose, the models must be approached by a suitable solution method respecting its characteristics (number of objectives in the problem, the state of uncertainty of the decision variable, etc.). The discussed models are referred to as "**Problem-Representative Optimization Models**" (PROM) in the literature. The PROMs are the heart of the decision support systems which means for having a worthwhile answer to the problem, the PROM must represent the problem as accurate and realistic, as possible (Forst, 2016; Varela & Acuna, 2011).

One of the factors that may reduce the accuracy of the decisions is the uncertainty of the decision variables. In other words, the decisions are likely to have a better quality if they are made considering the uncertainty factor. Consequently, the expert decision support systems are much more useful tools when they are uncertainty-proof (considered the uncertain factors in decision making procedure). To best of author's knowledge, there is no evidence of a prior study on the application of the expert uncertainty-proof decision support systems in the world of FREM.

As formerly mentioned, the ambiguity is an integral part of the real-life problems. If a model is about to represent the real state of a problem, it should be capable of reflecting the uncertainty. Such models are implacable in uncertainty proof expert decision support systems (as the PROM) and addressed as **possibilistic models** in the literature (Ghadiri Nejad, Shavarani, Vizvári, & Barenji, 2018; Golabi et al., 2017; Mosallaeipour, 2017; Niroomand, Mosallaeipour, Mahmoodirad, & Vizvari, 2018; Shavarani, Nejad, Rismanchian, & Izbirak, 2017).

Reflecting the uncertainty of the problem in the representative model depends on the type of uncertain variables in the problem. If the uncertain variables follow a probability distribution, the problems' reflective model should be a probabilistic model. Similarly, if a problem variable has a stochastic nature, stochastic modeling is required to reflect the uncertainty (Liu, 2010).

If the uncertainty of the variables in a problem is due to lack of perfect knowledge and the values are stated based on the belief of the subjects (as it is in this research), the uncertainty will be of the possibilistic type which means the values are vague and imprecise (Zadeh, 1965). In such cases, **fuzzy modeling** is most suitable for reflecting the uncertainty of the problem (Zadeh, 1983). However, solving fuzzy models is rather complicated and requires special problem-solving techniques of which possibilistic method is amongst the bests (Dubois & Prade, 2012). Therefore, in this research the fuzzy theory is utilized to reflect the uncertainty of the decision variables in the optimization model and the possibility theory is used to solve the uncertainty-based optimization model. Both of the utilized approaches are highly effective and have a diverse application in the literature (Mosallaeipour, 2017).

The present study is an empirical research on developing a high-quality expert decision support system (capable of dealing with uncertainties of the problem parameters) to deal with a multi-criteria decision-making problem for selecting the real estate locations for a case of investor-developer-user organization in an expansion project (please recall that solving the model is identical to solving the problem).

Solving the mentioned problem required using several bodies of knowledge and awareness of the trends and developments in the world of FREM. For this purpose, the decision criteria; objectives of the problem owners; the weight of each objective; alternatives, and constraints determined properly, the role of uncertainty incorporated in the PROM, and proper solution approach utilized to solve the model. The outcome of the EDSS is a set of suitable real estate locations for establishing the company's new facilities which are approved by the company's decision maker (please see chapter figure 8 as well as chapter 4.3 for more details about operationalization and chapter 4.4 about the studied case).

Note: *an expert decision support system which is used to solve real estate location decision fall in the category of tech tools for property management which is known as Prop-Tech in the literature* (Assetti, 2018; Lecamus, 2017; Vaden Hogen, 2018).

KEY ABBREVIATIONS:

1. Facility Management (**FM**),
2. Corporate Real Estate Management (**CREAM**),
3. Facility and Real Estate Management (**FREM**),
4. Multi-Criteria Decision Making (**MCDM**),
5. Real Estate Location Decision (**RELD**),
6. Technological Tool (**Tech-Tools**),
7. Technological Property Tool (**Prop-Tech**),
8. Expert Decision Support System (**EDSS**),
9. Problem Representative Optimization Model (**PROM**).

KEY RESEARCH WORDS: Facility and Real Estate Management (FREM), Strategic Decision Making, Location Analysis, Technological Decision-Making Tools, Expert Decision Support systems, Real Estate Location Decisions, Real Estate Strategy, Investment Appraisal, Asset Management, Real Estate Projects, Investment Efficiency.

CHAPTER 2

LITERATURE REVIEW

As previously discussed, the FREM department is responsible for solving various multi-criteria decision-making problems regarding the facility services and real estate issues in the modern organizations as the nature of the work involves considering several factors for making a single decision. It is acknowledged that all kind of the FREM's decisions and actions must comply with the expectations and requirements of the core business (Ing et al., 2005; Lindholm & Levainen, 2006; Pfnur, 2011).

On the other hand, technological development and application of the Tech-Tools in different layers and sections of the organizations can provide more synchronization between the core business objectives and the other departments, enhancing their function for more integration, efficiency, and effectiveness. Knowing the nature of FREM activities and problems in addition to awareness of the possible enhancements made available by technology in the modern world justifies using the decision support systems to support the multi-criteria decision-making procedure in the FREM organizations.

Building on the mentioned facts, the main objective of this study was to find the best location for a company to invest in new properties using a tech-tool known as expert decision support system. This approach implied dealing with a multi-criteria decision-making procedure in a macro level location analysis problem (discussed in the previous chapter) whose solution was a list of the suitable locations.

This chapter provides a brief background information about the required bodies of knowledge for solving the problem in this study.

2.1 REAL ESTATE LOCATION ANALYSIS AND DECISION MAKING

The science of location analysis is historically dated back to almost one-hundred years ago when different people independently proposed a basic Euclidean spatial median method to deal with the problem of selecting an appropriate location (Drezner & Hamacher, 2002). However, almost all scientists acknowledge that the book by Weber (1929) is the initiation point in location sciences (Hansen, Labbe, & Nicolas, 1991). In the modern time, deciding on the location of the real estate has enormous application in many different fields (municipal facilities, private facilities, military environment, and business areas) within both national and international spans (Farahani et al., 2010; Hage et al., n.d.; Heragu, 2008). The problem basically refers to selection of one, or a greater number of locations (a set of locations) from a larger set of candidate locations for a specific purpose (see figure 2).

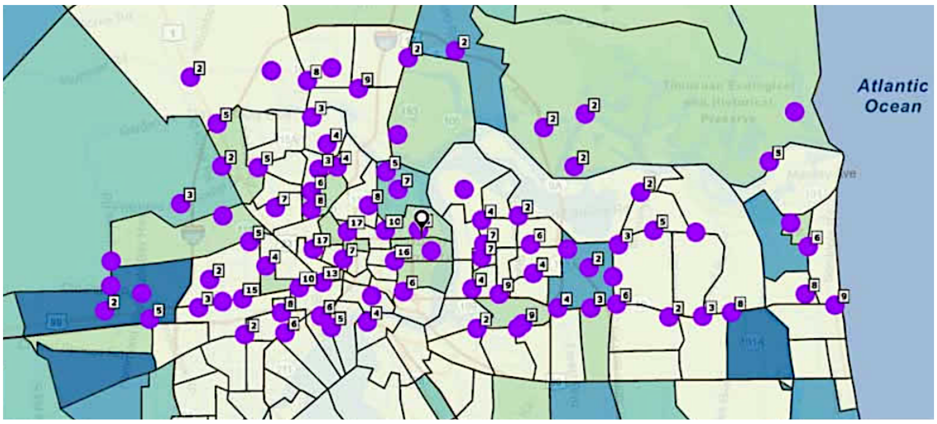

FIGURE 2. A HYPOTHETICAL SET OF CANDIDATE LOCATIONS

Figure 2 represents a hypothetical set of candidate locations among which, one or more locations might be attractive for the decision maker to invest in, develop, or use as private property.

2.2 THE REALM OF DECISION MAKING

Decision making is an indispensable part of the modern life as a procedure that is involved with analyzing different circumstances and making appropriate decisions. In fact, the capability to analyze a phenomenon, predict the possible outcome, and decide based on the evaluations are the qualities that separate human from other beings.

In reality, even for a simple decision, the decision makers (**DMs**) need to take more than one factor, objective, criteria, or measure into account before deciding. Consequently, the procedure of decision-making transforms into the process of solving a multi-objective problem with several decision criteria. Such problems are addressed as multi-criteria decision making (**MCDM**) problems in the literature. Hence, there is no wonder why **MCDM** problems have a diverse appearance in various principles including but not limited to real estate management, engineering, economics, logistics, and various management disciplines in which decisions should be elaborated considering a certain amount of trade-off between the commonly conflicting desires (Farahani et al., 2010; Ginevicius & Zubrecovas, 2009; Lee, 2014).

2.2.1 MULTI-ATTRIBUTE AND MULTI-OBJECTIVE DECISION MAKING

Multi-criteria decision-making (**MCDM**) is, in fact, a combination of two different approaches: multi-attribute decision making (**MADM**) and multi-objective decision making (MODM) as follows:

MADM - This approach is in fact a ranking method that is more applicable in the cases where a few alternative solutions and a set of decision criteria are available. The challenge is to select the solutions that satisfy the decision criteria to a larger extent. In other words, the superior solution has better attributes and gets a higher ranking among the other competitors.

An obvious example of such kind of decision-making problems occurs in tendering procedures, supplier selection, or outsourcing problems. In all of the mentioned activities, the decision maker has a few characteristics in mind (**lower costs, better quality, better value for money proposition, having a circular business setting, etc**.) and seeks an alternative that satisfies his desires about the decision criteria best. For instance, a supplier who is able to provide the requisites with lower price and faster than the others may win a tendering. Similarly, a supplier whose offer delivers the best value for money might beat the other players in a selection competition.

Multi attribute decision making is extremely simple for small problems but can become really sophisticate for large problems with several decision criteria (Mullins, 2017). TOPSIS and **AHP** are two of the most famous methods for solving multi attribute decision making problems (Tsaur, Chang, & Yen, 2002; Yang & Lee, 1997; Yoon & Hwang, 1995).

MODM - Multi-objective decision making (MODM) is more applicable in the cases when by deciding, the decision maker intents to achieve several objectives (most often contradictory) in several criteria of interest. This technique also applies when the DM aims to select a set of solutions instead of a single solution.

For instance, suppose a company such as Amazon decides to minimize the amount of total expenditure on warehouse while maximizing the coverage of its services. It means, the problem's decision criteria are cost and coverage and the objectives are minimization and maximization respectively. Obviously, the requirements for satisfying each objective in its respected criterion are different; maximizing the coverage is likely to need more locations to be opened whereas reducing the cost implies the need to reduce the number of open locations. Ergo, the objectives are contradictory in this problem which means solving the problem requires a trade-off between the degree of achievement in the objectives. A possible satisfactory solution to the problem might be choosing a smaller set of locations with sufficient access to delivery roads and logistics infrastructure, in places with lower prices. In such cases, every candidate would be evaluated based on its total cost for the company and possessing a satisfactory level of coverage potential.

In comparison with the previous technique, MODM is more complicated and needs more mathematical modeling and problem-solving skills even for small problems. There are enormous modeling and problem-solving techniques proposed for solving multi-objective decision-making problems in the literature such as Goal Programming (GP) and Global Criterion (GC) methods (Badri et al., 1998; Niroomand, Mosallaeipour, Mahmoodirad, & Vizvari, 2018). Nevertheless, choosing a proper method highly depends on the complexity level of the problem, number of objectives to be satisfied, number of decision criteria, and the uncertainty state of the problems decision variables(Zionts, 1979; Szidarovszky, Gershon, & Duckstein, 1986; Ulungu & Teghem, 1994; Hwang & Masud, 2012).

It is noteworthy that there is hardly an example of a pure multi-attribute or multi-objective decision-making problem in real problems. Instead, most common are the cases where the decision maker has several objectives, over several decision criteria, and a finite number of alternatives aiming to find a satisfactory solution using a combination of both methods. In this regard, the common practice is to solve the practical MCDM problems is to utilize an MADM technique to determine the worthiness or value of the available options or decision criteria followed by a MODM technique select a set of solution based on best achievable performance respecting the available resources and the objective of the decision maker. In this study, the procedure of dealing with the MCDM problem is quite similar to what mentioned.

Note 1 - In this study, the decision criteria are defined by the company's key stakeholders at the strategic level of the core business and instructed to the FREM department that is responsible for determining the best locations for investment, development, and preparation for usage. The alternative solutions are the available set of locations from which the company's FREM department selects the sites that have a better condition in satisfying the decision criteria and objective functions of the company. The combination of multi-attribute and multi-objective decision-making techniques, applied in this study are as follows:

- Multi-Attribute: This technique was utilized to determine the weight of the decision criteria and their corresponding objectives based on their degree of importance for the decision maker, using AHP method (one of the most popular, widely applied techniques for this purpose in the literature).
- Multi-Objective: This technique was utilized in the whole process of mathematical modeling and problem-solving steps. The proposed multi-objective mathematical model was created using a combination of fuzzy theory and possibilistic theory and solved by Global Criterion (GC) method.

Note 2 - The reason for using such combination is that all mentioned methods are the most applicable, widely utilized approaches in literature and work perfectly fine with one another (see Appendix 4, 5, and 6).

2.2.2 IMPORTANT DECISION CRITERIA IN MULTI-CRITERIA LOCATION ANALYSIS PROBLEMS

Usually, the decision criteria in real estate location analysis problems are the characteristics of locations that make them either desirable or undesirable. Clearly, the overall locations' added values to the organization differ based on the interest and requirement of the problem owners and decision makers. In other words, the problem owners and decision makers define the objectives, attainable by selecting the proper real estate locations as well as the decision criteria and their degree of importance (Moghadas, Monabbati, & Kakhki, 2013; Owen & Daskin, 1998; Yang & Lee, 1997).

The addressed criteria in the literature of location decision problems are various and diverse. In this regard, Farahani et al. (2010) provided one of the most comprehensive databases about the decision criteria in MCDM problems. Based on their research, as well as the studies by Denicol, Cassel, and Pryke (2016); Deloitte (2015), and Rymarzak and Sieminska (2012), the most common criteria in multi-criteria location analysis and decision making problems classified into seven categories that are depicted in figure 3, followed by a brief explanation.

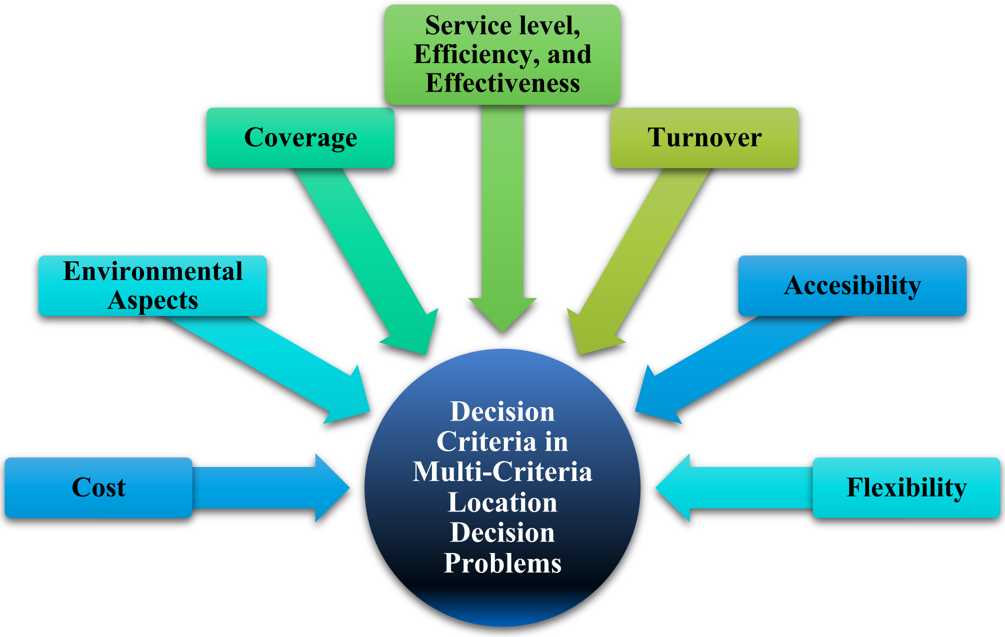

FIGURE 3. MOST POPULAR DECISION CRITERIA IN MULTI CRITERIA LOCATION DECISION PROBLEMS (Deloitte, 2015; Farahani et al., 2010)

1. **COST:** The costs are either fixed or variable. Installation, constructions and investment cost, are the most common types of fixed cost whereas the variables costs are mainly related to transportation, production, operations, services, distribution, logistics, waste disposal, maintenance, tax environment, and environmental concerns. Depending on the problem description, one or more than one type of the costs might be a decision criterion.
2. **ENVIRONMENTAL ASPECTS:** These criteria include transportation concerns, exposure degree to natural hazard, waste disposal or treatment infrastructures, sustainability requirements, etc.
3. **COVERAGE:** In many problems, distance, time, and population coverage are among the most important decision criteria. The idea is to have minimum traveling distance, in minimum time, with maximum demand satisfaction capability (i.e., capacity).
4. **SERVICE LEVEL, EFFICIENCY, AND EFFECTIVENESS:** This criterion corresponds to impact of the location on quality of service, delivery, process efficiency, and effectiveness.
5. **TURNOVER:** Decision makers are typically interested in the matters such as net profit, the difference between benefits and costs, and similar investment related issues. Such concerns, as well as intellectual values, are normally classified under the turnover category.
6. **ACCESSIBILITY:** This category is often concerned with having access to skilled labor, talents, transportation infrastructure, and availability of suitable options (including real estate, suppliers, distribution means, market, etc.)
7. **FLEXIBILITY:** The possibility for change after the investment, legalization, and Statutory and discretionary incentives that are fungible, executable, and valuable.

The decision criteria for location selection in this study are the location's futuristic (aka. advantage) score, tax disadvantage, distribution score, establishment cost, and potential income (More elaboration is provided in chapter 3).

Note 3: An objective is defined by the decision maker corresponding to each decision criteria in location selection problems. These objectives indicate targets for each decision criteria that satisfies the decision maker.

Note 4: In all kind of multi-criteria decision-making problems, satisfying all objectives simultaneously at the maximum level is not possible. For instance, in the decision of buying a laptop, it is not possible to purchase an item with all features, from a luxury brand, with the minimum cost. Similarly having the best quality of highly customized facility service with the cheapest value in the market is not imaginable. The same is true in location selection problems when the direction of the objective functions are opposite (cost minimization and coverage maximization at the same time). In reality, each solution might be good enough to satisfy the objectives of the decision maker to some extent. The solution that satisfies more objectives to a higher degree is more preferred (Deb, Pratap, Agarwal, & Meyarivan, 2002; Fonseca & Fleming, 1993; Neufeld, Gupta, & Buscher, 2015; Schaffer, 1985; Ulungu & Teghem, 1994).

2.3 COMMON OBJECTIVES IN REAL ESTATE LOCATION DECISION PROBLEMS

A research by ReVelle and Eiselt (2005) is one of the best references in classifications of objectives in real estate location decision (RELD) problems. Recall that the RELDs are multi criteria decision making problems meaning that in most cases several objectives should be satisfied simultaneously (Chou et al., 2008). It was also mentioned that the weight of decision criteria and objectives might be different. For instance, when the decision criteria in an investment project are "cost", "profit", and "sustainability", and objectives are “being more sustainable”, “having minimum cost”, and “having maximum sale potential” simultaneously, one organization may put the emphasize on cost minimization, and accept smaller profit margin and sustainability level, whereas another organization may aim for highest profit margin, moderate sustainability level, an acceptable amount of costs. Keeping the specified matters in mind, some of the most common objective functions in location decision problems are outlined as follows:

- Minimizing the longest distance from the existing establishments;
- Minimizing the cost (different categories, sometimes combined);
- Maximizing the service level;
- Minimizing average time/ distance traveled;
- Minimizing maximum time/distance traveled;
- Minimizing/maximizing the number of located establishments;
- Maximizing responsiveness.

In general, the type of organizational culture and value-adding model in organizations plays a crucial role in defining the objective functions. For instance, in Angelo-Saxon culture the achievements are heavily measured on a monetary basis, therefore, the objective is formulated to make more wealth. On the contrary, other issues such as the well-being of more diverse category stakeholders, environmental aspects, and similar concerns play a crucial role in defining the project objectives in Nordic culture (Kok, Mobach, & Omta, 2011; Lindholm & Levainen, 2006; Vries, Jonge, & Voordt, 2008; Wauters, 2005). In recent years, due to increasing the environmental awareness, globalization, and emergence of circular thinking in business, new categories of demands related to sustainability, social objectives, energy efficiency, fuel pollution, and customer attractions are added to the location analysis problems (Ghisellini, Cialani, & Ulgiati, 2016).

In this study, there are five objectives defined by the company’s top-level management and instructed to the FREM department. These objectives are discussed in detail in section **5.1.3**.

Please note that although each location may score better in satisfying an objective in a specific criterion individually, the objective is to select a set of selected locations that satisfy all mentioned objective functions better than any other set of locations among the available options.

As mentioned previously, the other critical factor that affects the quality of the decisions in **MCDM** (including **RELD**) problems is the uncertainty associated with the decision variables. This factor is elaborated more in the next section.

2.4 THE IMPACT OF UNCERTAINTY IN DECISION MAKING PROBLEMS

As mentioned formerly, the results of the decisions might be unrealistic and misleading if uncertainty (fuzziness) of the decision variables or input data is not taken into account (Khanjani Shiraz, Tavana, Fukuyama, & Di Caprio, 2015). There are several methods for reflecting the uncertain nature of a problem in the model that represents it. Unfortunately, in most of these methods (such as probabilistic modeling, stochastic modeling, etc.) a huge amount of knowledge about the uncertain variables is required (probability distribution of the events, type of the stochastic processes, etc.). In reality, having such information about the random events is extremely difficult and limited to controlled environments (Dubois, Fargier, & Fortemps, 2003). On the contrary, the fuzzy set theory is capable of dealing with the uncertainty of data even in absence of complete information, which is why this logic has become so popular since its introduction in 1965 (see section **2.6.1**).

In this study, the demand on location and the cost of construction per location are the two uncertain inputs of the problem that are reflected using fuzzy variables in the optimization model (PROM) which was created to represent the multi criteria-decision making problem of the real estate location selection (discussed in chapter one).

2.4.1 FUZZY SETS THEORY

The **fuzzy set theory** was first introduced by Zadeh (1965) to solve the problems involving vagueness and ambiguity. Ever since, this theory has been continuously applied for dealing with uncertainty and vagueness of the decision variables and input data in lots of managerial and decision making problems (Bellman & Zadeh, 1970; Bhattacharya, Rao, & Tiwari, 1993; Darzentas, 1987; Homaifar & McCormick, 1995; Kuo et al., 2002; Mosallaeipour et al., 2017; Ozgen & Gulsun, 2014; Yang, 2008).

This Logic reflects how people think. It attempts to model the sense of words and effects of common sense in decision making. **Fuzzy logic** is based on the idea that every value admits a degree of **belongingness** to a category (membership) which is unlike the **Boolean (crisp)** logic that uses a sharp distinction between the members and non-members of a class. Expressions such as quite likely, possibly, approximately, and etcetera indicates some degree of uncertainty in the value of a parameter (e.g., demand, cost, weight, height, etc.) that can be managed utilizing the fuzzy theory (Ayhan, 2013; Sheng-Hshiung, Gwo-Hshiung, & Kuo-Ching, 1997; Tsaur et al., 2002). The next example provides a better illustration of this concept.

Suppose the value of discussion is tallness, in crisp logic, one is either tall or is not tall (discrete values: 0 or 1) whereas in Fuzzy logic everybody is tall to a certain extent between “Very Short” to “Very Tall” (continues spectrum; from 0 to 1). The following figure (**Figure 4)** depicts the classic example of the tall man in fuzzy sets (Klir & Yuan, 1996).

	Name	Height, cm	Degree of Membership		
			Crisp	*Fuzzy*	
	Chris	208	1	1.00	Very Tall
	Mark	205	1	1.00	
TALL	John	198	1	0.98	
	Tom	181	1	0.82	Tall
	David	179	0	0.78	
	Mike	172	0	0.24	Slightly Tall
	Bob	167	0	0.15	
	Steven	158	0	0.06	Short
SHORT	Bill	155	0	0.01	
	Peter	152	0	0.00	Very Short

FIGURE 4. THE CLASSIC EXAMPLE OF TALL MAN IN FUZZY SETS

As shown in figure 4, in crisp logic, some people are tall and some others are short whereas in fuzzy logic all people are tall (or short) to a certain degree. Those persons whose membership value of being tall is 1 are considered absolute tall people. The opposite holds for people whose membership value of being tall is 0. Everybody else is tall (or short) to some extent. For this example, the fuzzy measure "**height of a person**" can be illustrated as $\tilde{\boldsymbol{h}}$ which is a member of the closed interval of $[\boldsymbol{Very\ Short}$, $\boldsymbol{Very\ Tall}]$.

The fuzzy set can also be used to illustrate the interval of the variation of a real number. For instance, suppose the construction cost of an establishment was estimated to be ***around*** $\mathbf{550}\ \epsilon$ per square meter. In reality, this value might be anything between $\mathbf{450}\ \epsilon$ (minimum possible value in the market) and $\mathbf{800}\ \epsilon$ (maximum possible value in the market). However, any value below $\mathbf{450}\ \epsilon$ and above $\mathbf{800}\ \epsilon$ may not be considered as the construction cost (i.e. not a member of construction cost category). On the other hand, if some prices within this interval are more likely to be given as the construction cost in the market, they will possess more membership value to the construction cost. Suppose the most common prices in the market are $\mathbf{500}\ \epsilon$ and $\mathbf{600}\ \epsilon$ with the membership value equal to 1. In such situation, the construction cost would be represented as $\widetilde{\mathbf{550}}$ which is a fuzzy number whose real value might be any price from the interval $[\mathbf{450}, \mathbf{800}\ ]$.

2.4.2 FUZZY NUMBERS

A fuzzy number is a generalization of a regular real number in the sense that it does not refer to one single value but rather to a connected set of possible values, where each possible value has its own belongingness degree between 0 and 1 which is called membership function (Dijkman, van Haeringen, & de Lange, 1983). In other words, fuzzy numbers are an extension of real numbers which means a fuzzy number defines an ambiguous interval in the set of real numbers.

Definition 1: The Trapezoidal Fuzzy Number can be defined as whose membership functions is show as depicted in figure 5. This numbers are most suitable for the cases when the value of the variable lays between a maximum and minimum in a closed interval in which at least two values have the maximum membership value (similar to the last example in previous section).

$$\mu_A(x) = \begin{cases} 0, & x < a_1 \\ \dfrac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ 1, & a_2 \le x \le a_3 \\ \dfrac{a_4-x}{a_4-a_3}, & a_3 \le x \le a_4 \\ 0, & x > a_4 \end{cases}$$

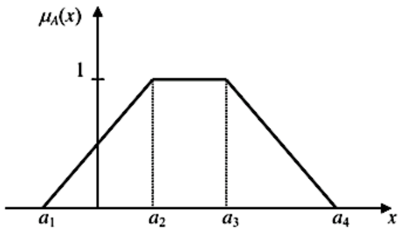

FIGURE 5. TRAPEZOIDAL FUZZY NUMBER AND ITS MEMBERSHIP FUNCTION (Dijkman et al., 1983)

As shown is figure 5, the membership value of and is zero whereas and have the maximum membership value. The belongingness degree of any value less than, between and, between and, and more than can be calculated using the illustrated formula.

Knowing the type of the fuzzy variables and their corresponding membership function is necessary to provide a correct fuzzy measure in problem-solving (**see Appendix 8**). In this study, the nature of the **establishing cost per location** and **demand on locations**, match the description of trapezoidal fuzzy numbers which is why this type of fuzzy number is utilized to represent them.

2.5 UNCERTAINTY IN REAL ESTATE LOCATION DECISION PROBLEMS

Facility and real estate management (**FREM**) is not different from any other management discipline in terms of facing decision making problems (Badri et al., 1998; Geltner, Miller, Clayton, & Eichholtz, 2001). As previously discussed, decision making involves dealing with several decision criteria and uncertain data in most of the cases (Chou et al., 2008). Accordingly, making the strategic choice of location for investment, development, or usage as one of the main tasks of modern organization's FREM department is not exempted from what mentioned.

For most of the investors (as well as developers) spotting the right location is important due to the cost and revenue issues; nobody wants an investment with heavy cost a no payoff (Finkenzeller et al., 2010; Ginevicius & Zubrecovas, 2009). Being aware of the exact amount of investment cost and revenue can significantly facilitate the decision of **DO**, **DO NOT**, or **Do** to a **SPECIFIC EXTENT**; however, the only problem is that no one can be sure about the exact amount of the mentioned parameters (Walker et al., 2003). Such obstacles have always been the driving force for finding solutions to deal with uncertain situations.

As mentioned previously, modeling the problem in a proper mathematical format (PROM), using fuzzy variables to reflect the uncertainty of the problem in the model, and choosing a proper solution approach to resolve the proposed model, are the most common, effective approaches for dealing with multi-criteria decision making, under uncertainty, in real estate location analysis problems.

Note 5: Recall that such systems operate baes on the empirical input data, collected through consulting with the experts who possess enough experience, knowledge, and authority in the respected fields. In fact, the reason why the problem solving involves dealing with uncertainty is the imprecise and vague nature of the mentioned input data. Terminologies such as "about 180" weekly demand, "above 500" customers per day, or "less than 5200" Euro per quarter are some examples of the inexplicit statements that taints the data accuracy in this regard.

Using fuzzy logic, such ambiguities can be depicted by fuzzy variables in the mathematical model of the problem effectively (Dubois et al., 2003; Khanjani Shiraz et al., 2015; Liu, 2016). The last step in the procedure for getting an appropriate answer to the problem is solving the proposed mathematical model which is multi-objective and fuzzy. In other words, in order to find out what the right choices are, a multi-criteria uncertain decision-making problem must be solved (Khanjani Shiraz et al., 2015; Mosallaeipour et al., 2017; Niroomand et al., 2018; Yang, 2008).

In this study, several objectives and decision criteria are outlined by the directors of the company to be considered by the FREM department in an expansion project. The project goal is to determine enough number of locations, with right qualifications to satisfy the company's stated desires for constructing new sites considering the available expansion budget. The uncertain factors in this project are the construction cost and the potential sale in each candidate location for which the corresponding data are illustrated using fuzzy logic. Based on what mentioned in chapter one and two, a mathematical optimization model (PROM) is formulated to represent the problem in which the variables corresponding to cost and sales are fuzzy. Due to having several objective functions, the model is also multi-objective. Solving fuzzy multi-objective models needs proper initiation approaches (discussed in **chapter 3 -** ***SQ9***, and **Appendix 5** with more technical details). The final outcome of the problem is a set of locations in which investing satisfies the company's key stakeholder's objectives, aspirations, and expectations (aka. decision criteria).

2.6 CONCEPTUAL MODEL

The conceptual model of this study is largely adopted from the research by Farahani et al. (2010) with slight modifications accepted from Deloitte (2015), Rymarzak and Sieminska (2012), and (Lannon, 2016).

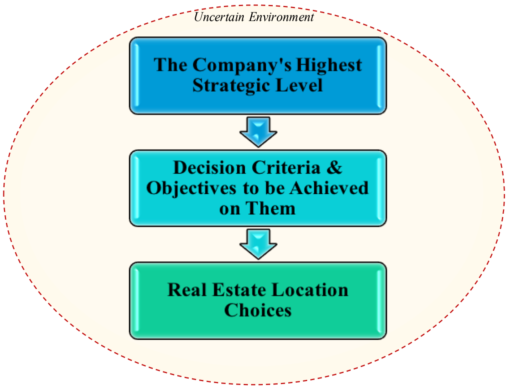

FIGURE 6. CONCEPTUAL MODEL FOR LOCATION DECISION (AUTHOR, 2018)

The literature clearly shows that the desires and aspirations of the organizations directly affect the choice of locations(s) (Hwang & Masud, 2012; Kuo et al., 2002; Turban, 1993; Walker et al., 2003). The requisites of the organizations manifest in the form of decision criteria and the objectives defined on them, which are to be satisfied by making the decision. As previously discussed, there is more than one criterion of decision and objective in making location decisions. Moreover, the uncertainty of the environment in which the decision making occurs may significantly affect the choice of locations. The solution of a location selection problem under uncertainty satisfies the decision criteria respecting the objectives of the decision maker.

As can be seen in figure 6, five decision criteria and corresponding desires in each criterion (objectives) are outlined at the company's highest strategic level. Selecting the most suitable set of locations considering the uncertainties in decision-making environment satisfies the company's decision criteria respecting the requested goals.

CHAPTER 3

PROBLEM DESCRIPTION, OBJECTIVES, AND RESEARCH QUESTIONS

In this chapter, the structure of the research, research objective, and research questions are discussed. The following flow chart represents the process followed in this research.

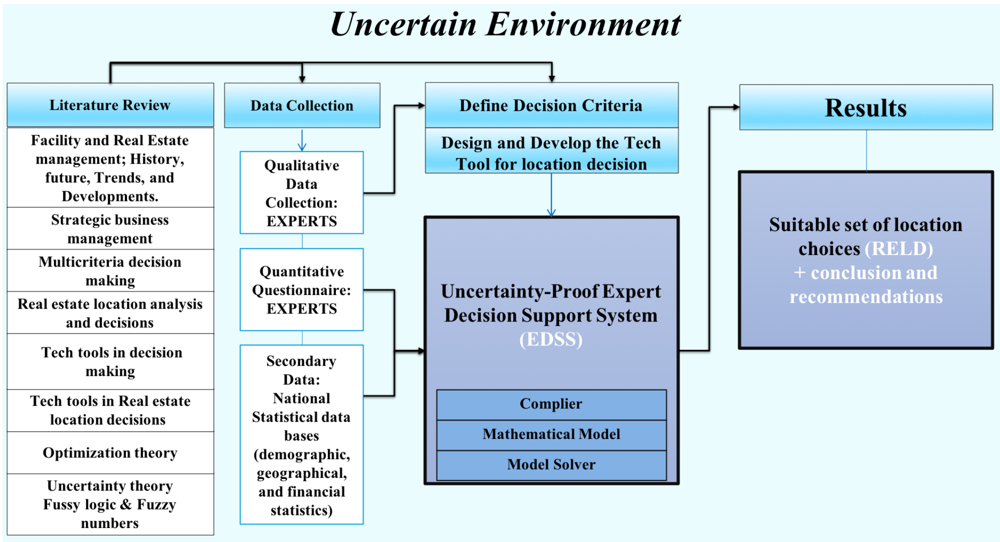

FIGURE 7. THE RESEARCH PROCESS FLOWCHART

As shown by figure 7, the ultimate goal of this project is to find the best set of locations to make investments and develop new properties for a company - respecting their decision criteria and objectives - through creating an expert decision support system (EDSS) that facilitates the decision-making procedure of real estate location selection problem. The depicted flowchart outlines five stages before the optimal the locations can be selected: a literature review on the required body of knowledge, data collection from the experts, considering the uncertainty when relevant, creating the PROM, and finally, solving the PROM.

One of the major concerns in the data collecting stage in this study is the role of experts. Essentially, all kind of information, required for solving the location decision problem in this study is the professional knowledge that is accessible by the people who are professionally related to the research topic. In fact, only those individuals who have enough knowledge, experience, and expertise about the issues are able to answers research questions. For instance, the fuzzy values used in this research can only be determined based on the knowledge and experience of the professionals who have an idea about the value of the data (see 2.5). Choosing the name “Experts” for the people who answer the questions refers to the fact that they are the professionals who are qualified to answer the questions (**please see section 4.2 for more information about the role of experts in data collection**). The information, collected from the experts not only forms the required input for creating a functional decision support system, but also provides the required input for the **PROM** which is the most critical ingredient of an EDSS, **providing a comprehensive model to represent the problem and its associated characteristics**. In other words, the PROM is the engine that translates the problem into a fuzzy mathematical model, inserts the required data in the model, and solves the model using a proper solving approach. The following questions are formulated and answered in this research considering the mentioned preliminaries.

3.1 RESEARCH OBJECTIVE

The main objective of the research is to deal with the multi-criteria real estate location selection problem of a Persian company (LGI) which is active in producing industrial end constructional glasses for the buildings, using an expert decision support system developed for this purpose (for more information about the case company please see section 4.3). The decision criteria and objective to be achieved in this problem are illustrated by the conceptual model of this research (see figure 6). As discussed previously, the outcome of this research is a set of locations that satisfy the company's five decision criteria according to their five stated objectives **(see figure 6 and section 2.5)**. In this regard, the main research question, as well as the relevant sub-questions, are formulated as follows.

3.2 MAIN RESEARCH QUESTIONS

MRQ: AMONG ALL AVAILABLE LOCATIONS, WHAT IS THE MOST SUITABLE SET OF LOCATIONS TO INVEST IN NEW PROPERTIES FOR THE LGI COMPANY?

3.2 SUB-QUESTIONS

In order to answer the main research question, the following sub-questions must be answered:

SQ1. **What is the scope of the project?**

SQ2. **What are the decision criteria?**

SQ3. **What are the objectives in each decision criterion?**

SQ4. **What kind of uncertainties exist in this problem and how they are dealt with?**

SQ5. **What is importance degree of each objective?**

SQ6. **What are the total available number of locations?**

SQ7. **What are the attributes of the locations respecting the decision criteria**

SQ8. **What is the proposed problem's representative model (PROM)?**

SQ9. **What is the proper initiation approach for solving the PROM?**

SQ10. **What is the schematic representation of the sub-questions?**

The Next figure shows the links between the research questions to the research framework.

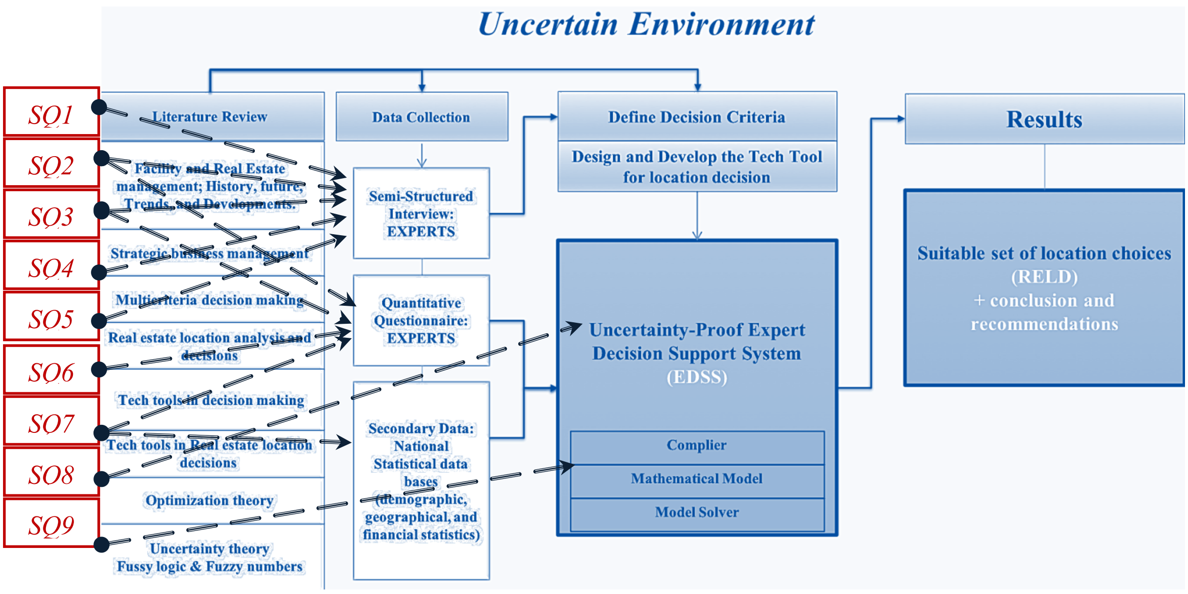

FIGURE 8.THE LINK BETWEEN THE RESEARCH QUESTIONS AND THE RESEARCH FRAMEWORK

CHAPTER 4

RESEARCH METHODS, OPERATIONALIZATION, ANALYSIS

This study is an interdisciplinary research using various knowledge areas and principles aiming to provide a new solution to RELD problems of which the most important knowledge areas are operation research (OR), optimization theory, mathematical modeling, decision making, business management, and facility and real estate management. This means that the present study is different from pure data analysis research in essence that sometimes implies employing different and unconventional approaches compared with data analysis. Nonetheless, this study's relevant research method, operationalization, and analysis are explained in this chapter as follows.

4.1 RESEARCH STRATEGY AND APPROACH

The initial motive of this study is to propose a suitable method for dealing with multi-criteria decision making in real estate location selection problems, ergo, the nature of research is **exploratory,** making it possible to seek new insights an assess the phenomena through a different approach (Saunders, Lewis, & Thornhill, 2012). For this purpose, extensive literature, knowledge area, and problem-solving techniques were surveyed. Eventually, a new **"mathematical modeling approach for creating an expert decision support system (EDSS)"** is proposed to deal with this category of problems. The mentioned EDSS is a prop-tech software in which developed an internal decision-making algorithm for dealing with the decision-making problem. The idea is to see whether the proposed methods functions well enough.

Case study strategy is one of the most suitable strategies for getting a reach understanding of the applicability of the newly proposed solutions in real cases in exploratory research topics (Ayhan, 2013; Saunders et al., 2012). Normally, for the cases similar to this research, a **single case study** that is a **typical representative** of the tackled problem in a real organization can be utilized to observe and evaluate the applicability of the proposed solutions (that is not applied before) in real-life examples (Golabi et al., 2017; Mosallaeipour, Nazerian, & Ghadirinejad, 2018; Saunders et al., 2012; Shavarani et al., 2017; Toni, Fornasier, Montagner, & Nonino, 2007). Therefore, in this research, a **case study strategy** on a **representative case** is employed to test the proposed approach. Since the "real estate location decision" problem belongs to an organization and a sub-unit of an organization (i.e. FREM department) investigated in a limited time span, the mentioned **single case study** is considered an **embedded** one, conducted in a **cross-sectional** time frame (Saunders et al., 2012; Yin, n.d.).

The research approach is a mix of **deductive** and **inductive** approaches. The inductive approach is observed in creating the mathematical model of the proposed decision support system whereas deductive approach is more distinguished when the proposed solution method applied for dealing with the company's location selection problem and making strategic choices.

The required information for this study is collected in two steps; the first step was a set of interviews with the decision makers collecting **qualitative** data about their perspective, expectations, and desires from selecting a set of locations. This information was particularly useful to identify the decision criteria and objective functions that should be defined in this problem. In other words, the outputs of this stage were used to determine what **quantitative** data are required as the input for the proposed methodology. The second step was collecting the specified quantitative data that were mainly the characteristics of the available locations, used for selection of the solution locations by the proposed approach.

Note 6: Collecting the quantitative data is a required and popular approach when a proposed model is constructed to imitate the behavior of a system or represent a real problem as it is the case for this research (Migiro & Magangi, 2011; Poch, Comas, Rodriguez-Roda, Sanchez-Marre, & Cortes, 2004; Saunders et al., 2012).

4.2 DATA COLLECTION TECHNIQUES AND INSTRUMENT

In this research, both qualitative and quantitative data were collected from the experts who had enough knowledge, experience, and authority to determine and define the decision criteria and objectives of the organizations using interview and questionnaire. As formerly mentioned, this method of collecting data is common and effective for research topics similar to this study (Chou et al., 2008; Kuo et al., 2002; Tsaur et al., 2002; Yang & Lee, 1997).

Considering the enormous decision criteria and objective that may apply in real estate location analysis problems (discussed in sections **2.2.2** and **2.3**), the data collection in this study occurred in two rounds. Initially, the experts from the company participated in **semi-structured** Skype interview and talked about the characteristics of their expansion project, including their motives, objectives, decision criteria, preferences, restrictions, etc. This information was utilized to determine what decision criteria and objective are active in their organization providing a view over the required inputs to be used in the proposed problem-solving approach. The decision criteria, their objective, the scope of their expansion project, the list of available locations, and the location attributes were the most important inputs for which quantitative data collection was required (section **3.2**, ***SQ1, SQ2, SQ3,*** and ***SQ6***).

Remark 1*:* The attributes of the locations correspond to the satisfactoriness of the location regarding the decision maker's decision criteria.

In the second round, the experts filled a **quantitative questionnaire** regarding the decision criteria, objectives, the ranked importance of the objectives, limitations, and preferences as well as the information about the attributes of the locations with a return rate of 100% (related to section2, ***SQ1*** *to* ***SQ7***). This information was used as the input to the model that was created to represent the problem (**PROM**).

Remark 2: Please note that the nature of related to cost and selling price is fuzzy, therefore, the value stated for these items is fuzzy and based on the perception, and expectation of the participants (**see Appendix 3, Table 12 and, Table 14**).

4.3 OPERATIONALIZATION

The semi conducted the interview conducted in this research was based on the guideline provided by Migiro and Magangi (2011), and Liu and Zhang (2014), in order to collect the information required for getting a grip over the state of the problem, influential factors and the way of handling those factors. Sub-questions 1 to 4 (i.e. ***SQ1* to *SQ4*).** In order to increase the accuracy of the collected data, the first two questions of the distributed questionnaire were designed to confirm the conclusion of the interviews (**see Appendix 2**).

The questionnaire used in this study is formed based on the research by Farahani et al. (2010), Mosallaeipour et al. (2018), Shavarani et al. (2017) in which a model imitates the behavior of a real-life system, and modified based on the inputs of the company's decision makers during the interview phase based on the guidelines by Siniscalco and Auriat (2005) (see section **4.2**). Farahani et al., (2010) specified the most common decision criteria and objective functions in multi objective real estate location analysis problems. His research was used as a guide line for designing the types of questions to be answered in data collection for such analysis. The first two questions of the questionnaire are designed to confirm the accuracy of the outlined decision criteria and objectives. As expected, no alteration in the proposed decision criteria and objective was observed. The third question (***Q3)*** is adapted from the research by Al-Harbi (2001) using AHP method to determine the importance degree of the objectives in comparison with one another (**see Appendix 6**). Question 8 and 13 (***Q8*** and ***Q13***) are designed based on a research by Mosallaeipour (2017) to collect fuzzy data as the nature cost and income is uncertain and needs to be reflected by fuzzy numbers (please see section 2.6.1 as well). The remaining questions are adopted from the research by Farahani et al. (2010) and used to collect the information about the attributes of the locations respecting the decision criteria and objectives of the company.

4.4 SAMPLING

In case studies, sampling takes place in two stages (Saunders et al., 2009). The first step is selecting a case which is a typical representative of the same category of problems. For this research, it was essential to find an organization, willing to run an expansion project in which required was dealing with a multi-criteria real estate location decision problem. Moreover, the project needed to be large enough to justify the application of the EDSS as decision making is simple and easy for small-scale projects (Abdollahi et al., 2015; Poch et al., 2004). The following case was selected for this research as it complied with all mentioned requirements.

> **The Studied Case -** Liana Glass Industries (LGI), registered by number 444457, is a large company in producing and distributing industrial and luxury glasses. One of the LGI's main products is special ornamental glasses produced by their exclusive method. The glasses are purchasable in various colors and graphical features. Furthermore, they are extremely resistant to scratches and fraction and can also be bulletproof, heatproof. The mentioned properties make them desirable for a large variety of the customers including building companies and factories. The headquarter as well as their main manufacturing site is in Tehran. The company has active commercial relations with Turkey, Cyprus, Iraq, and some of the Arabic countries in the south of Persian Gulf. Due to the distribution difficulties that creates an extra restriction on LGI's strategic goals, the company decided to initiate an expansion project and establish new units in different districts and cities in Iran in the first phase. The characteristics of the company's project, as well as their targets, and objective have a perfect alignment with the framework of this research. Hence, the researcher selected LGI as the case study of this research after negotiation with the company's authorities.

The second stage of sampling in case studies is the respondent selection. In this research, **qualitative** and **quantitative** data were collected from the professionals who had enough knowledge and decision making authority over the problem and the project, as a common practice in similar research subjects (Ayhan, 2013; Kuo et al., 2002; Mosallaeipour et al., 2018; Tsaur et al., 2002). This approach is addressed as data collecting from the experts in the literature (Kandel, 1991; Yager & Filev, 1994; Zadeh, 1983).

For this purpose, a non-probabilistic, **purposive homogenous** sampling approach including four to twelve experts was required (Migiro & Magangi, 2011). Therefore, six of the experts in LGI were selected, interviewed, and asked to filled out the questionnaires. The participants were the director manager, marketing manager, production manager, head of the R&D department, real estate manager, and the project manager of LGI.

In the interview phase, the experts provided an overall description about the problem, the way they are planning to proceed with their project, what options are available to them, and what are the variables with which they have to deal. Consequently, the entire quantitative questionnaire, filled by the same experts, was designed based on the information that was determined necessary by them. One of the most important decisions made based on these interviews was using the fuzzy variables for dealing with the uncertainty of establishment cost, and the potential income per location (recall what mentioned in **2.6.2**). Furthermore, during the interview, it became apparent that in order to design an efficient solution method the traveling distance between the cities needs to be determined. For this purpose, the secondary data by the Institute of Geography and Cartography of Gita (n.d.) was utilized (**see Appendix 4**).

4.5 DATA ANALYSIS

The analysis of the qualitative data was the least complicated part of data analysis in this study. The discussions with the experts were continuously pointing to the same major issues to consider when designing the system. These matters were highlighted and summarized as the answer to the first four research questions (***SQ1*** to ***SQ4***) by the researcher.

The massive body of knowledge, literature, and expert's inputs were used to propose an EDSS to represent and solve the problem in this study. As mentioned previously, the EDSS simulates the process of decision-making based on the problem's input data - the attributes on the locations in this case - and offers a solution that meets the requests of the decision makers. However, the proposed EDSS could not be used until its algorithm is coded and ran in a solver software (the mathematical, logical, and coded form of the EDSS are depicted in **tables 3, 4,** and **Appendix 5** respectively). Several solver programs are available for this purpose such as LINGO, LINDO, Cplex, and **GAMS** among which, the last one is the most capable and flexible one which is why it is used to write the codes and run the algorithm of the EDSS, proposed in this study.

In continuation, quantitative data were collected from the experts and used as the input for the EDSS. The outcome was a set of locations capable of satisfying the declared intentions of the LGI.

Since the location's attribute is the fact that affects the choice of location, a comparison is made between the attributes of the solution set of locations and other available alternatives, providing LGL a better view over the solution. These results, are shown in the result section of this report. Furthermore, it was interesting for LGL to know whether the selected set of locations could be different if not all objective were to be satisfied simultaneously. For this purpose, a sensitivity analysis was performed by running the algorithm having one objective activated at a time. As expected, the set of solution locations contained different choices for each different objective. Finally, a comparison between the performance of the solution set against the cases when the single objective functions were activated is provided, illustrating the utilization of the obtained solution. All mentioned comparisons are carried out using Microsoft Excel 2016 and represented in chapter 5.

4.6 RELIABILITY

The operationalization of this study was based on the extensive literature of location analysis research in other businesses and industries such as "A decision support system for selecting convenience store location through integration of fuzzy AHP and artificial neural network" by Kuo et al., (2002); "Multiple criteria facility location problems: A survey" by Farahani et al. (2010), and "Combining possibilistic linear programming and fuzzy AHP for solving the multi-objective capacitated multi-facility location problem" by Ozgen and Gulsun (2014). The reliability of the measurement instruments and problem-solving steps highly relies on such research topics.

Furthermore, according to Saunders et al. (2009), the reliability of a study is concerned with the answer to the question "whether the same results can be repeated if the study is conducted by another researcher?". In other words, a research is reliable if the procedure, data collection, and analysis are transparent and the same results are achievable by another researcher who approaches the problem. Furthermore, Saunders et al. (2009) outline four types of threats to be minimized in order to increase the reliability of a research. These threats are the participant error, participant bias, researcher error, and researcher bias respectively.

In this regard, the following measures are taken into consideration to increase the reliability of this research:

1. **Increasing the transparency:** All procedures and approach are explained in as much detail as possible to increase the transparency of the work in this research.
2. **Minimizing the participant error:** Time pressure is one of the main reasons for participants error. Therefore, in order to eliminate the effect of time stress, the questionnaire was submitted to the respondents through email and an extended time span was provided for them for answering the questions (**see Appendix 1**). Moreover, the answers to the questions about objectives and decision criteria - required for constructing the problem's proposed model - were checked with the criteria and objectives in the literature, making sure they are coherent and logically complying.

Remark 3: The quantitative data, provided by the respondents, were based on the company's database, historical data, and forecasting. Controlling the results with those databases guaranteed the accuracy and correctness of the data.

3. **Minimizing participant bias:** The respondents were the main problem's stakeholders who had sufficient stake, knowledge, and expertise to answer the questions. They were well informed of the company's strategic objectives, decision criteria, and characteristics of the expansion project and had access to the company's database, forecasting, and historical data. Hence, they were not only highly qualified to answer the questions, but also it was extremely important for them to provide correct and precise answers.
4. **Minimizing the researcher's error:** The data collection procedure was conducted free of stress and pressure. Sufficient time was devoted to the process and results were double-checked with the respondents for correctness before being used.
5. **Minimizing the Researcher bias:** Minimizing the Researcher bias: This study is based on highly reliable mathematical models and theories in the literature, providing a clear and explicit research framework. Hence, the risk of "researcher bias" occurrence is remarkably low as long as the problem characteristics are not misinterpreted. For this purpose, all decisions criteria, propositions, model, interpretation, and approaches were double-checked prior to use, by both highly-skilled professionals in the relevant fields and the company's authorities.

The measures taken into consideration in this study were highly beneficial for increasing the reliability and validity of the research. Moreover, utilizing a typical case study of which characteristics are extendable to similar cases, plus using highly reliable modeling techniques, explicit data collecting method (from all company's key decision makers with a return rate of 100%), and benefiting from fuzzy theory problem solving, significantly contributed to improving the reliability of the present study.

4.7 VALIDITY

The validity of a study is about the accuracy of the discoveries (Manion, Cohen, & Morrison, 2013; Saunders et al., 2009). The most relevant types of validities in this research are internal validity, external validity, and constructive validity. In the following, all three types of mentioned validity are discussed.

4.7.1 CONSTRUCT VALIDITY

In general, construct validity concerns the extent to which a test measures what it claims, or intents, to be measuring (Saunders et al., 2009). In other words, this type of validity concerns about the validity of the measurement tools and problem-solving steps. In the present study, the interview guide, designed expert questionnaire, and referring to the secondary databases when necessary, is adapted from the similar research topics in various other industries (as previously mentioned) and validated by controlling the acquired inform compared to the Persian official databases such as Iranian Center of Statistics (https://www.amar.org.ir/english), Institute of Geography and Cartography of Gita, (n.d.), and most importantly, the company's historical data which is used for forecasting and making strategic decisions by the company.

Furthermore, in this study, the measuring device is an expert decision support system which is created by the researcher which means, the nature is not observed directly, instead, it is exposed the proposed method of problem-solving. Consequently, a better way to define the construct validity in this study is to address it as the validity that can legitimately be made from the operationalizations in a study to the theoretical constructs on which, those operationalizations were based (Agarwal, 2011). Thereby, the construct validity of this study is tied to the accuracy of the model's representation of the real system (Refsgaard, 1990; Sargent, 2011; Yücesan, Chen, Snowdon, & Charnes, 2002). Form this viewpoint, a model built for a specific goal or set of objectives must serve its purpose correctly. Many approaches are applicable in this regard ranging from subjective review to applying objective statistical tests. Considering the nature and characteristic of the research as well as the extensive amount of the reviewed literature, subjective review by the experts in fields of "modeling and optimization" was utilized to ensure the validity of this research. For this purpose, the typical model validation step proposed by Naylor and Finger (1967) was utilized (**see figure 9**).

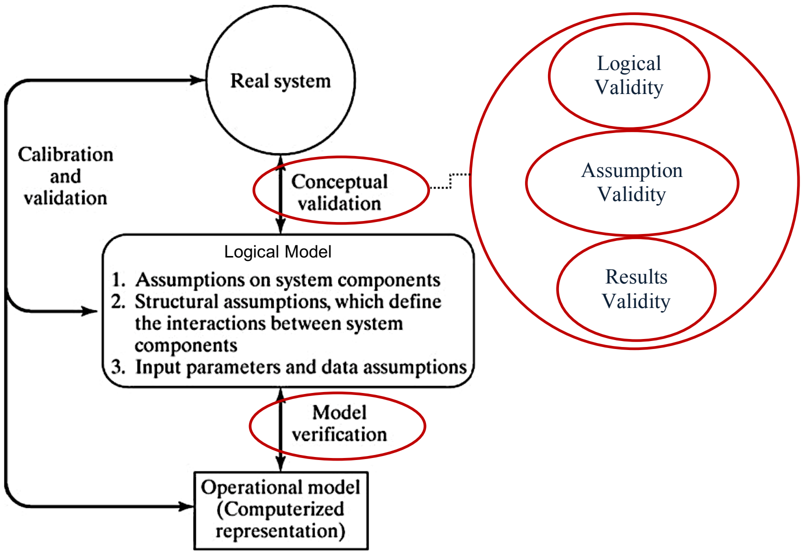

FIGURE 9. MODEL VALIDATION STEPS, BASED ON THE MODEL BY Naylor and Finger (1967)

The main components of this method of validation are **face validity (logical validity)**, **assumptions validity**, and **results interpretation** respectively. As mentioned, a subjective review by the experts and comparison with the literature was the main tools to ensure the validity of the model. The model successfully passed all criteria respecting the **original objectives**, **assumptions**, **requisites**, and **definitions**.

Furthermore, having mathematical modeling and computer programming as the backbone of this study, it becomes evident that **verification** of the model is crucial component of construct validity.

Note 7: Conceptual validity corresponds to constructing the <u>right model</u> whereas verifiability corresponds to creating the <u>model right</u>.

Remark 4: In the context of computer simulation and mathematical modeling, verification of a model is the process of confirming that it is correctly implemented with respect to the conceptual model (Refsgaard, 1990; "Terminology for model credibility," 1979; Yucesan et al., 2002). The purpose of model verification is to assure the model matches specifications and assumptions respecting the model concept and to ensure that the implementation of the model is correct. There are many techniques that can be utilized to verify a model including but not limited to, having the model checked by the experts, examining the model output for reasonableness with the experts, and using an interactive debugger (Refsgaard, 1990; Sargent, 2011).

In this study, all three mentioned techniques stated in **Remark 4** were utilized as follows. Initially, the proposed model was checked by highly skilled professionals (**Appendix 9**) in the fields of mathematical modeling, operation research, and optimization. Then, the model was debugged using the software that was used to create it (**GAMS**); and finally, the outcome of the research (based on the studied case) was presented to the company for final check (Ayhan, 2013; Golabi et al., 2017; Mosallaeipour, Nejad, Shavarani, & Nazerian, 2018; Salonen, 2004; Shavarani et al., 2017; Toni et al., 2007). The mentioned procedures verified the model confidently.

4.7.2 INTERNAL VALIDITY

Internal validity concerns about the accuracy of the conclusions, drawn within the research (Campbell, 1986).

In this study, the problem of real estate location selection decision in a typical case of an investor-developer-user organization was tackled by modeling the problem mathematically and developing a decision support system to handle it. The conclusion drawn from the problem-solving procedure is a "set of locations" qualified for satisfying the objective of the problem owners (i.e., LGI company).

According to Sargent (2011), one of the best methods to check the validity of the results in studies such as the present one is to compare the outcomes with credible references (e.g., the results of similar research subjects when available, or the results to the predicted outcome by the experts). However, since this study is carried out on a case for the first time, there are no previous results to be used as a reference. Hence, the professional judgment of the company's experts was alternatively used to validate the conclusion. Accordingly, the proposed "set of locations" was reported logically and accurate by the FREM department of LGI company.

Additionally, the following factors increases the credibility of the acquired results in this study:

1. The problem-solving method of this study is highly reliable and has extensive application in various decision-making problems in the literature;
2. The model proposed for solving the problem is highly accurate and inclusive;
3. The data collected as the input to the model are accurate and reliable;
4. The compiling approach used for initiating the EDSS is among the most reliable ones;
5. The model is solved using an exact method which means there is no risk of having parallel solutions.

Nevertheless, eliminating the chance of having a solution set with better quality of satisfying the objectives of the problem owners in not possible. In other words, there might be a better set of solution which is not approachable by the proposed procedure in this study. This statement implies that there might exist a theoretical solution approach which is more accurate and credible for solving the problem and delivering better results. However, no such solution is proposed for this particular problem by far.

Finally, while it is impossible to guarantee that there is no better solution than what is proposed, it is assured that the proposed solution is sufficiently accurate and serves the objectives and intentions well. It concludes that the proposed solution is suitable, reliable, and adequate and hence valid internally.

4.7.3 EXTERNAL VALIDITY

This aspect of validity concerns whether the results can be generalized to a larger scale, population, or cases (Saunders et al., 2012).

In this study, a typical case (capable of properly representing the same category of problems) in combination with a non-probabilistic purposeful sampling technique was utilized. At first glance, it might seem that due to the mentioned reason, the results of the problem cannot be generalizable to larger scales. However, in this particular sense, this research should be assessed from two points of view:

1. **The set of locations:** In this sense, the results are too specific to this study only. The aim of the study was to solve a specific problem, in a specific region (i.e., Iran), ergo, the "set of locations" that serves LGI well may not serve another organization with different project specifications, purposes, and/or problem settings. Nonetheless, the acquired results might be still usable for informative purposes or as a reference for comparable organizations. Variation of the decision criteria in different organizations is the main reason why this result may not suit other organizations adequately.
2. **The developed problem-solving methodology:** This aspect is about the method which is developed to tackle the problems with similar settings. From this viewpoint, the problem-solving method proposed in this research is universal and applicable to all variation of location analysis and decision-making problems. It means the mindset and logic which is used to optimize the decision-making problem is independent from the details of the problem which means, using a correct logic, the technique for developing an EDSS to handle complex decision-

making problems can be used to create modified EDSSs for handling a large variety of decision making, location selection, and optimization problems. The successfulness of the approach is, however, at the stake of the proper determination of the problem's components, objectives, and assumptions as well as the correct construction of the PROM and the right selection of the PROM solver.

4.8 LIMITATIONS

The main limitation of the research topics comprised of uncertain factors is the uncertainty itself. First of all, by far there is no known method that can neutralize the impact of uncertainty by 100%. All methods utilized for this purpose have their own specific limitations and restrictions. Furthermore, they all operate by a level of accuracy defined by the researcher which means the outcomes are feasible, useful, and applicable, but not optimal (Liu, 2007, 2010, 2016). In the case of this research, the fuzzy logic used to deal with the uncertainty suffers from similar limitations. Accordingly, the collected data possess a fuzzy and subjective nature; therefore, despite being stated by highly skilled and knowledgeable experts, there is no way to prove they are 100% true.

Furthermore, the methodology utilized to solve the RELD problem is only an approach with a good performance that is capable of solving the problem and provide correct answers who satisfy the decision makers. However, there is no guarantee that this approach is the best possible solution unless there are other solutions applied to the problem compared with it. Moreover, even in the case that there are other solutions to which the proposed EDSS is dominant, there is always a chance to develop better solutions in the future.

Finally, the results could not be compared to any other alternative since there was no other research performed for this case. Therefore, in spite of satisfactoriness of the obtained results, commenting on the performance of the proposed method was impossible.

CHAPTER 5

RESULTS AND DISCUSSION

In this chapter, the results obtained in this study are summarized and discussed based on the structure of the research questions and conceptual model starting with the results of the data collections followed by the outputs of the problem-solving procedure.

5.1 RESULTS OF THE EXPERT INTERVIEWS AND QUESTIONNAIRE

In this section, the results of the data collecting procedure corresponding to the research questions are provided.

5.1.1 THE SCOPE OF THE PROJECT

Based on the information, provided by the experts, the scope of the project at the current state is within Iran. Having the total available budget for this expansion project equal to 7.000.000 euros, the company seeks suitable locations in the districts of the country for establishing new properties. The districts may not host more than two locations. Furthermore, the traveling distance between any two neighboring locations must be at least 400 km (see **Appendix 4** for travelling distance between the cities). Finally, the minimum and a maximum number of investments are 10 and 50 respectively which means the number of locations needs to be at least 10 and at most 50. In other words, the company is not necessarily interested in investing in all available locations.

5.1.2 THE DECISION CRITERIA

Derivate from the interviews and collected data by the questionnaire, the company has specific expectations from the locations that represent the company's decision criteria. Each potential location has a score in each decision criterion indicating the gravity of its attribute. The following decision criteria apply for each location.

C1. Futuristic (advantage) Score: This score refers to the possibility for change of the function after developing the property, value adds of the property, and flexibility of the business-related rules and regulation. The score for each location varies between **1 to 100** indicating the minimum and maximum advantage respectively.

C2. Tax Disadvantage score: Each city is located in a different tax region which means the amount of tax to be paid by the company in each location is different. Tax disadvantage refers to the amount of tax to be paid in each location. Tax disadvantage score varies between **1 to 100** depicting minimum and maximum tax disadvantages of each location. In this case, locations with lower scores are more desirable.

C3. Fixed Costs: This cost is related to the property establishment costs. The size of the property, as well as construction cost / square meter, is highly related to the locations of the property. It is only possible to guess the minimum and maximum of the required establishment costs in each location, imposing a **fuzzy** nature on this criterion.

C4. Accessibility Score: This criterion is based on having access to the distribution roads, workforce, and convenience of providing facility management services. Each location gets a score between **1 to 100** indicating the minimum and maximum accessibility score respectively.

C5. Potential Income: Depending on the variation of the selling price, as well as the population, potential demand, and targeted market share in each location, the amount of company's income may vary in each location. Similar to establishment costs, the amount of income can only be estimated, giving this criterion a **fuzzy** nature as well.

5.1.3 THE OBJECTIVES IN EACH DECISION CRITERION

The objectives are related to the decision criteria, the company's experts who participated in the data collecting have defined the following objectives on the mentioned decision criteria:

OBJ 1: The futuristic score has a **positive nature**; therefore, the company wants to obtain the **maximum** futuristic score from the selected locations.

OBJ 2: Tax disadvantage has a **negative nature**: therefore, the company wants to have the **minimum** disadvantage score from the selected locations.

OBJ 3: Fixed cost also has a **negative nature**; the company wants a set of locations for which **minimum** establishment cost is required.

OBJ 4: Accessibility has a **positive** nature; therefore, the company wants a set of locations from which the **maximum** accessibility can be obtained.

OBJ 5: The potential income has also a **positive nature**; by selecting the proper set of locations, the company wants to **maximize** its potential income.

Figure 10, in the following represents the detailed version of the conceptual model and shows the standing point of the decision criteria and objectives in the present study.

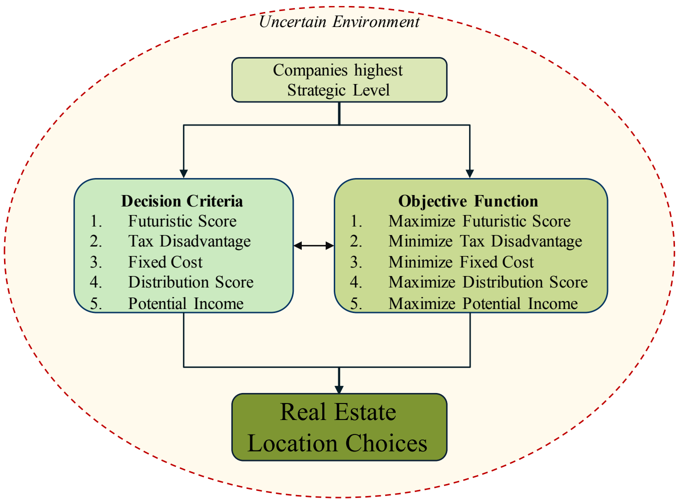

FIGURE 10. COMPLETED CONCEPTUAL MODEL FOR LOCATION DECISION (AUTHOR, 2018)

This conceptual model illustrates five decision criteria with five objectives defined on them, that outlines the necessary attributes of a location to be selected. The five attributes of the locations are the futuristic score, tax disadvantage, establishment costs, accessibility score, and potential income. The company aimed to select a set of location with dominant attributes compared to any other alternative set of solution (see **section 3.2**, ***SQ2*** and ***SQ3***). For this purpose, an expert decision support system (EDSS) was designed to help the company selecting the complying set of location. Since the proposed EDSS required input data to carry out the process of decision making, a questionnaire was designed to collect the necessary information (**see Appendix 2**).

5.1.4 UNCERTAINTIES OF THIS PROBLEM

he uncertainties in this problem are related to establishment cost and potential, whose exact amount can never be determined accurately due to the changes in the market. Therefore, any estimation of this measure includes a certain degree of vagueness. Previously it was explained in section 2.4 and 2.5 that how such situation can be handled by fuzzy variables and uncertainty theory. In case of these components of the problem, the expert who participated in data collecting procedure and filled the questionnaire answered to the related questions by providing the boundaries of the variation of these values and indicated what values are most likely to be observed in reality.

5.1.5 THE DEGREE OF IMPORTANCE OF OBJECTIVES

As previously pointed, not all objectives are equally important. Therefore, it is imperative to determine the importance degree of the objectives in comparison with one another. As discussed in **section 2.2.1,** the Analytical Hierarchy Process (AHP) is utilized to determine the importance degree of each objective respecting each decision criterion <u>based on the idea of the experts</u> (please refer to **Appendix 6** to see **the complete steps for forming table 1**). The final importance degree of the objectives is depicted in the following figure.

TABLE 1. IMPORTANCE DEGREE OF EACH OBJECTIVE USING AHP METHOD

	OBJ1	OBJ2	OBJ3	OBJ4	OBJ5	Importance Degree
OBJ1	--	0,03	0,07	0,09	0,05	0,06
OBJ2	0,22	--	0,12	0,12	0,08	0,13
OBJ3	0,23	0,25	--	0,33	0,28	0,28
OBJ4	0,13	0,18	0,18	--	0,27	0,19
OBJ5	0,37	0,44	0,33	0,25	--	0,34

In this table, the intersection of rows and columns show the importance degree of the relevant objectives against one another. The last column shows the marginal importance degree of each objective

5.1.6 THE TOTAL AVAILABLE SET OF LOCATIONS?

Determined by the company's department of research and development, and stated by the experts who participated in data collecting procedure, only the following 59 location in 28 districts all around the country have the potential and required infrastructures to host the company's new properties (see **table 2**). In other words, before starting the expansion project, the company had determined the possible places that have the essential requirements (regardless of the company's decision criteria) for establishing the new properties from which they intended to select the best options as a solution set.

TABLE 2. THE LIST OF ALL POSSIBLE LOCATIONS

District	Code	City	Code
Ardabil	1	Ardabil	1
		Aslandooz	2
		Pilesavar	2
Azarbayejan East	2	Oromiye	4
		Bazargan	5
		Piranshahr	6
		Sarv	7
		Mahabad	8
Azarbayejan West	3	Tabriz	9
		Jolfa	10
		Nordooz	11
Boshehr	4	Bandarboshehr	12
Char. & Bakhtiari	5	Shahrkord	13
Gilan	6	Astara	14
		Bandaranzali	15
		Rasht	16
Fars	7	Shiraz	17
		Laar	18
Golestan	8	Dashlibron	19
		Gorgan	20
Hamadan	9	Hamadan	21
Hormozgan	10	Bandarabbas	22
Ilam	11	Ilam	23
Isfahan	12	Isfahan	24
		Kashan	25
Kerman	13	Kerman	26
Kermanshah	14	Khosravi	27
		Kermanshah	28

District	Code	City	Code
Khoorasan	15	Bajgiran	29
		Bojnord	30
		Taibad	31
		Sarakhs	32
		Lotfabad	33
		Mashhad	34
		Birjand	35
Khoozestan	16	Abadan	36
		Ahwaz	37
		Bandarimam	38
		Khoramshahr	39
Kohgilooye	17	Yasooj	40
Kordestan	18	Sanadaj	41
Lorestan	19	Khoramabad	42
Markazi	20	Arak	43
Mazandaran	21	Babol	44
		Babolsar	45
		Chaloos	46
		Ramsar	47
		Sari	48
Qazvin	22	Qazvin	49
Qom	23	Qom	50
Semnan	24	Semnan	51
		Shahrood	52
Sistan and Baloochestan	25	Iranshahr	53
		Chabahar	54
		Zahedan	55
		Mirjaveh	56
Tehran	26	Tehran	57
Yazd	27	Yazd	58
Zanjan	28	Zanjan	59

5.1.7 WHAT ARE THE ATTRIBUTES OF THE LOCATIONS RESPECTING THE DECISION CRITERIA

This question refers to the score of the locations in each decision criterion (including futuristic score, tax disadvantage score, estimated cost of construction, accessibility score, and estimated potential income). This information is the critical factors for selecting or not selecting a location for making an investment by the company **(see Appendix 2, and 3)**.

5.1.8 THE PROPOSED PROBLEM'S REPRESENTATIVE MODEL (PROM)

As previously mentioned, the PROM is the most important part of the decision support system which is designed for solving this problem. The PROM formulates the whole aspects of the problem in a mathematical format. By solving the PROM, the answer to the problem would be obtained. (please note that the determined set of locations must reasonably satisfy all five objectives simultaneously)

The parameters that are used in the PROM are defined as follow:

$\boldsymbol{K}$ = The set of **existing districts** ($k \in K = 28$);

$\boldsymbol{J}$ = The set of **available cities** ($j, j' \in J = 59$);

$\boldsymbol{d_{jj'}}$ = The distance between **city $\boldsymbol{j}$** and **$\boldsymbol{j'}$**;

$\boldsymbol{y_{jk}}$ = Shows the belongingness of a city to a district; it is equal to **1** if **city $\boldsymbol{j}$** is located in **district $\boldsymbol{k}$**, otherwise it is equal to **0;**

$\boldsymbol{\tilde{c}_j}$ = The establishment cost of a property in **city $\boldsymbol{j}$ (fuzzy)**;

$\boldsymbol{S_j}$ = The accessibility Score of **city $\boldsymbol{j}$**;

$\boldsymbol{T_j}$ = Tax disadvantage score of **city $\boldsymbol{j}$**;

$\boldsymbol{\tilde{h}_j}$ = Potential Income of the **city $\boldsymbol{j}^{th}$ location (fuzzy)**;

$\boldsymbol{r_j}$ = The futuristic score of the **city $\boldsymbol{j}^{th}$ location**;

$\boldsymbol{B}$ = Total available Budgets;

$\boldsymbol{F_j}$ = The variable to show if a property is constructed in city $\boldsymbol{j}$ or not, it is **1** if city $\boldsymbol{j}$ hosts a property and **0** otherwise.

The following formulation in table 3 is the mathematical form of the PROM for this problem.

TABLE 3. THE **PROM** OF THE LOCATION DECISION PROBLEM IN THIS RESEARCH (AUTHOR, 2018)

Objective Functions to be satisfied simultaneously		
$Objective\ function1$: $\boldsymbol{Maximize}\ \sum_j r_j F_j$		(1)
$Objective\ function2$: $\boldsymbol{Minimize}\ \sum_j T_j F_j$		(2)
$Objective\ function3$: $\boldsymbol{Minimize} \sum_j \tilde{c}_j\, F_j$		(3)
$Objective\ function4$: $\boldsymbol{Maximize}\ \sum_j S_j F_j$		(4)
$Objective\ function5$: $\boldsymbol{Maximize}\ \sum_j \tilde{h}_j F_j$		(5)
***Subject to*:**		
$\sum_j F_j y_{jk} \leq 2$	$for\ all\ k$	(6)
$d_{jj'} \geq 400(F_j F_{j'})$	$for\ all\ j\ and\ J'\ provided\ that\ j \neq j'$	(7)
$\sum_j F_j \leq 50$		(8)
$\sum_j F_j \geq 10$		(9)
$\sum_j F_j \tilde{c}_j \leq B$		(10)
$F_j \in \{0,1\}$		(11)

Despite of a complicated look, the model represents a simple concept, the linguistic equivalent of the model is provided in table 4.

TABLE 4. THE DESCRIPTIVE VERSION OF **PROM**, LOGICAL MODEL (AUTHOR, 2018)

***Objective*: *select a set of location whose*:**		
OBJ. F1 - Summation of Futuristic score is **Maximum**		(12)
OBJ. F2 - Summation of Tax disadvantage is **Minimum**		(13)
OBJ. F3 - Summation of establishment cost is **Minimum**		(14)
OBJ. F4 - Summation of Accessibility score is **Maximum**		(15)
OBJ. F5 - Summation of Accessibility score is **Maximum**		(16)
On the condition that		
1.	No more than **2 cities** in one district are selected;	(17)
2.	The travelling distance between neighboring locations is **at least 400 km;**	(18)
3.	The total number of locations is **at most 50;**	(19)
4.	The total number of locations is **at least 10;**	(20)
5.	The total establishment cost of the properties does not exceed the available budget (*in this case 7.000.000 euros*).	(21)

The fuzziness and multi objectivity of the PROM should be handled through a proper initiation approach. After this step, it can be coded to a programming software and solved.

The common practice in dealing with multi-objective fuzzy models is defuzzification of the model and finding its crisp equivalent as well as converting the multi-objective model to its equivalent single objective (Liu, 2016; Mosallaeipour, 2017). This process is called initiation and explained in detail in **Appendix 5**. After this step, the model is ready to be coded as an expert decision support system (EDSS) and deliver the solution to the problem (**see Appendix 7**).

Figure 11 represents a tree diagram which is the schematic representation of the sub-questions and objectives of this research.

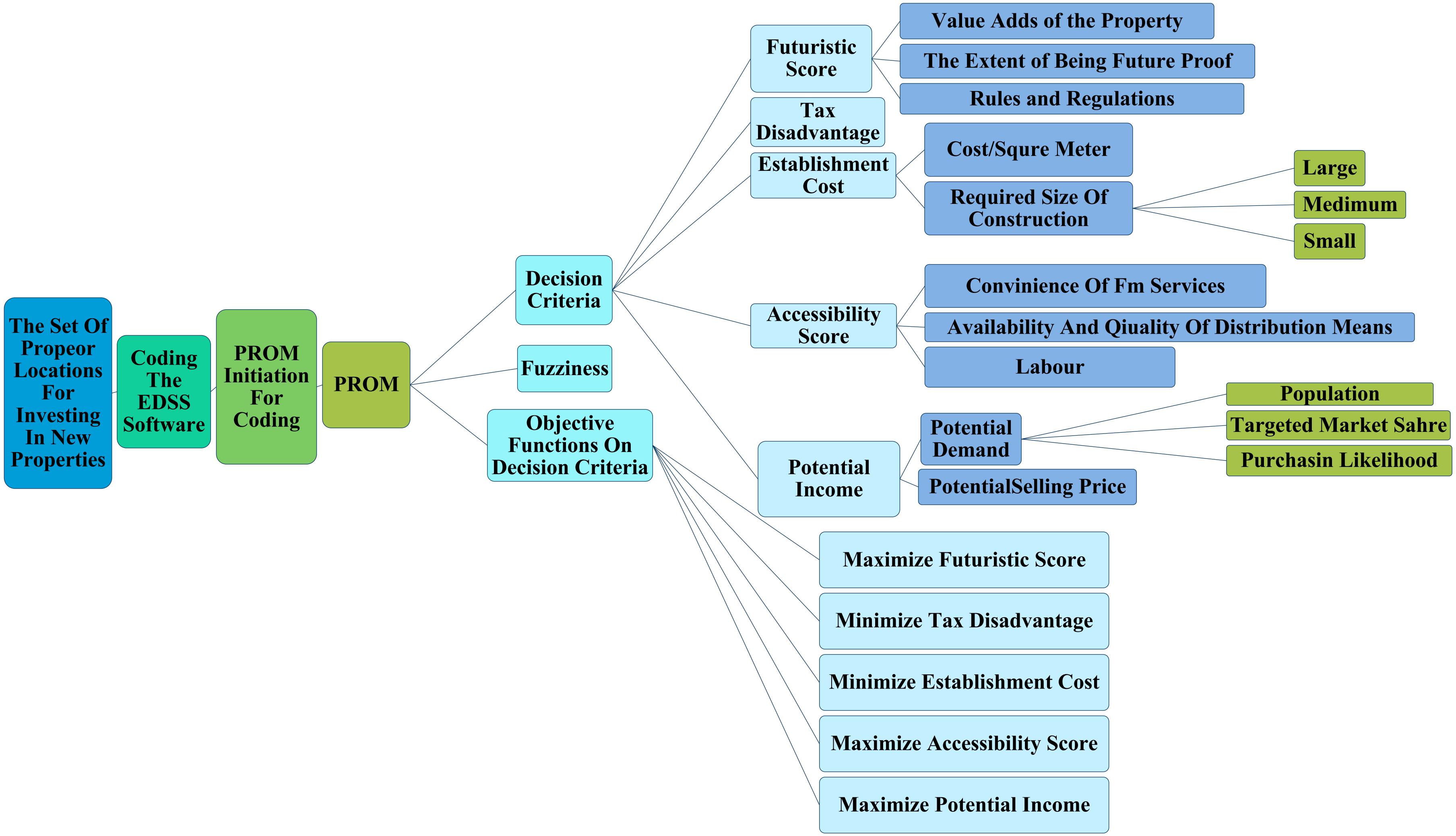

FIGURE 11. THE STUDY'S TREE DIAGRAM

5.2 THE LOCATION CHARACTERISTICS

As pointed out in section **3.2**, several criteria of importance in selecting a set of locations in combination with the objectives of the company resulted in 5 criteria of concern in this study. The company had a large set of candidate locations from which had to select a limited number of locations to invest in and develop new functional sites. From a total of 59 locations available location choices, the company required to select **at least 10** and **at most 50** new locations. Determining the optimal number of locations respecting the available budget and capable of satisfying the objectives of the company was the main objective of this study. The first step in solving this problem was to determine how much each location scores in each criterion of the decision. The results are shown in the following.

5.2.1 THE LOCATION'S FUTURISTIC SCORE

Based on the data collected from the experts, the futuristic scores of the locations are determined as shown in figure 12.

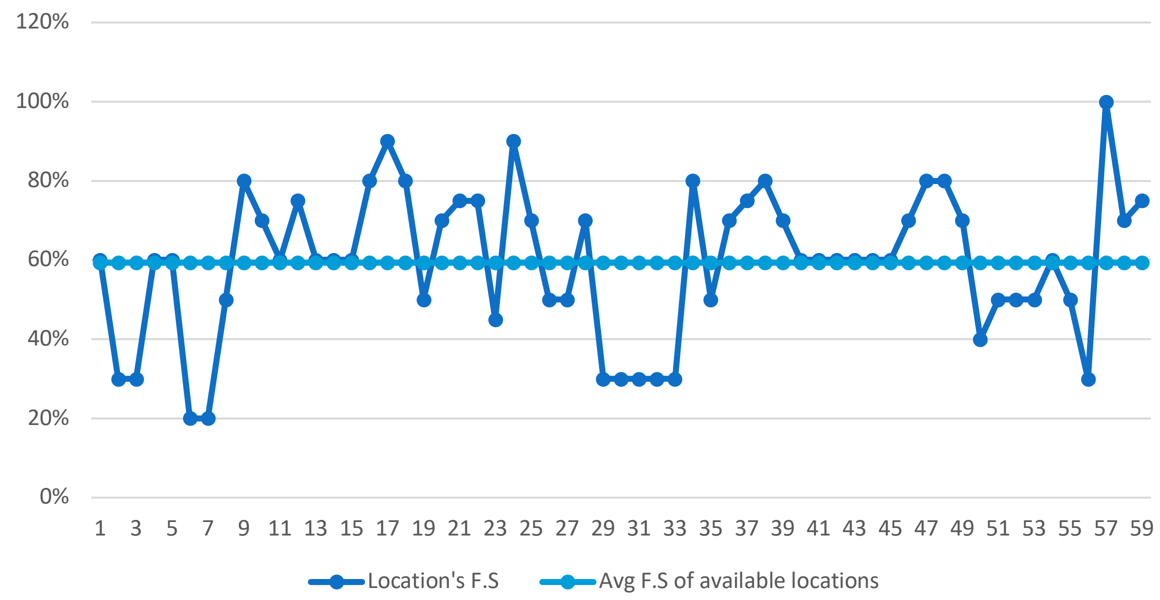

FIGURE 12. FUTURISTIC SCORE OF THE AVAILABLE LOCATIONS VS. THEIR AVERAGE

As represented in this figure, the average futuristic score of the available 59 locations is approximately **60%**. Moreover, out of 59 locations, 21 cities score below average, 24 cities score above average, and the remaining score an average futuristic score. Since having a more futuristic score means more potential for future projects, cities with the higher score are considered better candidates.

5.2.2 THE LOCATION'S TAX DISADVANTAGE

Each region in Iran has a specific tax situation based on which, the company has assigned a tax disadvantage score to each location. More tax disadvantage means the tax percentage is higher that makes a location less attractive for the company. The tax disadvantage status of the locations is illustrated in figure 13 based on the collected data.

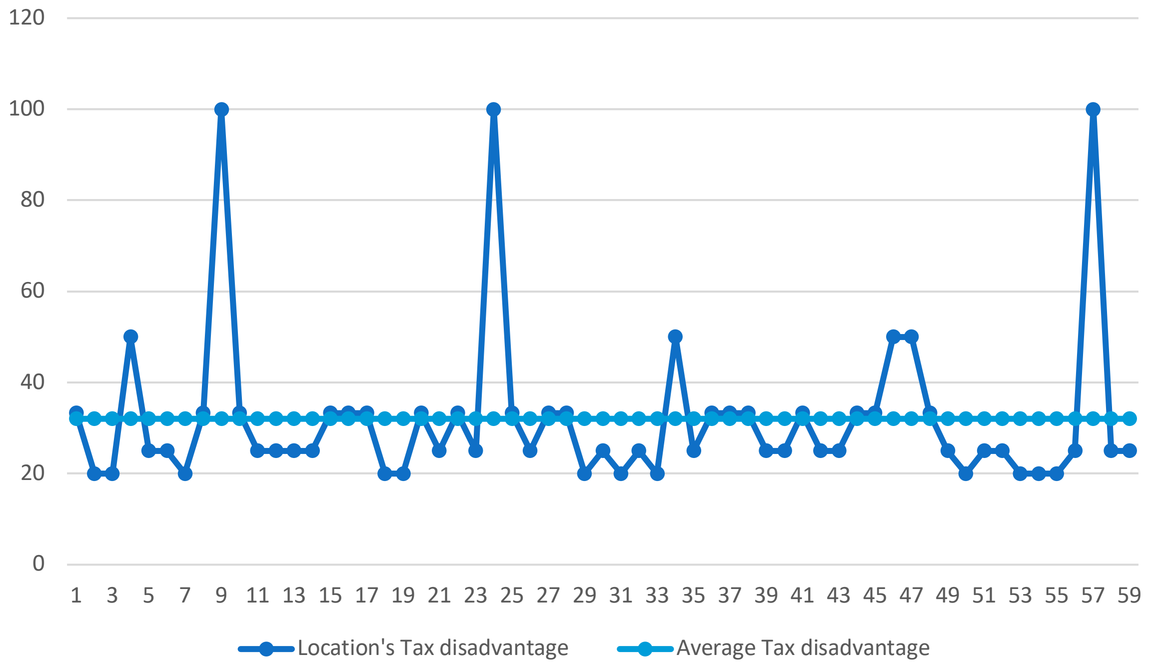

FIGURE 13. TAX DISADVANTAGE OF THE AVAILABLE LOCATIONS VS. THEIR AVERAGE

As can be seen in figure 11, the average tax disadvantage of the available locations is approximately **33%**. Among all locations, 7 of them have an above average tax disadvantage, making them less attractive from this perspective. 18 cities have an average tax disadvantage and the remaining have an attractive tax disadvantage score being below the average.

5.1.3 THE LOCATION'S ASSOCIATED ESTABLISHMENT COST

One of the most important criteria of decision for the company was the investment cost per location, addressed as the location's associated establishment cost. The company prefers choosing the locations with lower establishment cost requirements. The status of establishment cost per locations is depicted in figure 14.

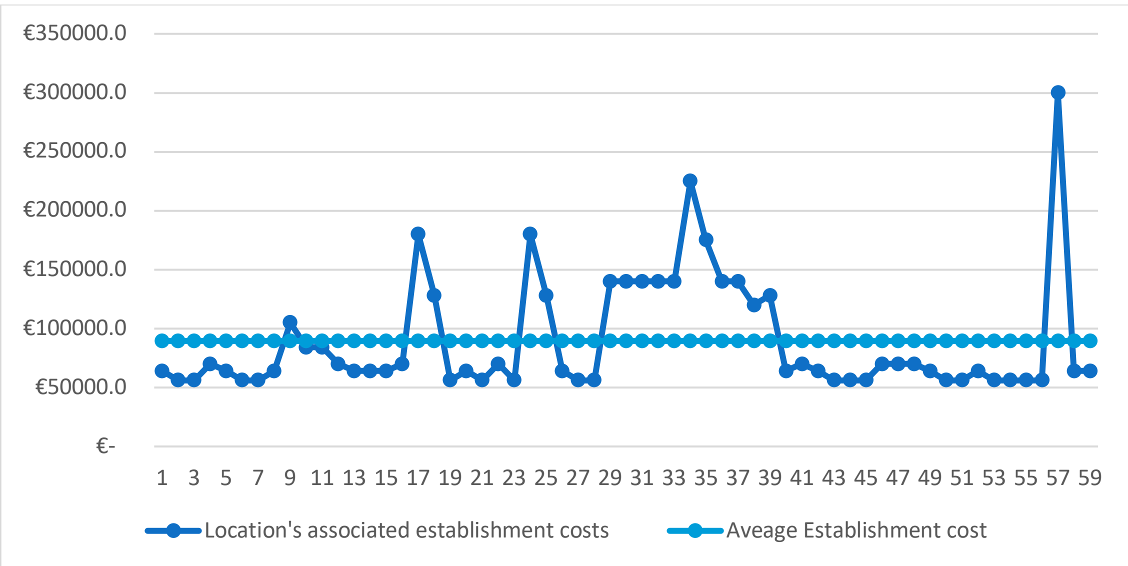

FIGURE 14. LOCATION'S ASSOCIATED ESTABLISHMENT COST VS. AVERAGE ESTABLISHMENT COST

The average establishment cost is approximately 90,000 euros. Location 57 which is the capital and the most expensive city in the country, has the highest amount of establishment cost. Apart from that, locations 9, 17,18, 24,25, and 29-39 have an above average establishment cost. Hence, they are less attractive to the investors.

5.2.4 THE LOCATION'S ACCESSIBILITY SCORE

Another important aspect of the location for the company was the ease of access form those locations to the distribution roads, workforce, and other conveniences (**see section 3.2**). Based on the criteria, the company has assigned an accessibility score to each location that can be seen in the next figure. The average attainable accessibility score is approximately 59%. Since the accessibility score is a positive attribute, the locations with the higher score are more attractive for the company.

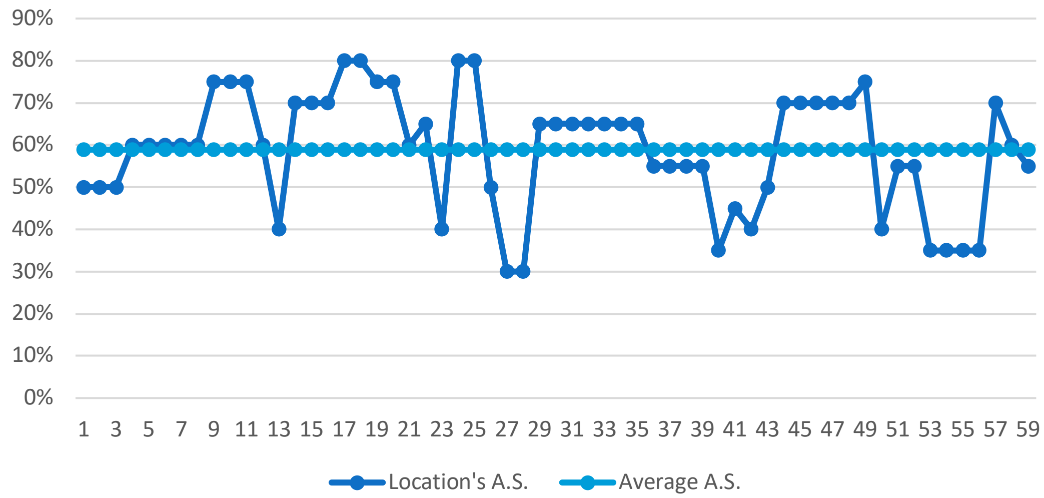

FIGURE 15. THE LOCATION'S ACCESSIBILITY SCORE VS. THEIR AVERAGE

As can be seen in figure 15, slightly more than half of the locations score above average in the accessibility score, only 5 locations have an average score, and the others score below the average.

5.2.5 THE LOCATION'S ASSOCIATED POTENTIAL INCOME

The other important decision criteria for the company was the potential income attainable by investing in a location. The locations that potentially may generate more income for the company are most favored by the decision makers in LGI. The next figure represents the status of the potential income in each location.

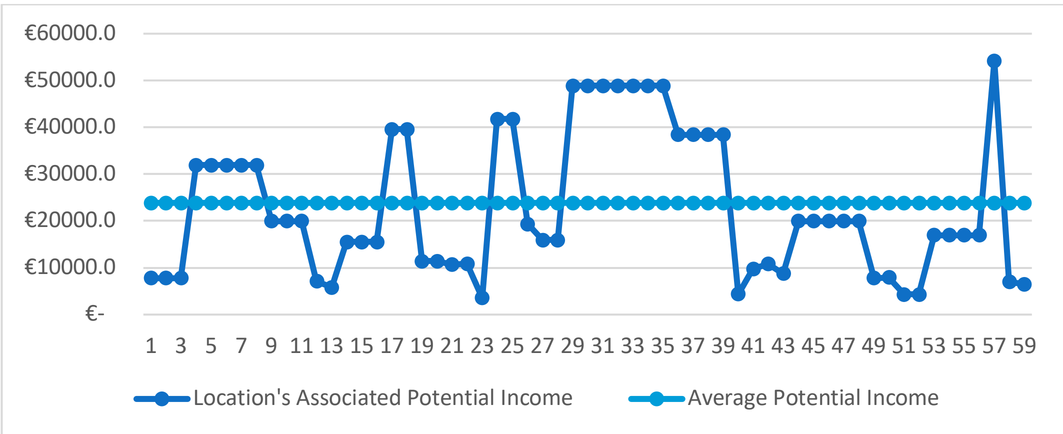

FIGURE 16. THE LOCATION'S ASSOCIATED POTENTIAL INCOME VS. THEIR AVERAGE

As illustrated in figure 16, the average potential income is around 22000 euros; less than half of the locations may generate an above average income for the company. Quite expectedly, location 57 again has the highest amount of potential income as the capital and trade center in the country.

5.3 THE SELECTED SET OF LOCATIONS

The location characteristics in the previous section formed the input data for the designed expert decision support system. The designed system aimed to determine a set of location capable of satisfying the company's objectives simultaneously. The term "simultaneously" indicates that the selection of the set of locations must comply with all decision criteria and satisfy the defined objectives at once. Taking all conditions into consideration, the expert decision support system designed in this study delivered the set of appropriate locations, illustrated in the following table.

TABLE 5. THE SELECTED LOCATIONS DELIVERED BY EDSS

District	Code	City	Code	District	Code	City	Code
Ardabil	1	Ardabil	1	**Khoorasan**	15	Bajgiran	29
		Aslandooz	2			Bojnord	30
		Pilesavar	2			Taibad	31
Azarbayejan East	2	Oromiye	4			Sarakhs	32
		Bazargan	**5**			Lotfabad	33
		Piranshahr	**6**			Mashhad	34
		Sarv	7			Birjand	35
		Mahabad	8	**Khoozestan**	16	Abadan	36
Azarbayejan West	3	Tabriz	9			Ahwaz	37
		Jolfa	10			Bandarimam	38
		Nordooz	11			Khoramshahr	39
Boshehr	4	Bandarboshehr	12	**Kohgilooye and Boirahmad**	17	Yasooj	40
Char. & Bakhtiari	5	Shahrkord	13	**Kordestan**	18	Sanadaj	41
Gilan	6	**Astara**	**14**	**Lorestan**	19	Khoramabad	42
		Bandaranzali	15	**Markazi**	20	Arak	43
		Rasht	16	**Mazandaran**	21	Babol	44
Fars	7	Shiraz	17			Babolsar	45
		Laar	**18**			Chaloos	46
Golestan	8	**Dashlibron**	**19**			Ramsar	47
		Gorgan	20			Sari	48
Hamadan	9	**Hamadan**	**21**	**Qazvin**	22	Qazvin	49
Hormozgan	10	Bandarabbas	22	**Qom**	23	Qom	50
Ilam	11	Ilam	23	**Semnan**	24	**Semnan**	**51**
Isfahan	12	Isfahan	24			Shahrood	52
		Kashan	25	**Sistan and Baloochestan**	25	Iranshahr	53
Kerman	13	**Kerman**	**26**			**Chabahar**	**54**
Kermanshah	14	Khosravi	27			**Zahedan**	**55**
		Kermanshah	28			Mirjaveh	56
				Tehran	26	**Tehran**	**57**
				Yazd	27	Yazd	58
				Zanjan	28	Zanjan	59

In table 5, the locations that are determined appropriate by the EDSS are highlighted. As can be seen, 11 locations are determined among which, 10 locations are to be opened. The location "Tehran" already host the main headquarter of the company and its relative establishments. The next figure depicts the schematic distribution of the location over the country.

FIGURE 17. SCHEMATIC DISTRIBUTION OF THE DETERMINED LOCATIONS OVER THE COUNTRY

As shown in figure 17, the distribution pattern of the locations over the country enables the company to cover all critical demand points and deliver their goods to the destinations efficiently. The next table depicts the detail information about the selected location versus all available of locations from which they were selected.

TABLE 6. THE DETAILS OF THE SELECTED LOCATIONS COMPARED WITH ALL AVAILABLE LOCATIONS

Selected Set of Locations				AVG Futuristic score of the set / location	AVG Tax Disadvantage of the set/location	AVG Total Establishment cost of the set/location	AVG Accessibility score of the set/location	AVG Income of the set/location
District		City						
2	Azarbayejan East	5	Bazargan	50%	21%	59637	53%	1805831
		6	Piranshahr					
6	Gilan	14	Astara					
7	Fars	18	Laar					
8	Golestan	19	Dashlibron					
9	Hamadan	21	Hamadan					
13	Kerman	26	Kerman					
24	Semnan	51	Semnan					
25	Sistan & Baloochestan	54	Chabahar					
		55	Zahedan					
26	Tehran	57	Tehran					
Total of the selected set				555%	230%	6,560,000 Euros	580%	1.986.414 Euros
Average of the available locations				**59%**	**32%**	**89509**	**59%**	**2294561**
Total of the available options				3500%	1890%	52.810.000 Euros	3475%	13.537.928 Euros
Available budget				7,000,000 Euros				

Table 6 depicts the set of locations determined suitable by the designed expert decision support system in this study. In the upper half of the table, the selected set of locations, as well as the average of the scores, cost, and income associated with the determined set, are represented. The next row "Total of the selected set" shows the objective value related to each objective satisfied with the chosen location. In other words, the score of the set in each criterion is shown in this row. The next row shows the average score of the total available locations giving an idea about the average attainable score if all locations were selected. “Total f the available options” refers to total attainable score if all locations could be selected. The last row, depict the budget available for the company’s expansion project. The next figure provides a better illustration of the selected set compared to the total available options.

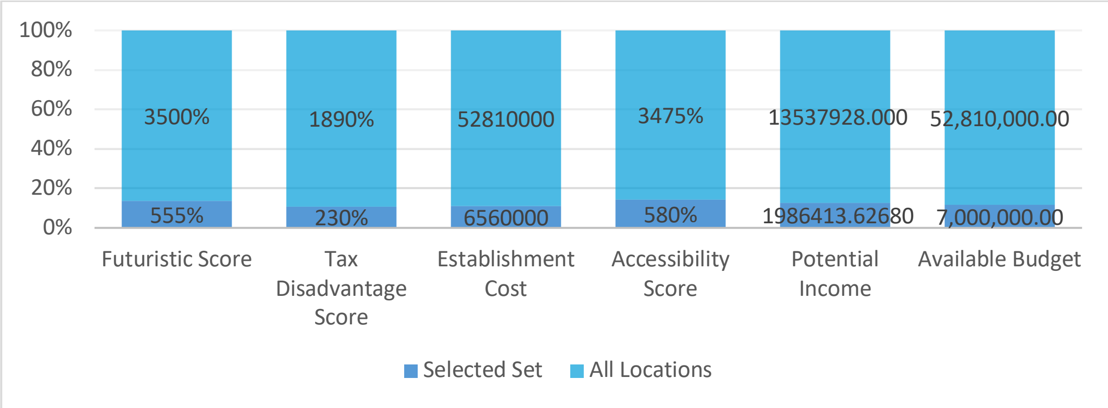

FIGURE 18. THE SCORE OF SELECTED SET VS. THE SCORE OF ALL LOCATIONS CONSIDERED

As shown by figure 18, from the total 3500 points in the criterion of the futuristic score, 555 points are achieved by the selected set of locations that accounts for around 12% of the total available points. Similarly, 230 points from a total of 1890 in tax disadvantage, and 580 points from a total of 3475 in accessibility score is attained by the selected set. Recall that lower disadvantage score and lower cost are better whereas for other criteria more value is better. The selected set has a reasonable accessibility and futuristic score but performs exceptionally well in delivering a low tax disadvantage score. Finally, the amount of required establishment cost is almost 10% of the cost of selecting all locations. Interestingly, all company's objectives were satisfied with such a low establishment cost, to a satisfying degree. Please also note that selecting all locations was not possible from the first place which is why selecting the locations wisely was required to achieve all the objectives of the company. The last column shows that within the given budget, a maximum of 13% of the available locations could be selected. The potential income deliverable by the selected set is as large as 15% of the total potential income (if all locations were selected) which is again very satisfactory for the company.

5.4 SENSITIVITY ANALYSIS

In this section, a brief sensitivity analysis is performed to illustrate what would be the outcome of the EDSS if not all objectives were to be satisfied simultaneously (the cases when only one objective is active). The performances of each single criterion focus solutions are depicted in tables **7** to **11**.

This analysis helps to provide a better understanding of how the solution to the problem could be different if the focus of the decision makers were only on one decision criteria. Please note that the purpose of the following sensitivity analysis is to outline the extremes of the decision-making problem that helps the company to determine the boundaries of their decisions. By the end of this section, a comparison between single focused scenarios versus the multi-criteria focused scenario is provided and illustrated in **tables 13** and **14.**

5.4.1 FOCUS ON MAXIMIZING THE FUTURISTIC SCORE

The following results were obtained from the case when no other decision criteria matter but maximizing the futuristic score. In other words, the selected set of locations in this scenario were supposed to solely score the highest in the “futuristic score” criteria:

1. Location: 6 – Piranshahr;
2. Location: 10 – Jolfa;
3. Location: 14 – Astara;
4. Location: 17 – Shiraz;
5. Location: 22 – Bandarabbas;
6. Location: 24 – Isfahan;
7. Location: 26 – Kerman;
8. Location: 28 – Kermanshah;
9. Location: 34 – Mashhad;
10. Location: 35 – Birjand;

11. Location: 38 – Bandarimam;
12. Location: 45 – Babolsar;
13. Location: 52 – Shahrood;
14. Location: 54 – Chabahar;
15. Location: 55 – Zahedan;
16. Location: 59 – Zanjan.

Futuristic Score of this plan: 1030%

TABLE 7. PERFORMANCE OF SINGLE FOCUS ON FS MAXIMIZATION

Focus on Maximizing the FS	Solution Score	Total Accumulated Score of all locations	The Ration of The Solution Score Compared to Accumulated Score	Avg Score of the Solution Set / Location
Futuristic Score	**1030%**	3500%	**29%**	**64%**
Tax Disadvantage Score	490%	1890%	**26%**	**31%**
Establishment Cost	15.700.000,00	52.810.000,00	**30%**	**981250,00**
Accessibility Score	945%	3475%	**27%**	**59%**
Potential Income	3.959.522,17	13.537.928,00	**29%**	**247470,14**

The illustrated set of location scores almost twice as much has the case were simultaneous objectives were requested, however, the average extra score per location is only 14% more than the case where all criteria were considered. Furthermore, although this scenario scores higher in other criteria and accounts for a higher percentage of total available scores, it is not desirable because of the heavy expenses and a higher level of tax disadvantage.

5.4.2 FOCUS ON MINIMIZING THE TAX DISADVANTAGE

The following locations are determined assuming tax disadvantage minimization the only objective of the company by selecting the locations:

1. Location: 3 – Pilesavar;
2. Location: 7 – Sarv;
3. Location: 18 – Laar;
4. Location: 19 – Dashlibron;
5. Location: 29 – Bajgiran;
6. Location: 31 – Taibad;
7. Location: 39 – Khoramshahr;
8. Location: 50 – Qom;
9. Location: 54 – Chabahar;
10. Location: 55 – Zahedan.

Objective Value: 205%

TABLE 8. PERFORMANCE OF SINGLE FOCUS ON TD MINIMIZATION

Focus on Minimizing the TD	Solution Score	Total Accumulated Score of all locations	The Ration of The Solution Score Compared to Accumulated Score	Avg Score of the Solution Set / Location
Futuristic Score	460%	3500%	**13%**	46%
Tax Disadvantage Score	**205%**	1890%	**11%**	20%
Establishment Cost	8.720.000,00	52.810.000,00	**17%**	872000,00
Accessibility Score	560%	3475%	**16%**	56%
Potential Income	2.688.348,52	13.537.928,00	**20%**	268834,85

Obtaining the score of 205% shows that the tax disadvantage has a better situation when the focus is solely on minimizing it. However, the amount of improvement is only 1% compared to the case where all other criteria were considered. Being over budget and having lower futuristic score disqualifies this solution.

5.4.3 FOCUS ON MINIMIZING THE COST

When the company's only objective assumed having the minimum cost of establishment, the following result obtained:

1. Location: 3 - Pilesavar,
2. Location: 5 - Bazargan,
3. Location: 6 - Piranshahr,
4. Location: 19 – Dashlibron,
5. Location: 27 – Khosravi,
6. Location: 43 – Arak,
7. Location: 51 - Semnan,
8. Location: 53 - Iranshahr,
9. Location: 56 – Mirjaveh,
10. Location: 58 – Yazd.

Objective Value: 5,760,000

TABLE 9. PERFORMANCE OF SINGLE FOCUS ON EC MINIMIZATION SOLUTION SET

Focus on Minimizing the EC	Solution Score	Total Accumulated Score of all locations	The Ration of The Solution Score Compared to Accumulated Score	Avg Score of the Solution Set / Location
Futuristic Score	420%	3500%	**12%**	42%
Tax Disadvantage Score	243%	1890%	**13%**	24%
Establishment Cost	**5.760.000,00**	52.810.000,00	**11%**	576000,00
Accessibility Score	510%	3475%	**15%**	51%
Potential Income	1.529.291,24	13.537.928,00	**11%**	152929,12

In this scenario, 10 locations are determined for which the establishment cost is minimum in the expansion project. Although the establishment cost is lower than the case in which all decision criteria were considered, this scenario is not feasible due to having the scores in all other criteria lower than the multi-criteria focused solution.

5.4.4 FOCUS ON MAXIMIZING THE ACCESSIBILITY SCORE

When the focus on expansion project was assumed to be selecting the locations with maximum accessibility score, the following locations were selected:

1. Location: 6 – Piranshahr,
2. Location: 11 – Nordooz,
3. Location: 14 – Astara,
4. Location: 17 – Shiraz,
5. Location: 19 – Dashlibron,
6. Location: 22 – Bandarabbas,
7. Location: 23 – Ilam,
8. Location: 24 – Isfahan,
9. Location: 26 – Kerman,
10. Location: 31 – Taibad,
11. Location: 32 – Sarakhs,
12. Location: 39 – Khoramshahr,
13. Location: 51 – Semnan,
14. Location: 54 – Chabahar,
15. Location: 55 – Zahedan,
16. Location: 59 – Zanjan.

Objective Value: 960%

TABLE 10. PERFORMANCE OF SINGLE FOCUS ON AS MAXIMIZATION SOLUTION SET

Focus on Maximizing the AS	Solution Score	Total Accumulated Score of all locations	The Ration of The Solution Score Compared to Accumulated Score	Avg Score of the Solution Set / Location
Futuristic Score	690%	3500%	**20%**	43%
Tax Disadvantage Score	427%	1890%	**23%**	27%
Establishment Cost	13.300.000,00	52.810.000,00	**25%**	831250,00
Accessibility Score	**960%**	3475%	**28%**	60%
Potential Income	3.515.689,83	13.537.928,00	**26%**	219730,61

In this scenario, the maximum accessibility score can be achieved by the company. However, similar to previous cases, this is not a feasible scenario due to over budget establishment cost, as well as lower futuristic score, and higher tax disadvantage score compared with the multi-criteria focused solution.

5.4.5 FOCUS ON MAXIMIZING THE POTENTIAL INCOME

Aiming to determine a set of the location containing the cities that may deliver the maximum potential income for the company, the following set is determined:

1. Location: 5 – Bazargan,
2. Location: 6 – Piranshahr,
3. Location: 14 – Astara,
4. Location: 17 – Shiraz,
5. Location: 19 – Dashlibron,
6. Location: 22 - Bandarabbas
7. Location: 24 – Isfahan,
8. Location: 26 – Kerman,
9. Location: 27 – Khosravi,
10. Location: 32 – Sarakhs,
11. Location: 35 – Birjand,
12. Location: 36 – Abadan,
13. Location: 53 – Iranshahr,
14. Location: 56 – Mirjaveh,
15. Location: 57 – Tehran.

Objective Value: <u>4.426.865</u>

TABLE 11. PERFORMANCE OF SINGLE FOCUS ON PI MAXIMIZATION SOLUTION SET

Focus on Maximizing the PI	Solution Score	Total Accumulated Score of all locations	The Ration of The Solution Score Compared to Accumulated Score	Avg Score of the Solution Set / Location
Futuristic Score	875%	3500%	**25%**	58%
Tax Disadvantage Score	535%	1890%	**28%**	36%
Establishment Cost	16.570.000,00	52.810.000,00	**31%**	1104666,67
Accessibility Score	909%	280%	**325%**	61%
Potential Income	**4.426.865,00**	13.537.928,00	**33%**	295124,33

The achievable income in this scenario is twice as much as the attainable income when all objectives were considered. However, this scenario is also over budget and with a high tax disadvantage score. While maximizing the income may seem a very good idea, it may not serve the long-term objectives of the organizations very well. Therefore, in most problems, the strategic focus is not solely on maximizing the potential income.

5.5 INTERPRETATION OF THE SOLUTION CONSIDERING THE SENSITIVITY ANALYSIS

A brief look at results of the single focus scenarios and the multi-criteria focus scenarios shows that some of the locations that were selected in the multi-criteria focus, have also been selected in the single criterion focus scenarios. These locations are depicted in table 12.

TABLE 12. REPEATED LOCATIONS IN DIFFERENT SCENARIOS

Selected Locations in Multi-Criteria Focused Solution Approach	*repetition*	*Scenarios in which the location is repeated*
Location: 5	2	Max PI & Min EC
Location: 6	4	Max PI & Max AS & Min EC
Location: 14	3	Max PI & Max AS & Max FS
Location: 18	1	Min TD
Location: 19	4	Max PI &Max AS & Min EC & Min TD
Location: 21	0	--
Location: 26	3	Max PI & Max AS & Max FS
Location: 51	2	Max AS & Min EC
Location: 54	3	Min EC & Min TD & Max FS
Location: 55	3	Max AS & Min TD & Max FS
Location: 57	1	Max PI

In order to provide a better understanding of the effects of having different focuses in solving the location analysis problem on the characteristics of the solution set, a comparison is made between different solutions illustrated in table 13, and 14.

TABLE 13. A COMPARISON BETWEEN THE SCORES IN DIFFERENT FOCUS OF THE SCENARIOS

	The Ration of The Solution Score over Total Available Scores					
	Multi-Criteria Solution	**Focus on Max FS**	**Focus on Min TD**	**Focus on Min EC**	**Focus on Max AS**	**Focus on Max PI**
Futuristic Score	**16%**	**29%**	13%	12%	**20%**	**25%**
Tax Disadvantage Score	**12%**	26%	**11%**	13%	23%	28%
Establishment Cost	**12%**	30%	17%	**11%**	25%	31%
Accessibility Score	**17%**	**27%**	**16%**	15%	**28%**	**325%**
Potential Income	**15%**	**29%**	**20%**	11%	**26%**	**33%**

Table 13 depicts the ratio of the multi-criteria focused solution of the total available score in comparison with the same measure for single criterion focused solutions. In each row, the cells that are highlighted by green represent a better performance and the cells, highlighted by red, show a lower performance in comparison with the multi-criteria focused solution. As can be seen, all single criterion focused solutions are infeasible and dominated by the multi-criteria focused solutions.

TABLE 14. A COMPARISON BETWEEN AVERAGE LOCATION SCORES IN DIFFERENT SCENARIOS

Focus of The Solution	**All Criteria**	**Single Criterion (Max FS)**	**Single Criterion (Min TD)**	**Single Criterion (Min EC)**	**Single Criterion (Max AS)**	**Single Criterion (Max PI)**
Avg. Futuristic Score (FS)	**50%**	64%	46%	42%	43%	58%
Avg. Tax Disadvantage Score (TD)	**21%**	31%	21%	24%	27%	36%
Establishment Cost (EC)	**6.560.000**	15.700.000	8.720.000	5.760.000	13.300.000	16.570.000
Avg. Accessibility Score (AS)	**53%**	59%	56%	51%	60%	60%
Avg. Potential Income (PI)	**164.166,42**	247.470,14	268.834,85	152.929,12	219.730,61	295.124,33
Number of Selected Locations	**11**	16	10	10	16	15
Comment	Best Solution by considering all criteria in acceptable levels	Impossible Because Of The Expenses and High TD	Impossible Because Of The Expenses and Low FS	Possible, But Not Feasible Due to The Low Score in Every Other Criterion	Impossible Because Of The Expenses, Low FS, And, High TD	Impossible Because Of The Expenses and High Td

Table 14, represent a comparison between the average score per locations in different scenarios. At the first glance, the results of the sensitivity analysis indicate that aiming to **maximize** the **potential income**, **futuristic score**, and **accessibility score** immediately leads to selecting **more locations**. This approach **increases** the **cost of investment** as well as **tax disadvantage** and **negatively affect the futuristic score** in some cases. In a strategic prospect, having a large establishment cost as well as high tax disadvantage score are **strong dissatisfiers** for the company. Moreover, the scenarios that would cost more than 7,000,000 euros are simply **not possible** due to the budget limits.

On the contrary, when the focus was on **minimizing** the **establishment cost**, a smaller number of locations were selected. This scenario led to **declining of the potential income**, **futuristic score**, and **accessibility score**. Unlike the previous case, in this situation, the choice is **cheaper but less productive**. Finally, deciding to **minimize the tax disadvantage** declined the tax disadvantage score to the same level as the multi-criteria focused solution but made the establishment cost became much higher, and negatively affected the futuristic score that made this solution infeasible as well.

The conflict between the decision the attractiveness direction in multi criteria decision problem can be solved by moderating the expectations and finding the solutions that satisfy all objectives simultaneously to an acceptable level. In this problem, the design EDSS delivered a solution which as capable to satisfy all criteria on the decisions to an acceptable level for the company. The schematic form of the solution space for this problem is depicted figure 17.

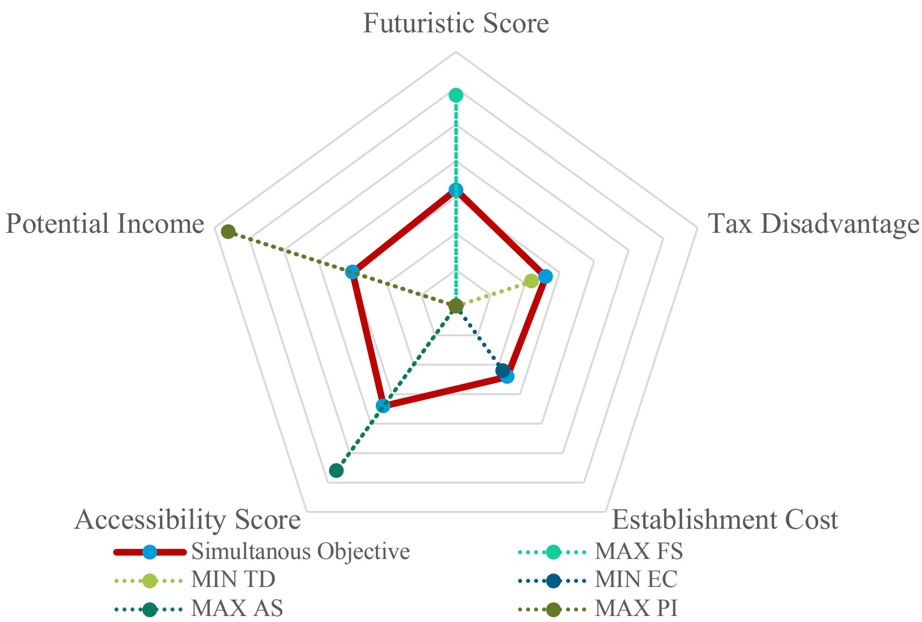

FIGURE 19. THE SOLUTION SPACE OF THE DISCUSSED REAL ESTATE LOCATION DECISION PROBLEM

Since the company had 5 objectives to satisfy, the proposed solution (the closed area in figure 17) is considered a five-dimensional solution which means it suits all 5 objectives of the company simultaneously. Each on the axis in figure 17 depicts a specific dimensioned of the solution. The boundaries of the company's decisions can be seen on five axes represented by dotted lines (corresponding to the performed sensitivity analysis). This dotted lines simply means that if the company dedicate all of its resources to improve the solution in only one direction, how much it can achieve (the extremes of the decisions).

It can easily be seen that in comparison with the extreme cases, the solution set of location satisfies all objective functions to very pleasant extent; the tax disadvantage and establishment cost are slightly larger that extreme minimization case whereas futuristic score, potential income, and accessibility score are nearly half of the individual extreme cases. It means with a reasonable investment the company can win a lot in all five dimensioned and pay a reasonable amount of tax for its activities.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

This Study tackled the problem of real estate location selection in an expansion project for an Investor-Developer-User Organization. The organization objective was to find new locations complying with detailed specifications and decision criteria for making investments in new properties, developing new sits, and utilize them. The set of selected locations had to satisfy the objectives that the company intended to achieve by making new investments. The decision criteria were the **futuristic score**, **tax disadvantage score**, **establishment cost**, **accessibility score**, and the **potential revenue per location** among which, establishment cost and potential revenue had an uncertain and contingent nature. Furthermore, the traveling distance between two neighboring locations had to be at least 400 km.

From a total number of 59 available locations, the company required to determine a suitable number (between 10 to 50) of locations in the current phase of the expansion project with a budget of 7,000,000 euros. While each location had a value or score in each decision criterion (known as locations attributes), the **objective** of the company was to **select a set of location by which the maximum total futuristic score, minimum tax disadvantage score, minimum establishment cost, maximum accessibility score, and maximum potential revenue can be achieved**.

Having several decision criteria, various location attributes, and different objectives to achieve, in addition to uncertain nature of the values of some decision criteria, turned the organization's real estate location selection problem into an “uncertain multi-criteria, multi-objective decision-making problem” with a **limited budget**.

Dealing with the mentioned problem, an expert decision support system (EDSS) based on mathematical modeling of the problem, using fuzzy variables to deal with the uncertain variables was proposed. The proposed **EDSS** took the defined objective, list of alternative locations, and their attributes as the required input for problem-solving, utilized a combination of AHP, Possibilistic approach, and global criterion method to solve the problem, and **delivered the right number of locations, with the right attributes to meet all objectives of the organization to a satisfying level, confirmed by the problem owners**.

The determined set of locations as the solution to the problem comprises 11 locations among which, Tehran already has a functioning establishment. In other words, the company needs to make 10 more investments in the remaining ten cities for developing new properties. The score of the selected set of locations (11 cities) has five dimensions, corresponding to the decision criteria and objectives of the organization. It means although it was not possible to select a solution set with best scores in each and every criterion, due to the contradictory objectives and different attributes of the available alternatives, the selected set of the solution had a satisfactory score in all criteria and satisfied all objectives adequately.

Considering the satisfactory performance of the proposed EDSS, it is safe to say that the proposed solution approach performs well and can be utilized to deal with similar problems.

6.2 RECOMMENDATIONS

Using the technology and innovative problem-solving methods is becoming a popular trend in almost all businesses in today’s world.

One of the most important issues to which new technologies can significantly contribute is the problem of decision making, particularly when the choice between potential alternatives depends on several factors and criteria. For this purpose, a category of technological tools (tech-tools), known as decision support systems, is developed and used in various businesses and industries. However, "facility and real estate management" has so far had a very slow pace in adopting and integrating the new technological tool for dealing with FREM problems and issues especially when it comes to portfolio management and decision making.

Considering the accelerated **development in the market**, **increasing competition level**, and the emergence of the **tech-tools usage in rival businesses**, it becomes **imperative** for the **FREM** organizations to improve the efficiency and performance of their activities by starting to **use more modern tools** in their daily procedures, especially for decision making.

The **tech-tool** that was developed and proposed **in this research** is a **property management tool** for dealing with the problem of **real estate location decision making** which is known as an **expert decision support system (EDSS)**. The proposed solution approach performed well in determining the correct location and satisfying the intended objective of the decision makers of the organization; therefore, it seems safe to say that such system can, and should be utilized in other FREM organization for dealing with such problems.

However, although the developed system in this study performs well, the optimality degree of its outcomes is still unknown. This unclarity is partly due to lack of any comparable results from the past studies, and partly due to existing different solution methods for dealing with the "uncertain multi-criteria, multi-objective decision-making problems" that may, or may not return better results by solving the same problems. Therefore, an attractive topic for **further studies** is to analyze and investigate the same, or similar problems using other **famous methods** (*such as Lexicographic Method; Elimination by Aspects; Permutation Method; Linear Assignment Method; Simple Additive Weighting (SAW); Elimination and Choice Expressing Reality (ELECTRE); Technique for Order Preference by Similarity To Ideal Solution (TOPSIS); Hierarchical Tradeoffs, and Interactive SAW Method*) **for solving the PROM** of the decision support systems in location analysis problems and compare the results with the present study.

Apart from the mentioned technicality, the proposed method in this study can be utilized in the following organizations:

Real Estate Investor: Due to globalization, using objective tools for making location decisions has become more important for the investors rooting around the world. The outcome of this research helps such organizations to determine to what extent and at which locations they should invest in their portfolios. In other words, such tech-tools helps the global organizations to make better decisions with less cost, and more accuracy and efficiency.

Real Estate Developer: One of the most important concerns of the developers when developing a real estate is to attract the investors. Similar to the case of investors, the outcome of this research may help the real estate developers to decide what development project to initiate, at which location, and to what extent of expenditure. Having an objective decision-making tool, instead of using the traditional gut-feeling and subjective ideas, can significantly enhance the decision to buy or not-to-buy as well as develop, or not-to-develop a certain concept for the developer organizations.

Municipalities: Expert decision support systems can help the municipalities to find a proper purpose for the entities in their portfolio respecting the locations (i.e., cinema, park, cultural center, etc.). In other words, each specific location might be suitable to be used for particular purposes. The decision-making tech-tools may help the municipalities to find the best applications for their entities as well as the feasible amount of investment for each entity development project.

Industrial Units: The location of industrial premises has a significant impact on the core business functions including but not limited to having access to suitable infrastructures for logistics and transportations as well as suppliers, right human resource, and etcetera. The right location immediately determines the amount and type of the investment on the real estate, contributing to organization's cost-saving and efficiency improvement.

To sum up, considering the flexibility of the decision support systems and their objectiveness when supporting a decision-making procedure, providing the foundation for developing and employing them for dealing with decision-making problems in different disciplines in FREM organizations is recommended. Furthermore, such support systems might be used for supplier selection, contract management, and ranking and selecting the external service providers in outsourcing procedures. Nevertheless, developing and using the expert decision support systems has several pre-requests. In this regard, there is a need for attracting more talented individuals with modern knowledge into FREM organizations, utilizing more scientific and knowledge-based approaches at the FREM strategic levels, and channelize the available expertise in the organizations to develop more objective tools to support decision-making procedures. Similarly, as the basis of developing such systems is the information and experiences of the experts and people who know the system very well, the FREM organizations need to move towards the setting that stimulates the collaboration and information sharing between the individuals and facilitate the interactions between the experts.

Word Count, Excluding the Appendix, references, summary, and foreword.	
Pages	44
Words	19.138
Characters (no spaces)	105.035
Characters (with spaces)	123.205
Paragraphs	1.245
Lines	2.690

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APPENDIX 1: INVITATION EMAIL TO FILL THE QUESTIONNAIRE

Invitation Email for Filling the Questionnaire

Subject: Required Data for Designing and Running an Expert Decision Support System for Liana Glass Industries in Order to Select the Appropriate Set of Locations for Making Investment in New Properties.

Dear Madam/Sir

Following our interview sessions, the enclosed questionnaire is provided to collect the required data for designing and running an expert decision support system to assist your organization select the best locations in your expansion project.

The research conducted on this problem forms my graduation thesis for the Facility and Real Estate Management at Saxion university of Applied Science and London University of Greenwich.

You can cooperate fully anonymously with this research. The questionnaire will take approximately 45 minutes of your time.

Thank you very much for taking your time

Sincerely,

Sam M. Pour
Facility and Real Estate Management.
Ph.D., Industrial Engineering.
Saxion UAS, Deventer, **Netherlands.**
University of Greenwich, London, **UK.**
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APPENDIX 2: THE QUESTIONNAIRE FOR EXPERT DATA COLLECTION

Developing an uncertainty-proof Expert Decision Support System (EDSS) For Real Estate Location Decision (RELD) for Liana Glass Industries.

By: Sam M. Pour

Dear Madam/Sir,

The following questions intent to collect the required data for designing and running an Expert Decision Support System (EDSS), to assist your organization making the best location decisions when selecting a set of locations in your expansion project in Iran. Please answer to the questions in this questionnaire as accurate as possible to the best of your knowledge.

Q1. Do you approve the following decision criteria based on which, you may or may not select a location?

1. *C1: Futuristic (Advantage) Score*
2. *C2: Tax Disadvantage Score*
3. *C3: Potential Establishment Cost (Fixed Cost)*
4. *C4: Accessibility Score*
5. *C5: Potential Income*

☐ YES

☐ NO

Please specify if any other criteria apply

Q2. Do you approve the following objectives to achieve in decision criteria when selecting a set of location for your expansion project?

1. *Obj1: Maximizing the total Futuristic (Advantage) Score*
2. *Obj2: Minimizing the Total disadvantage Score*
3. *Obj3: Minimizing the Total Potential Establishment Cost (Fixed Cost)*
4. *Obj4Maximizing the Total Accessibility Score*
5. *Obj5: Maximizing the Total potential Income*

☐ YES

☐ NO

Please specify if any other criteria apply

Q3. Between 0.1 to 0.9, please specify what is the importance degree of objectives in comparison with one another using the rows in the following table (e.g. the importance degree of OBJ 1 compared to itself is 1)

	OBJ1	OBJ2	OBJ3	OBJ4	OBJ5
OBJ1	1,0				
OBJ2		1,0			
OBJ3			1,0		
OBJ4				1,0	
OBJ6					1,0

Q4. Between **1** to **100**, what is the **Futuristic (Advantage) Score** of each alternative location, please fill the numbers in the table below (1 indicates the minimum and 100 indicates the maximum Advantage)?

1

District	District's Code	City's Code	Cities	Futuristic score (Advantage Score)
Ardabil	1	1	Ardabil	
		2	Aslandooz	
		3	Pilesavar	
Azarbayejan East	2	4	Oromiye	
		5	Bazargan	
		6	Piranshahr	
		7	Sarv	
		8	Mahabad	
Azarbayejan West	3	9	Tabriz	
		10	Jolfa	
		11	Nordooz	
Boshehr	4	12	Bandarboshehr	
Charmahal and Bakhtiari	5	13	Shahrkord	
Gilan	6	14	Astara	
		15	Bandaranzali	
		16	Rasht	
Fars	7	17	Shiraz	
		18	Laar	
Golestan	8	19	Dashlibron	
		20	Gorgan	
Hamadan	9	21	Hamadan	
Hormozgan	10	22	Bandarabbas	
Ilam	11	23	Ilam	
Isfahan	12	24	Isfahan	
		25	Kashan	
Kerman	13	26	Kerman	
Kermanshah	14	27	Khosravi	
		28	Kermanshah	
Khoorasan	15	29	Bajgiran	
		30	Bojnord	
		31	Taibad	
		32	Sarakhs	
		33	Lotfabad	
		34	Mashhad	
		35	Birjand	
Khoozestan	16	36	Abadan	
		37	Ahwaz	
		38	Bandarimam	
		39	Khoramshahr	
Kohgilooye and Boirahmad	17	40	Yasooj	
Kordestan	18	41	Sanadaj	
Lorestan	19	42	Khoramabad	
Markazi	20	43	Arak	
Mazandaran	21	44	Babol	
		45	Babolsar	
		46	Chaloos	
		47	Ramsar	
		48	Sari	

District	District's Code	City's Code	Cities	Futuristic score (Advantage Score)
Qazvin	22	49	Qazvin	
Qom	23	50	Qom	
Semnan	24	51	Semnan	
		52	Shahrood	
Sistan and Baloochestan	25	53	Iranshahr	
		54	Chabahar	
		55	Zahedan	
		56	Mirjaveh	
Tehran	26	57	Tehran	
Yazd	27	58	Yazd	
Zanjan	28	59	Zanjan	

Q5. In previous question, please indicate if more score makes the location more desirable.

☐ YES

☐ NO

Q6. Between **1** to **100**, what is the **Tax disadvantage score** of each location (1 indicates the minimum and 100 indicates the maximum **disadvantage**)?

District	District's Code	City's Code	Cities	Tax disadvantage score
Ardabil	1	1	Ardabil	
		2	Aslandooz	
		3	Pilesavar	
Azarbayejan East	2	4	Oromiye	
		5	Bazargan	
		6	Piranshahr	
		7	Sarv	
		8	Mahabad	
Azarbayejan West	3	9	Tabriz	
		10	Jolfa	
		11	Nordooz	
Boshehr	4	12	Bandarboshehr	
Charmahal and Bakhtiari	5	13	Shahrkord	
Gilan	6	14	Astara	
		15	Bandaranzali	
		16	Rasht	
Fars	7	17	Shiraz	
		18	Laar	
Golestan	8	19	Dashlibron	
		20	Gorgan	
Hamadan	9	21	Hamadan	
Hormozgan	10	22	Bandarabbas	
Ilam	11	23	Ilam	
Isfahan	12	24	Isfahan	
		25	Kashan	
Kerman	13	26	Kerman	
Kermanshah	14	27	Khosravi	

District	District's Code	City's Code	Cities	Tax disadvantage score
		28	Kermanshah	
Khoorasan	15	29	Bajgiran	
		30	Bojnord	
		31	Taibad	
		32	Sarakhs	
		33	Lotfabad	
		34	Mashhad	
		35	Birjand	
Khoozestan	16	36	Abadan	
		37	Ahwaz	
		38	Bandarimam	
		39	Khoramshahr	
Kohgilooye and Boirahmad	17	40	Yasooj	
Kordestan	18	41	Sanadaj	
Lorestan	19	42	Khoramabad	
Markazi	20	43	Arak	
Mazandaran	21	44	Babol	
		45	Babolsar	
		46	Chaloos	
		47	Ramsar	
		48	Sari	
Qazvin	22	49	Qazvin	
Qom	23	50	Qom	
Semnan	24	51	Semnan	
		52	Shahrood	
Sistan and Baloochestan	25	53	Iranshahr	
		54	Chabahar	
		55	Zahedan	
		56	Mirjaveh	
Tehran	26	57	Tehran	
Yazd	27	58	Yazd	
Zanjan	28	59	Zanjan	

Q7. In previous question, please indicate if more score makes the location more desirable.

☐ YES

☐ NO

Q8. What is the **Interval** for **Establishment Cost/ Square Meter** for each location? Please indicate 4 of the likeliest numbers in the interval including minimum and maximum (*e.g. [145, 165] &145, 150, 155, 165*).

District	District's Code	City's Code	Cities	Establishment Cost/M^2
Ardabil	1	1	Ardabil	[☐ , ☐] & (☐☐☐☐)
		2	Aslandooz	[☐ , ☐] & (☐☐☐☐)
		3	Pilesavar	[☐ , ☐] & (☐☐☐☐)
Azarbayejan East	2	4	Oromiye	[☐ , ☐] & (☐☐☐☐)
		5	Bazargan	[☐ , ☐] & (☐☐☐☐)

District	District's Code	City's Code	Cities	Establishment Cost/M²
		6	Piranshahr	[□ , □] & (□□□□)
		7	Sarv	[□ , □] & (□□□□)
		8	Mahabad	[□ , □] & (□□□□)
Azarbayejan West	3	9	Tabriz	[□ , □] & (□□□□)
		10	Jolfa	[□ , □] & (□□□□)
		11	Nordooz	[□ , □] & (□□□□)
Boshehr	4	12	Bandarboshehr	[□ , □] & (□□□□)
Charmahal and Bakhtiari	5	13	Shahrkord	[□ , □] & (□□□□)
Gilan	6	14	Astara	[□ , □] & (□□□□)
		15	Bandaranzali	[□ , □] & (□□□□)
		16	Rasht	[□ , □] & (□□□□)
Fars	7	17	Shiraz	[□ , □] & (□□□□)
		18	Laar	[□ , □] & (□□□□)
Golestan	8	19	Dashlibron	[□ , □] & (□□□□)
		20	Gorgan	[□ , □] & (□□□□)
Hamadan	9	21	Hamadan	[□ , □] & (□□□□)
Hormozgan	10	22	Bandarabbas	[□ , □] & (□□□□)
Ilam	11	23	Ilam	[□ , □] & (□□□□)
Isfahan	12	24	Isfahan	[□ , □] & (□□□□)
		25	Kashan	[□ , □] & (□□□□)
Kerman	13	26	Kerman	[□ , □] & (□□□□)
Kermanshah	14	27	Khosravi	[□ , □] & (□□□□)
		28	Kermanshah	[□ , □] & (□□□□)
Khoorasan	15	29	Bajgiran	[□ , □] & (□□□□)
		30	Bojnord	[□ , □] & (□□□□)
		31	Taibad	[□ , □] & (□□□□)
		32	Sarakhs	[□ , □] & (□□□□)
		33	Lotfabad	[□ , □] & (□□□□)
		34	Mashhad	[□ , □] & (□□□□)
		35	Birjand	[□ , □] & (□□□□)
Khoozestan	16	36	Abadan	[□ , □] & (□□□□)
		37	Ahwaz	[□ , □] & (□□□□)
		38	Bandarimam	[□ , □] & (□□□□)
		39	Khoramshahr	[□ , □] & (□□□□)
Kohgilooye and Boirahmad	17	40	Yasooj	[□ , □] & (□□□□)

District	District's Code	City's Code	Cities	Establishment Cost/M²
Kordestan	18	41	Sanadaj	[□ , □] & (□□□□)
Lorestan	19	42	Khoramabad	[□ , □] & (□□□□)
Markazi	20	43	Arak	[□ , □] & (□□□□)
Mazandaran	21	44	Babol	[□ , □] & (□□□□)
		45	Babolsar	[□ , □] & (□□□□)
		46	Chaloos	[□ , □] & (□□□□)
		47	Ramsar	[□ , □] & (□□□□)
		48	Sari	[□ , □] & (□□□□)
Qazvin	22	49	Qazvin	[□ , □] & (□□□□)
Qom	23	50	Qom	[□ , □] & (□□□□)
Semnan	24	51	Semnan	[□ , □] & (□□□□)
		52	Shahrood	[□ , □] & (□□□□)
Sistan and Baloochestan	25	53	Iranshahr	[□ , □] & (□□□□)
		54	Chabahar	[□ , □] & (□□□□)
		55	Zahedan	[□ , □] & (□□□□)
		56	Mirjaveh	[□ , □] & (□□□□)
Tehran	26	57	Tehran	[□ , □] & (□□□□)
Yazd	27	58	Yazd	[□ , □] & (□□□□)
Zanjan	28	59	Zanjan	[□ , □] & (□□□□)

Q9. In previous question, please indicate if higher cost makes the location more desirable

- ☐ YES
- ☐ NO

Q10. What is the required **Size of the Potential Establishment** in each district and how do you categorize them (L: Large, M: Medium, S: Small)?

District	District's Code	City's Code	Cities	Required Size (M²)	Category (L, M, S)
Ardabil	1	1	Ardabil		
		2	Aslandooz		
		3	Pilesavar		
Azarbayejan East	2	4	Oromiye		
		5	Bazargan		
		6	Piranshahr		
		7	Sarv		
		8	Mahabad		
Azarbayejan West	3	9	Tabriz		
		10	Jolfa		
		11	Nordooz		
Boshehr	4	12	Bandarboshehr		
Charmahal and Bakhtiari	5	13	Shahrkord		
Gilan	6	14	Astara		

District	District 's Code	City's Code	Cities	Required Size (M^2)	Category (L, M, S)
		15	Bandaranzali		
		16	Rasht		
Fars	7	17	Shiraz		
		18	Laar		
Golestan	8	19	Dashlibron		
		20	Gorgan		
Hamadan	9	21	Hamadan		
Hormozgan	10	22	Bandarabbas		
Ilam	11	23	Ilam		
Isfahan	12	24	Isfahan		
		25	Kashan		
Kerman	13	26	Kerman		
Kermanshah	14	27	Khosravi		
		28	Kermanshah		
Khoorasan	15	29	Bajgiran		
		30	Bojnord		
		31	Taibad		
		32	Sarakhs		
		33	Lotfabad		
		34	Mashhad		
		35	Birjand		
Khoozestan	16	36	Abadan		
		37	Ahwaz		
		38	Bandarimam		
		39	Khoramshahr		
Kohgilooye and Boirahmad	17	40	Yasooj		
Kordestan	18	41	Sanadaj		
Lorestan	19	42	Khoramabad		
Markazi	20	43	Arak		
Mazandaran	21	44	Babol		
		45	Babolsar		
		46	Chaloos		
		47	Ramsar		
		48	Sari		
Qazvin	22	49	Qazvin		
Qom	23	50	Qom		
Semnan	24	51	Semnan		
		52	Shahrood		
Sistan and Baloochestan	25	53	Iranshahr		
		54	Chabahar		
		55	Zahedan		
		56	Mirjaveh		
Tehran	26	57	Tehran		
Yazd	27	58	Yazd		
Zanjan	28	59	Zanjan		

Q11. Between **1** to **100**, what is the **Accessibility score** of each location (1 indicates the minimum and 100 indicates the maximum **Accessibility**)?

District	District's Code	City's Code	Cities	Accessibility score
Ardabil	1	1	Ardabil	
		2	Aslandooz	
		3	Pilesavar	
Azarbayejan East	2	4	Oromiye	
		5	Bazargan	
		6	Piranshahr	
		7	Sarv	
		8	Mahabad	
Azarbayejan West	3	9	Tabriz	
		10	Jolfa	
		11	Nordooz	
Boshehr	4	12	Bandarboshehr	
Charmahal and Bakhtiari	5	13	Shahrkord	
Gilan	6	14	Astara	
		15	Bandaranzali	
		16	Rasht	
Fars	7	17	Shiraz	
		18	Laar	
Golestan	8	19	Dashlibron	
		20	Gorgan	
Hamadan	9	21	Hamadan	
Hormozgan	10	22	Bandarabbas	
Ilam	11	23	Ilam	
Isfahan	12	24	Isfahan	
		25	Kashan	
Kerman	13	26	Kerman	
Kermanshah	14	27	Khosravi	
		28	Kermanshah	
Khoorasan	15	29	Bajgiran	
		30	Bojnord	
		31	Taibad	
		32	Sarakhs	
		33	Lotfabad	
		34	Mashhad	
		35	Birjand	
Khoozestan	16	36	Abadan	
		37	Ahwaz	
		38	Bandarimam	
		39	Khoramshahr	
Kohgilooye and Boirahmad	17	40	Yasooj	
Kordestan	18	41	Sanadaj	
Lorestan	19	42	Khoramabad	
Markazi	20	43	Arak	
Mazandaran	21	44	Babol	
		45	Babolsar	
		46	Chaloos	
		47	Ramsar	
		48	Sari	
Qazvin	22	49	Qazvin	

District	District's Code	City's Code	Cities	Accessibility score
Qom	23	50	Qom	
Semnan	24	51	Semnan	
		52	Shahrood	
Sistan and Baloochestan	25	53	Iranshahr	
		54	Chabahar	
		55	Zahedan	
		56	Mirjaveh	
Tehran	26	57	Tehran	
Yazd	27	58	Yazd	
Zanjan	28	59	Zanjan	

Q12. In previous question, please indicate if more score makes the location more desirable.

☐ YES

☐ NO

Q13. What is the **Interval** of the LGI's **Expected Income** in each district? Please indicate 4 of the likeliest numbers in the interval including minimum and maximum (*e.g. [6500K, 12000K] &5000K, 6000K, 8000K, 10000K*).

District	District's Code	City's Code	Cities	Potential Income
Ardabil	1	1	Ardabil	[☐ , ☐] & (☐☐☐☐)
		2	Aslandooz	[☐ , ☐] & (☐☐☐☐)
		3	Pilesavar	[☐ , ☐] & (☐☐☐☐)
Azarbayejan East	2	4	Oromiye	[☐ , ☐] & (☐☐☐☐)
		5	Bazargan	[☐ , ☐] & (☐☐☐☐)
		6	Piranshahr	[☐ , ☐] & (☐☐☐☐)
		7	Sarv	[☐ , ☐] & (☐☐☐☐)
		8	Mahabad	[☐ , ☐] & (☐☐☐☐)
Azarbayejan West	3	9	Tabriz	[☐ , ☐] & (☐☐☐☐)
		10	Jolfa	[☐ , ☐] & (☐☐☐☐)
		11	Nordooz	[☐ , ☐] & (☐☐☐☐)
Boshehr	4	12	Bandarboshehr	[☐ , ☐] & (☐☐☐☐)
Charmahal and Bakhtiari	5	13	Shahrkord	[☐ , ☐] & (☐☐☐☐)
Gilan	6	14	Astara	[☐ , ☐] & (☐☐☐☐)
		15	Bandaranzali	[☐ , ☐] & (☐☐☐☐)
		16	Rasht	[☐ , ☐] & (☐☐☐☐)
Fars	7	17	Shiraz	[☐ , ☐] & (☐☐☐☐)
		18	Laar	[☐ , ☐] & (☐☐☐☐)
Golestan	8	19	Dashlibron	[☐ , ☐] & (☐☐☐☐)
		20	Gorgan	[☐ , ☐] & (☐☐☐☐)
Hamadan	9	21	Hamadan	[☐ , ☐] & (☐☐☐☐)
Hormozgan	10	22	Bandarabbas	[☐ , ☐] & (☐☐☐☐)

District	District's Code	City's Code	Cities	Potential Income
Ilam	11	23	Ilam	[☐ , ☐] & (☐☐☐☐)
Isfahan	12	24	Isfahan	[☐ , ☐] & (☐☐☐☐)
		25	Kashan	[☐ , ☐] & (☐☐☐☐)
Kerman	13	26	Kerman	[☐ , ☐] & (☐☐☐☐)
Kermanshah	14	27	Khosravi	[☐ , ☐] & (☐☐☐☐)
		28	Kermanshah	[☐ , ☐] & (☐☐☐☐)
Khoorasan	15	29	Bajgiran	[☐ , ☐] & (☐☐☐☐)
		30	Bojnord	[☐ , ☐] & (☐☐☐☐)
		31	Taibad	[☐ , ☐] & (☐☐☐☐)
		32	Sarakhs	[☐ , ☐] & (☐☐☐☐)
		33	Lotfabad	[☐ , ☐] & (☐☐☐☐)
		34	Mashhad	[☐ , ☐] & (☐☐☐☐)
		35	Birjand	[☐ , ☐] & (☐☐☐☐)
Khoozestan	16	36	Abadan	[☐ , ☐] & (☐☐☐☐)
		37	Ahwaz	[☐ , ☐] & (☐☐☐☐)
		38	Bandarimam	[☐ , ☐] & (☐☐☐☐)
		39	Khoramshahr	[☐ , ☐] & (☐☐☐☐)
Kohgilooye and Boirahmad	17	40	Yasooj	[☐ , ☐] & (☐☐☐☐)
Kordestan	18	41	Sanadaj	[☐ , ☐] & (☐☐☐☐)
Lorestan	19	42	Khoramabad	[☐ , ☐] & (☐☐☐☐)
Markazi	20	43	Arak	[☐ , ☐] & (☐☐☐☐)
Mazandaran	21	44	Babol	[☐ , ☐] & (☐☐☐☐)
		45	Babolsar	[☐ , ☐] & (☐☐☐☐)
		46	Chaloos	[☐ , ☐] & (☐☐☐☐)
		47	Ramsar	[☐ , ☐] & (☐☐☐☐)
		48	Sari	[☐ , ☐] & (☐☐☐☐)
Qazvin	22	49	Qazvin	[☐ , ☐] & (☐☐☐☐)
Qom	23	50	Qom	[☐ , ☐] & (☐☐☐☐)
Semnan	24	51	Semnan	[☐ , ☐] & (☐☐☐☐)
		52	Shahrood	[☐ , ☐] & (☐☐☐☐)
Sistan and Baloochestan	25	53	Iranshahr	[☐ , ☐] & (☐☐☐☐)
		54	Chabahar	[☐ , ☐] & (☐☐☐☐)
		55	Zahedan	[☐ , ☐] & (☐☐☐☐)
		56	Mirjaveh	[☐ , ☐] & (☐☐☐☐)
Tehran	26	57	Tehran	[☐ , ☐] & (☐☐☐☐)
Yazd	27	58	Yazd	[☐ , ☐] & (☐☐☐☐)
Zanjan	28	59	Zanjan	[☐ , ☐] & (☐☐☐☐)

Q14. In previous question, please indicate if more score makes the location more desirable.

☐ YES

☐ NO

APPENDIX 3: THE CHARACTERISTICS & SCORES OF THE LOCATIONS AS THE PROBLEMS INPUT

TABLE 15. LOCATIONS DECISION CRITERIA C1 & C2

Districts				Cities	C1 Futuristic score	C2 Tax Disadvantage Score
Ardabil	1	1	1	Ardabil	60%	167
		2	2	Aslandooz	30%	333
		3	3	Pilesavar	30%	333
Azarbayejan East	2	1	4	Oromiye	60%	167
		2	5	Bazargan	60%	167
		3	6	Piranshahr	20%	500
		4	7	Sarv	20%	500
		5	8	Mahabad	50%	200
Azarbayejan West	3	1	9	Tabriz	80%	125
		2	10	Jolfa	70%	143
		3	11	Nordooz	60%	167
Boshehr	4	1	12	Bandarboshehr	75%	133
Charmahal and Bakhtiari	5	1	13	Shahrkord	60%	167
Gilan	6	1	14	Astara	60%	167
		2	15	Bandaranzali	60%	167
		3	16	Rasht	80%	125
Fars	7	1	17	Shiraz	90%	111
		2	18	Laar	80%	125
Golestan	8	1	19	Dashlibron	50%	200
		2	20	Gorgan	70%	143
Hamadan	9	1	21	Hamadan	75%	133
Hormozgan	10	1	22	Bandarabbas	75%	133
Ilam	11	1	23	Ilam	45%	222
Isfahan	12	1	24	Isfahan	90%	111
		2	25	Kashan	70%	143
Kerman	13	1	26	Kerman	50%	200
Kermanshah	14	1	27	Khosravi	50%	200
		2	28	Kermanshah	70%	143
Khoorasan	15	1	29	Bajgiran	30%	333
		2	30	Bojnord	30%	333
		3	31	Taibad	30%	333

					C1	C2
Districts				Cities	Futuristic score	Tax Disadvantage Score
		4	32	Sarakhs	30%	333
		5	33	Lotfabad	30%	333
		6	34	Mashhad	80%	125
		7	35	Birjand	50%	200
Khoozestan	16	1	36	Abadan	70%	143
		2	37	Ahwaz	75%	133
		3	38	Bandarimam	80%	125
		4	39	Khoramshahr	70%	143
Kohgilooye and Boirahmad	17	1	40	Yasooj	60%	167
Kordestan	18	1	41	Sanadaj	60%	167
Lorestan	19	1	42	Khoramabad	60%	167
Markazi	20	1	43	Arak	60%	167
Mazandaran	21	1	44	Babol	60%	167
		2	45	Babolsar	60%	167
		3	46	Chaloos	70%	143
		4	47	Ramsar	80%	125
		5	48	Sari	80%	125
Qazvin	22	1	49	Qazvin	70%	143
Qom	23	1	50	Qom	40%	250
Semnan	24	1	51	Semnan	50%	200
		2	52	Shahrood	50%	200
Sistan and Baloochestan	25	1	53	Iranshahr	50%	200
		2	54	Chabahar	60%	167
		3	55	Zahedan	50%	200
		4	56	Mirjaveh	30%	333
Tehran	26	1	57	Tehran	100%	100
Yazd	27	1	58	Yazd	70%	143
Zanjan	28	1	59	Zanjan	75%	133

TABLE 16. INTERVAL OF ESTABLISHMENT COST PER LOCATION

Districts				Cities	Fuzzy Establishment cost / square meter			
Ardabil	1	1	1	Ardabil	€ 145	€ 150	€ 160	€ 165

		2	2	Aslandooz	€ 125	€ 130	€ 140	€ 145
		3	3	Pilesavar	€ 125	€ 130	€ 140	€ 145
Azarbayejan East	2	1	4	Oromiye	€ 165	€ 170	€ 175	€ 180
		2	5	Bazargan	€ 145	€ 150	€ 160	€ 165
		3	6	Piranshahr	€ 125	€ 130	€ 140	€ 145
		4	7	Sarv	€ 125	€ 130	€ 140	€ 145
		5	8	Mahabad	€ 145	€ 150	€ 160	€ 165
Azarbayejan West	3	1	9	Tabriz	€ 165	€ 170	€ 175	€ 180
		2	10	Jolfa	€ 125	€ 130	€ 140	€ 145
		3	11	Nordooz	€ 125	€ 130	€ 140	€ 145
Boshehr	4	1	12	Bandarboshehr	€ 165	€ 170	€ 175	€ 180
Charmahal and Bakhtiari	5	1	13	Shahrkord	€ 145	€ 150	€ 160	€ 165
Gilan	6	1	14	Astara	€ 145	€ 150	€ 160	€ 165
		2	15	Bandaranzali	€ 145	€ 150	€ 160	€ 165
		3	16	Rasht	€ 165	€ 170	€ 175	€ 180
Fars	7	1	17	Shiraz	€ 210	€ 215	€ 225	€ 230
		2	18	Laar	€ 145	€ 150	€ 160	€ 165
Golestan	8	1	19	Dashlibron	€ 125	€ 130	€ 140	€ 145
		2	20	Gorgan	€ 145	€ 150	€ 160	€ 165
Hamadan	9	1	21	Hamadan	€ 125	€ 130	€ 140	€ 145
Hormozgan	10	1	22	Bandarabbas	€ 165	€ 170	€ 175	€ 180
Ilam	11	1	23	Ilam	€ 125	€ 130	€ 140	€ 145

Isfahan	12	1	24	Isfahan	€ 210	€ 215	€ 225	€ 230
		2	25	Kashan	€ 145	€ 150	€ 160	€ 165
Kerman	13	1	26	Kerman	€ 145	€ 150	€ 160	€ 165
Kermanshah	14	1	27	Khosravi	€ 125	€ 130	€ 140	€ 145
		2	28	Kermanshah	€ 125	€ 130	€ 140	€ 145
Khoorasan	15	1	29	Bajgiran	€ 125	€ 130	€ 140	€ 145
		2	30	Bojnord	€ 125	€ 130	€ 140	€ 145
		3	31	Taibad	€ 125	€ 130	€ 140	€ 145
		4	32	Sarakhs	€ 125	€ 130	€ 140	€ 145
		5	33	Lotfabad	€ 125	€ 130	€ 140	€ 145
		6	34	Mashhad	€ 210	€ 215	€ 225	€ 230
		7	35	Birjand	€ 165	€ 170	€ 175	€ 180
Khoozestan	16	1	36	Abadan	€ 165	€ 170	€ 175	€ 180
		2	37	Ahwaz	€ 165	€ 170	€ 175	€ 180
		3	38	Bandarimam	€ 135	€ 140	€ 150	€ 155
		4	39	Khoramshahr	€ 145	€ 150	€ 160	€ 165
Kohgilooye and Boirahmad	17	1	40	Yasooj	€ 145	€ 150	€ 160	€ 165
Kordestan	18	1	41	Sanadaj	€ 165	€ 170	€ 175	€ 180
Lorestan	19	1	42	Khoramabad	€ 145	€ 150	€ 160	€ 165
Markazi	20	1	43	Arak	€ 125	€ 130	€ 140	€ 145
Mazandaran	21	1	44	Babol	€ 125	€ 130	€ 140	€ 145
		2	45	Babolsar	€ 125	€ 130	€ 140	€ 145

		3	46	Chaloos	€ 165	€ 170	€ 175	€ 180
		4	47	Ramsar	€ 165	€ 170	€ 175	€ 180
		5	48	Sari	€ 165	€ 170	€ 175	€ 180
Qazvin	22	1	49	Qazvin	€ 145	€ 150	€ 160	€ 165
Qom	23	1	50	Qom	€ 125	€ 130	€ 140	€ 145
Semnan	24	1	51	Semnan	€ 125	€ 130	€ 140	€ 145
		2	52	Shahrood	€ 145	€ 150	€ 160	€ 165
Sistan and Baloochestan	25	1	53	Iranshahr	€ 125	€ 130	€ 140	€ 145
		2	54	Chabahar	€ 125	€ 130	€ 140	€ 145
		3	55	Zahedan	€ 125	€ 130	€ 140	€ 145
		4	56	Mirjaveh	€ 125	€ 130	€ 140	€ 145
Tehran	26	1	57	Tehran	€ 210	€ 215	€ 225	€ 230
Yazd	27	1	58	Yazd	€ 145	€ 150	€ 160	€ 165
Zanjan	28	1	59	Zanjan	€ 145	€ 150	€ 160	€ 165

TABLE 17. REQUIRED SIZE OF THE ESTABLISHMENT / LOCATION, AND DECISION CRITERIA C3 & C4

							C3	**C4**
Districts				Cities	Required size of the establishment per location	Scale of the required establishment	Expected value of the total establishment cost per location	Accessibility score
Ardabil	1	1	1	Ardabil	400	small	€ 64.000	50%
		2	2	Aslandooz	400	small	€ 56.000	50%
		3	3	Pilesavar	400	small	€ 56.000	50%
Azarbayejan East	2	1	4	Oromiye	400	small	€ 70.000	60%
		2	5	Bazargan	400	small	€ 64.000	60%

							C3	C4
Districts				Cities	Required size of the establishment per location	Scale of the required establishment	Expected value of the total establishment cost per location	Accessibility score
		3	6	Piranshahr	400	small	€ 56.000	60%
		4	7	Sarv	400	small	€ 56.000	60%
		5	8	Mahabad	400	small	€ 64.000	60%
Azarbayejan West	3	1	9	Tabriz	600	small	€ 105.000	75%
		2	10	Jolfa	600	small	€ 84.000	75%
		3	11	Nordooz	600	small	€ 84.000	75%
Boshehr	4	1	12	Bandarboshehr	400	small	€ 70.000	60%
Charmahal and Bakhtiari	5	1	13	Shahrkord	400	small	€ 64.000	40%
Gilan	6	1	14	Astara	400	small	€ 64.000	70%
		2	15	Bandaranzali	400	small	€ 64.000	70%
		3	16	Rasht	400	small	€ 70.000	70%
Fars	7	1	17	Shiraz	800	Medium	€ 180.000	80%
		2	18	Laar	800	Medium	€ 128.000	80%
Golestan	8	1	19	Dashlibron	400	small	€ 56.000	75%
		2	20	Gorgan	400	small	€ 64.000	75%
Hamadan	9	1	21	Hamadan	400	small	€ 56.000	60%
Hormozgan	10	1	22	Bandarabbas	400	small	€ 70.000	65%
Ilam	11	1	23	Ilam	400	small	€ 56.000	40%
Isfahan	12	1	24	Isfahan	800	Medium	€ 180.000	80%

							C3	C4
Districts				Cities	Required size of the establishment per location	Scale of the required establishment	Expected value of the total establishment cost per location	Accessibility score
		2	25	Kashan	800	Medium	€ 128.000	80%
Kerman	13	1	26	Kerman	400	small	€ 64.000	50%
Kermanshah	14	1	27	Khosravi	400	small	€ 56.000	30%
		2	28	Kermanshah	400	small	€ 56.000	30%
Khoorasan	15	1	29	Bajgiran	1000	Large	€ 140.000	65%
		2	30	Bojnord	1000	Large	€ 140.000	65%
		3	31	Taibad	1000	Large	€ 140.000	65%
		4	32	Sarakhs	1000	Large	€ 140.000	65%
		5	33	Lotfabad	1000	Large	€ 140.000	65%
		6	34	Mashhad	1000	Large	€ 225.000	65%
		7	35	Birjand	1000	Large	€ 175.000	65%
Khoozestan	16	1	36	Abadan	800	Medium	€ 140.000	55%
		2	37	Ahwaz	800	Medium	€ 140.000	55%
		3	38	Bandarimam	800	Medium	€ 120.000	55%
		4	39	Khoramshahr	800	Medium	€ 128.000	55%
Kohgilooye and Boirahmad	17	1	40	Yasooj	400	small	€ 64.000	35%
Kordestan	18	1	41	Sanadaj	400	small	€ 70.000	45%
Lorestan	19	1	42	Khoramabad	400	small	€ 64.000	40%
Markazi	20	1	43	Arak	400	small	€ 56.000	50%

							C3	C4
Districts				Cities	Required size of the establishment per location	Scale of the required establishment	Expected value of the total establishment cost per location	Accessibility score
Mazandaran	21	1	44	Babol	400	small	€ 56.000	70%
		2	45	Babolsar	400	small	€ 56.000	70%
		3	46	Chaloos	400	small	€ 70.000	70%
		4	47	Ramsar	400	small	€ 70.000	70%
		5	48	Sari	400	small	€ 70.000	70%
Qazvin	22	1	49	Qazvin	400	small	€ 64.000	75%
Qom	23	1	50	Qom	400	small	€ 56.000	40%
Semnan	24	1	51	Semnan	400	small	€ 56.000	55%
		2	52	Shahrood	400	small	€ 64.000	55%
Sistan and Baloochestan	25	1	53	Iranshahr	400	small	€ 56.000	35%
		2	54	Chabahar	400	small	€ 56.000	35%
		3	55	Zahedan	400	small	€ 56.000	35%
		4	56	Mirjaveh	400	small	€ 56.000	35%
Tehran	26	1	57	Tehran	3500	Large	€ 300.000	70%
Yazd	27	1	58	Yazd	400	small	€ 64.000	60%
Zanjan	28	1	59	Zanjan	400	small	€ 64.000	55%

TABLE 18. INTERVAL OF POTENTIAL INCOME AND DECISION CRITERIA C5

Districts				Cities	Interval of the potential income				C5 Expected Value of the Potential Income
Ardabil	1	1	1	Ardabil	6479142	7774970,4	10366627,2	12958284	€ 77.750
		2	2	Aslandooz	6479142	7774970,4	10366627,2	12958284	€ 77.750
		3	3	Pilesavar	6479142	7774970,4	10366627,2	12958284	€ 77.750
Azarbayejan East	2	1	4	Oromiye	19939225,2	23927070,24	31902760,32	39878450,4	€ 319.028
		2	5	Bazargan	19939225,2	23927070,24	31902760,32	39878450,4	€ 319.028
		3	6	Piranshahr	19939225,2	23927070,24	31902760,32	39878450,4	€ 319.028
		4	7	Sarv	19939225,2	23927070,24	31902760,32	39878450,4	€ 319.028
		5	8	Mahabad	19939225,2	23927070,24	31902760,32	39878450,4	€ 319.028
Azarbayejan West	3	1	9	Tabriz	16652616,9	19983140,28	26644187,04	33305233,8	€ 199.831
		2	10	Jolfa	16652616,9	19983140,28	26644187,04	33305233,8	€ 199.831
		3	11	Nordooz	16652616,9	19983140,28	26644187,04	33305233,8	€ 199.831
Boshehr	4	1	12	Bandarboshehr	5933340	7120008	9493344	11866680	€ 71.200
Charmahal and Bakhtiari	5	1	13	Shahrkord	4833591,3	5800309,56	7733746,08	9667182,6	€ 58.003
Gilan	6	1	14	Astara	12952449,6	15542939,52	20723919,36	25904899,2	€ 155.429
		2	15	Bandaranzali	12952449,6	15542939,52	20723919,36	25904899,2	€ 155.429
		3	16	Rasht	12952449,6	15542939,52	20723919,36	25904899,2	€ 155.429
Fars	7	1	17	Shiraz	24741497,4	29689796,88	39586395,84	49482994,8	€ 395.864
		2	18	Laar	24741497,4	29689796,88	39586395,84	49482994,8	€ 395.864

									C5
Districts				Cities	Interval of the potential income				Expected Value of the Potential Income
Golestan	8	1	19	Dashlibron	9529956,9	11435948,28	15247931,04	19059913,8	€ 114.359
		2	20	Gorgan	9529956,9	11435948,28	15247931,04	19059913,8	€ 114.359
Hamadan	9	1	21	Hamadan	8864891,4	10637869,68	14183826,24	17729782,8	€ 106.379
Hormozgan	10	1	22	Bandarabbas	9059716,5	10871659,8	14495546,4	18119433	€ 108.717
Ilam	11	1	23	Ilam	2958805,8	3550566,96	4734089,28	5917611,6	€ 35.506
Isfahan	12	1	24	Isfahan	26116335	31339602	41786136	52232670	€ 417.861
		2	25	Kashan	26116335	31339602	41786136	52232670	€ 417.861
Kerman	13	1	26	Kerman	16140061,8	19368074,16	25824098,88	32280123,6	€ 193.681
Kermanshah	14	1	27	Khosravi	9957413,4	11948896,08	15931861,44	19914826,8	€ 159.319
		2	28	Kermanshah	9957413,4	11948896,08	15931861,44	19914826,8	€ 159.319
Khoorasan	15	1	29	Bajgiran	30569400	36683280	48911040	61138800	€ 489.110
		2	30	Bojnord	30569400	36683280	48911040	61138800	€ 489.110
		3	31	Taibad	30569400	36683280	48911040	61138800	€ 489.110
		4	32	Sarakhs	30569400	36683280	48911040	61138800	€ 489.110
		5	33	Lotfabad	30569400	36683280	48911040	61138800	€ 489.110
		6	34	Mashhad	30569400	36683280	48911040	61138800	€ 489.110
		7	35	Birjand	30569400	36683280	48911040	61138800	€ 489.110
Khoozestan	16	1	36	Abadan	24023595,9	28828315,08	38437753,44	48047191,8	€ 384.378
		2	37	Ahwaz	24023595,9	28828315,08	38437753,44	48047191,8	€ 384.378

									C5
Districts				Cities	Interval of the potential income				Expected Value of the Potential Income
		3	38	Bandarimam	24023595,9	28828315,08	38437753,44	48047191,8	€ 384.378
		4	39	Khoramshahr	24023595,9	28828315,08	38437753,44	48047191,8	€ 384.378
Kohgilooye and Boirahmad	17	1	40	Yasooj	3636565,2	4363878,24	5818504,32	7273130,4	€ 43.639
Kordestan	18	1	41	Sanadaj	8175356,1	9810427,32	13080569,76	16350712,2	€ 98.104
Lorestan	19	1	42	Khoramabad	8979309,9	10775171,88	14366895,84	17958619,8	€ 107.752
Markazi	20	1	43	Arak	7290322,5	8748387	11664516	14580645	€ 87.484
Mazandaran	21	1	44	Babol	16652616,9	19983140,28	26644187,04	33305233,8	€ 199.831
		2	45	Babolsar	16652616,9	19983140,28	26644187,04	33305233,8	€ 199.831
		3	46	Chaloos	16652616,9	19983140,28	26644187,04	33305233,8	€ 199.831
		4	47	Ramsar	16652616,9	19983140,28	26644187,04	33305233,8	€ 199.831
		5	48	Sari	16652616,9	19983140,28	26644187,04	33305233,8	€ 199.831
Qazvin	22	1	49	Qazvin	6496181,1	7795417,32	10393889,76	12992362,2	€ 77.954
Qom	23	1	50	Qom	6590643,3	7908771,96	10545029,28	13181286,6	€ 79.088
Semnan	24	1	51	Semnan	3582036	4298443,2	5731257,6	7164072	€ 42.984
		2	52	Shahrood	3582036	4298443,2	5731257,6	7164072	€ 42.984
Sistan and Baloochestan	25	1	53	Iranshahr	14152571,4	16983085,68	22644114,24	28305142,8	€ 169.831
		2	54	Chabahar	14152571,4	16983085,68	22644114,24	28305142,8	€ 169.831
		3	55	Zahedan	14152571,4	16983085,68	22644114,24	28305142,8	€ 169.831
		4	56	Mirjaveh	14152571,4	16983085,68	22644114,24	28305142,8	€ 169.831

									C5
Districts				Cities	Interval of the potential income				Expected Value of the Potential Income
Tehran	26	1	57	Tehran	67664948,7	81197938,44	108263917,9	135329897,4	€ 541.320
Yazd	27	1	58	Yazd	5806518,3	6967821,96	9290429,28	11613036,6	€ 69.678
Zanjan	28	1	59	Zanjan	5393051,1	6471661,32	8628881,76	10786102,2	€ 64.717

APPENDIX 4: THE DISTANCE BETWEEN LOCATIONS

Locations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
1	0	207	155	527	499	515	580	435	219	354	333	1610	1134	77	226	266	1515	1879	887	764	667	1925	975	1030	837	1629	978	791	1269	1080	1557	1518	1332	1333	1814	1401	1305	1453	1403	1329	655	930	843	592	568	470	387	634	451	723	828	977	2181	2552	2158	2242	591	1268	377
2	207	0	121	543	515	586	596	506	290	235	172	1850	1433	284	433	433	1813	2177	1094	971	874	2223	1062	1328	1044	1836	1065	958	1476	1287	2007	1725	1539	1540	2202	1488	1365	1540	1485	1987	742	1169	1075	799	775	636	554	841	618	930	1125	1144	2479	2850	2456	2540	798	1475	570
3	155	121	0	664	636	670	717	590	374	356	293	1945	1289	232	381	421	1670	2034	1042	919	822	2080	1130	1185	992	1784	1133	946	1424	1235	1712	1673	1487	1488	1969	1743	1620	1795	1558	1484	810	1085	998	747	723	625	543	789	606	878	982	1132	2336	2707	2313	2397	746	1423	532
4	527	543	664	0	314	119	53	123	308	308	371	1549	1178	604	753	793	1559	1923	1427	1304	610	2026	766	1074	1153	1735	769	582	1809	1620	2025	1986	1800	1801	2220	1192	1064	1239	1189	1373	446	783	786	1136	1116	997	914	1174	763	1039	1143	1319	2287	2614	2264	2348	907	1374	588
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54	2552	2850	2707	2614	2658	2599	2667	2512	2560	2695	2578	1798	1688	2475	2326	2286	1494	1482	2284	2216	2048	1137	2262	1584	1655	923	2839	2211	1879	1900	1871	1832	1936	1647	1166	2088	2153	2009	2107	1668	2212	1954	1872	2190	2210	2170	2252	2228	2028	1769	2197	2049	371	0	696	780	1961	1284	2280
55	2158	2456	2313	2264	2446	2205	2317	2118	2166	2301	2364	1404	1294	2081	1932	1892	1100	1088	1588	1520	1654	743	1868	1190	1261	529	1871	1817	1183	1204	1175	1136	1240	951	470	1694	1759	1615	1713	1274	1818	1560	1478	1692	1712	1776	1858	1650	1717	1375	1609	1353	325	696	0	84	1567	890	1886
56	2242	2540	2397	2348	2530	2289	2401	2202	2250	2385	2448	1488	1378	2165	2016	1976	1184	1172	1672	1604	1738	827	1952	1274	1345	613	1955	1901	1267	1288	1259	1220	1324	1035	554	1778	1843	1699	1797	1358	1902	1644	1562	1776	1796	1860	1942	1734	1785	1459	1693	1519	409	780	84	0	1651	974	1970
57	591	798	746	907	879	774	960	687	599	734	797	1228	543	514	365	325	924	1288	520	397	337	1334	710	439	246	1038	713	526	902	713	1118	1079	893	894	1313	997	874	1049	994	738	501	499	293	229	249	209	291	267	150	132	236	412	1590	1961	1567	1651	0	677	319
58	1268	1475	1423	1374	1556	1315	1427	1228	1276	1411	1474	726	404	1191	1042	1002	425	786	1197	1074	734	657	978	300	371	361	981	953	1579	1390	1146	1107	1211	922	873	1016	1081	937	1035	532	928	670	588	906	926	886	968	944	780	485	913	727	913	1284	890	974	677	0	996
59	377	570	532	588	560	455	642	368	280	415	478	1338	862	454	388	348	1243	1607	839	716	329	1653	598	757	565	1357	601	414	1221	1032	1437	1398	1212	1213	1623	1090	967	1142	1093	1057	278	592	505	548	568	530	320	586	175	451	555	731	1909	2280	1886	1970	319	996	0

FIGURE 20. TRAVELLING DISTANCE BETWEEN THE CITIES IN IRAN (Institute of Geography and Cartography of Gita, n.d.)

APPENDIX 5: INITIATION OF THE MATHEMATICAL MODEL (PROM)

In this appendix, the initiation of the Problem mathematical model (PROM) is explained using possibilistic theory and global criterion method.

1. Possibilistic Theory:

Definition 1. Let $\tilde{\ell} = (\ell^1, \ell^2, \ell^3, \ell^4)$ be a trapezoidal fuzzy number with the following membership function:

$$\mu_{\tilde{\ell}}(x) = \begin{cases} \frac{x-\ell^1}{\ell^2-\ell^1} & \ell^1 \le x \le \ell^2 \\ 1 & \ell^2 \le x \le \ell^3 \\ \frac{\ell^4-x}{\ell^4-\ell^3} & \ell^3 \le x \le \ell^4 \\ 0 & Otherwise \end{cases} \quad (1)$$

The expected interval and expected value (EI & EV respectively) of a trapezoidal fuzzy number $\tilde{\ell} = (\ell^1, \ell^2, \ell^3, \ell^4)$ are defined as follows (Jimenez, Arenas, Bilbao, & Rodríguez, 2007):

$$EI(\tilde{\ell}) = [\, E_1^{\ell}, E_2^{\ell}\,] = \left[\frac{\ell^1 + \ell^2}{2}, \frac{\ell^3 + \ell^4}{2}\right] \quad (2)$$

$$EV(\tilde{\ell}) = \frac{E_1^{\ell} + E_2^{\ell}}{2} = \frac{\ell^1 + \ell^2 + \ell^3 + \ell^4}{4} \quad (3)$$

Definition 2. If ℓ is is a trapezoidal fuzzy number, then EV $(\ell) \cong \ell$.

Example: From (1), (2), and (3), It concludes that:

$$\begin{aligned} & min\ \widetilde{\ell^T}\, x \\ & Subject\ to \\ & a_i x \ge b_i \qquad\qquad i = 1,2,\dots,l \\ & x \ge 0 \end{aligned}$$

is equivalent to

$$\begin{aligned} & min\ \left(\frac{\ell^1 + \ell^2 + \ell^3 + \ell^4}{4}\right) x \\ & Subject\ to \\ & a_i x \ge b_i \qquad\qquad i = 1,2,\dots,l \\ & x \ge 0 \end{aligned}$$

2. Global Criteria Method

The first step in solving the multi objective mathematical models and achieving a proper decision is to transform them into a single objective mathematical model. For this purpose, formula (4) can be used to unify the objective functions. This Method aims to minimize the difference between each objective and its optimal value ($f_i^* \in \mathbb{R}^Q$):

$$Global\ Criterion\ Objective\ Function: Min\ F(x) \sum_{i=1}^{Q} \left(w_i \left| \frac{f_i^* - f_i(x)}{f_i^*} \right| \right) \quad (4)$$

In (4), w_i is the weight of objective function i that is acquired by AHP method and data collected from the experts.

- The Q is the total number of objective functions that is equal to 5 in this case study.
- The f_i^* is the optimal value of i^{th} objective function and is calculated by solving the problem with only i^{th} objective and discarding the other ones.

3. Initiation of the PROM in this study

Fuzzy Model:

$\boldsymbol{Objective\ Functions\ to\ be\ satisfied\ simultaneously}$

$Objective\ function 1$: $\boldsymbol{Maximize}\ \sum_j r_j F_j$ (5)

$Objective\ function 2$: $\boldsymbol{Minimize}\ \sum_j T_j F_j$ (6)

$Objective\ function 3$: $\boldsymbol{Minimize} \sum_j \tilde{c}_j F_j$ (7)

$Objective\ function 4$: $\boldsymbol{Maximize}\ \sum_j S_j F_j$ (8)

$Objective\ function 5$: $\boldsymbol{Maximize}\ \sum_j \tilde{h}_j F_j$ (9)

$\boldsymbol{Subject\ to}$:

$\sum_j F_j y_{jk} \leq 2$ $\quad for\ all\ k$ (10)

$d_{jj'} \geq 400(F_j F_{j'})$ $\quad for\ all\ j\ and\ J'\ provided\ that\ j \neq j'$ (11)

$\sum_j F_j \leq 50$ (12)

$\sum_j F_j \geq 10$ (13)

$\sum_j F_j \tilde{c}_j \leq B$ (14)

$F_j \in \{0,1\}$ (15)

Defuzzied Model

$\boldsymbol{Objective\ Functions\ to\ be\ satisfied\ simultaneously}$

$Objective\ 1$: $\boldsymbol{Maximize}\ \sum_j r_j F_j$ (16)

$Objective\ 2$: $\boldsymbol{Minimize}\ \sum_j T_j F_j$ (17)

$Objective\ 3$: $\boldsymbol{Minimize} \sum_j \left(\frac{c_j^1 + c_j^2 + c_j^3 + c_j^4}{4}\right) F_j$ (18)

$Objective\ 4$: $\boldsymbol{Maximize}\ \sum_j S_j F_j$ (19)

$Objective\ 5$: $\boldsymbol{Maximize}\ \sum_j \left(\frac{h_j^1 + h_j^2 + h_j^3 + h_j^4}{4}\right) F_j$ (20)

$\boldsymbol{Subject\ to}$:

$\sum_j F_j y_{jk} \leq 2$ $\quad$ $for\ all\ k$ (21)

$d_{jj'} \geq 400(F_j F_{j'})$ $\quad$ $for\ all\ j\ and\ J'\ provided\ that\ j \neq j'$ (22)

$\sum_j F_j \leq 50$ (23)

$\sum_j F_j \geq 10$ (24)

$\sum_j F_j \left(\frac{c_j^1+c_j^2+c_j^3+c_j^4}{4}\right) \leq B$ (25)

$F_j \in \{0,1\}$ (26)

Hence, equation (4) is applied to create the ultimate version of the PROM as follows:

$$\boldsymbol{Min} \left(\mathbf{0,06} \left(\mathbf{1030} - \sum_j \boldsymbol{r_j F_j} \Big/ \mathbf{1030} \right) + \mathbf{0,13} \left(\mathbf{205} - \sum_j \boldsymbol{T_j F_j} \Big/ \mathbf{205} \right) + \mathbf{0,28} \left(\mathbf{5,760,000} - \left(\frac{\boldsymbol{c_j^1 + c_j^2 + c_j^3 + c_j^4}}{\mathbf{4}} \right) \Big/ \mathbf{5,760,000} \right) + \mathbf{0,19} \left(\mathbf{960} - \sum_j \boldsymbol{S_j F_j} \Big/ \mathbf{960} \right) + \mathbf{0,34} \left(\mathbf{4.426.865} - \left(\frac{\boldsymbol{h_j^1 + h_j^2 + h_j^3 + h_j^4}}{\mathbf{4}} \right) \Big/ \mathbf{4.426.865} \right) \right)$$

$\boldsymbol{Subject\ to}$:

$\sum_j F_j y_{jk} \leq 2$ $\quad$ $for\ all\ k$

$d_{jj'} \geq 400(F_j F_{j'})$ $\quad$ $for\ all\ j\ and\ J'\ provided\ that\ j \neq j'$

$\sum_j F_j \leq 50$

$\sum_j F_j \geq 10$

$\sum_j F_j \left(\frac{c_j^1+c_j^2+c_j^3+c_j^4}{4}\right) \leq B$

$F_j \in \{0,1\}$

The Results of solving the PROM are the followings:

TABLE 19. VALUES AFTER SOLVING THE PROM USING POSSIBILISTIC THEORY AND GLOBAL CRITERION METHOD

OBJECTIVE FUNCTION	1	2	3	4	5
SOLUTION SET	555%	230%	6,560,000	580%	1.986.414
f_i^*	1030	205	5,760,000	960	4.426.865
w_i	**0.06**	**0.13**	**0.28**	**0.19**	**0.34**
GLOBAL CRITERION VALUE			0.362		

APPENDIX 6: AHP METHOD FOR DETERMINING THE WEIGHT OF OBJECTIVE IN THE PROM

Al-Harbi (2001) very well describes steps of AHP method for determining the importance of decision criteria and problem objectives. Based on his research, the weight of the objectives in this study are determined as follows.

1. The decision makers and authorities of the company filled the AHP table in the questionnaire that was provided for them. A total of 6 tables were filled as follows (see table 8):

TABLE 20. AHP TABLE FILLED BY THE EXPERTS

Expert-1	**Obj-1**	**Obj-2**	**Obj-3**	**Obj-4**	**Obj-5**
Obj-1	1,0	0,3	0,2	0,4	0,1
Obj-2	3,3	1,0	0,4	0,6	0,3
Obj-3	5,0	2,5	1,0	1,5	0,8
Obj-4	2,5	1,7	0,7	1,0	0,7
Obj-5	10,0	3,3	1,3	1,4	1,0
Expert-2	**Obj-1**	**Obj-2**	**Obj-3**	**Obj-4**	**Obj-5**
Obj-1	1,0	0,2	0,3	0,4	0,2
Obj-2	5,0	1,0	0,3	0,5	0,4
Obj-3	3,3	3,3	1,0	1,3	0,8
Obj-4	2,5	2,0	0,8	1,0	0,8
Obj-5	5,0	2,5	1,3	1,3	1,0
Expert-3	**Obj-1**	**Obj-2**	**Obj-3**	**Obj-4**	**Obj-5**
Obj-1	1,0	0,2	0,2	0,4	0,1
Obj-2	5,0	1,0	0,4	0,6	0,2
Obj-3	5,0	2,5	1,0	1,6	0,7
Obj-4	2,5	1,7	0,6	1,0	0,9
Obj-5	10,0	5,0	1,4	1,1	1,0
Expert-4	**Obj-1**	**Obj-2**	**Obj-3**	**Obj-4**	**Obj-5**
Obj-1	1,0	0,2	0,2	0,3	0,1
Obj-2	5,0	1,0	0,3	0,5	0,1
Obj-3	5,0	3,0	1,0	1,0	1,0
Obj-4	3,0	2,0	1,0	1,0	1,0
Obj-5	9,0	9,0	1,0	1,0	1,0
Expert-5	**Obj-1**	**Obj-2**	**Obj-3**	**Obj-4**	**Obj-5**
Obj-1	1,0	0,3	0,3	0,5	0,2
Obj-2	3,3	1,0	0,5	0,7	0,2
Obj-3	3,3	2,0	1,0	2,0	0,9
Obj-4	2,0	1,4	0,5	1,0	0,8
Obj-5	5,0	5,0	1,1	1,3	1,0

Expert-6	Obj-1	Obj-2	Obj-3	Obj-4	Obj-5
Obj-1	1,0	0,4	0,3	0,6	0,3
Obj-2	2,5	1,0	0,6	0,6	0,3
Obj-3	3,3	1,7	1,0	2,5	1,1
Obj-4	1,7	1,7	0,4	1,0	0,9
Obj-5	3,3	3,3	0,9	1,1	1,0

2. In the next step, the group AHP table is formed by calculating the geometrical average of peer to peer cells in the table (see table 9).

TABLE 21. GROUP AHP TABLE

Group AHP	Obj-1	Obj-2	Obj-3	Obj-4	Obj-5
Obj-1	1,0	0,3	0,2	0,4	0,2
Obj-2	3,9	1,0	0,4	0,6	0,2
Obj-3	4,1	2,4	1,0	1,6	0,9
Obj-4	2,3	1,7	0,6	1,0	0,8
Obj-5	6,5	4,3	1,1	1,2	1,0
Column Sum	17,8	9,7	3,4	4,8	3,1

3. Finally, the normalized Group AHP table should be calculated from which, the actual weight of each objective can be obtained by calculating the average of the values of each objective in each row (see table 10).

TABLE 22. NORMALIZED GROUP AHP AND THE WEIGHT OF EACH OBJECTIVE

Normalized Group AHP	Obj-1	Obj-2	Obj-3	Obj-4	Obj-5	**Weight of Objectives**
Obj-1	0,06	0,03	0,07	0,09	0,05	0,06
Obj-2	0,22	0,10	0,12	0,12	0,08	0,13
Obj-3	0,23	0,25	0,29	0,33	0,28	0,28
Obj-4	0,13	0,18	0,18	0,21	0,27	0,19
Obj-5	0,37	0,44	0,33	0,25	0,32	0,34

APPENDIX 7: THE CODED VERSION OF THE DECISION SUPPORT SYSTEM IN GAMZ

```
Sets
        i province     /   1*28/
        j cities     /1*59/;
alias(j,jp);
parameter   r(j) ;
$ call GDXXRW D:\Projects\Sam-realState\Data.xlsx trace=3 par==r rng=Futuristic!A1:B59
rdim=1
$GDXIN Data
$LOAD r
$GDXIN
display r
parameter   t(j) ;
$ call GDXXRW D:\Projects\Sam-realState\Data.xlsx trace=3 par==T rng=Tax!A1:B59
rdim=1
$GDXIN Data
$LOAD T
$GDXIN
display T
Parameter  A(j,i);
$ call GDXXRW D:\Projects\Sam-realState\Data.xlsx trace=3 par==A
rng=Assignment!A1:AC60 rdim=1  cdim=1
$GDXIN Data
$LOAD A
$GDXIN
display A
parameter   c(j) ;
$ call GDXXRW D:\Projects\Sam-realState\Data.xlsx trace=3 par==c
rng=FixedCost!A1:B59 rdim=1
$GDXIN Data
$LOAD c
$GDXIN
display c
parameter   s(j) ;
$ call GDXXRW D:\Projects\Sam-realState\Data.xlsx trace=3 par==s
rng=Distribution!A1:B59 rdim=1
$GDXIN Data
$LOAD s
$GDXIN
display s
parameter   h(j) ;
$ call GDXXRW D:\Projects\Sam-realState\Data.xlsx trace=3 par==h  rng=Income!A1:B59
rdim=1
$GDXIN Data
$LOAD h
```

```
$GDXIN
display h
parameter d(j,jp)     distance in between i and j ;
$ call GDXXRW D:\Projects\Sam-realState\Data.xlsx trace=3 par==d
rng=DistanceMatrix!A1:BH60 rdim=1   cdim=1
$GDXIN Data
$LOAD d
$GDXIN
display d
variables
        F(j)        if location j is selected
        z;
binary variable        F;
equations
        OBJ       define objective function
        number(i)   upper limit for number of facilities in a province
        dis(j,jp)   distance limit 400
        mini  functioning of or j
        maxi    surgeon should be assigned to one hospital
        budget    anesthetists should be assigned to one hospital;
*OBJ ..          z  =e=  sum(j, F(j)*c(j)) ;
*OBJ ..          z  =e=  sum(j, F(j)*s(j)) ;
*OBJ ..          z  =e=  sum(j, F(j)*t(j)) ;
*OBJ ..          z  =e=  sum(j, F(j)*r(j)) ;
*OBJ ..          z  =e=  sum(j, F(j)*h(j)) ;
 OBJ ..          z  =e=  0.28*((sum(j, F(j)*c(j))-5.7600E+5)/5.7600E+5)+0.19*((9.6-sum(j,
F(j)*s(j)))/9.6)+0.13*((sum(j, F(j)*t(j))-205)/205)+0.06*((10.30-sum(j,
F(j)*r(j)))/10.3)+0.34*((4.9682E+8-sum(j, F(j)*h(j)))/4.9682E+8) ;
number(i)        ..   sum(j,F(j)*A(j,i))=l=2;
dis(j,jp)$[not sameas(j,jp)]     ..   400*F(j)*F(jp)=l=d(j,jp);
mini   ..   sum(j, F(j))=g=10;
maxi ..  sum(j, F(j))=l=50;
budget .. sum(j, F(j)*c(j))=l=  6000000;
Model RealState /all/ ;
RealState.optcr = 0;
RealState.optca = 0;
RealState.optfile = 1;
RealState.reslim=10000000;
Solve RealState using minlp minimizing z ;
Display F.l, F.m ;
```

APPENDIX 8: KEY ISSUES IN FUZZY PROBLEM-SOLVING APPROACH

1. **Fuzzy Thinking:**
   - Fuzzy logic is not logic that is fuzzy, but logic that is used to describe fuzziness. Fuzzy logic is the theory of fuzzy sets that calibrate vagueness.
   - Fuzzy logic is based on the idea that all things admit of degrees. Temperature, height, speed, distance, beauty – all come on a sliding scale.
   - Fuzzy Logic reflects how people think. It attempts to model our sense of words, our decision making and our common sense. As a result, it is leading to new, more human, intelligent systems.
2. **Fuzzy Systems:**
   - It works on fuzzy logic, which superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth values between "completely true" and "completely false".
   - It provides a systematic, intuitive and mathematical means of handling uncertainty in natural and artificial systems.
3. **Different types of uncertainty:**
   - **Classical uncertain**
     "Will I get a "100" for this course?"
     - Uncertain but precise,
       Mostly can be handle by probability theory
   - **Vague**
     "Roger is tall"
     - Certain but imprecise,
       Can be handle by fuzzy sets and fuzzy logic
   - **Imprecise (e.g., interval)**
     "Jemma weighs between 50 kg and 65 kg"
     - Uncertain and imprecise,
       Can be handled by fuzzy logic and possibilities theory (used in this study)
4. **Types of fuzzy numbers** (Rouse, n.d.)

   In many respects, fuzzy numbers depict the physical world more realistically than single-valued numbers. Suppose, for example, that you are driving along a highway where the speed limit is 55 miles an hour (mph). You try to hold your speed at exactly 55 mph, but your car lacks "cruise control," so your speed varies from moment to moment. If you graph your instantaneous speed over a period of several minutes and then plot the result in rectangular coordinates, you will get a function that looks like one of the curves shown in figure 18.

   The red curve (top) represents a triangular fuzzy number; the blue curve(middle) shows a trapezoidal fuzzy number; the green curve (bottom) illustrates a bell-shaped fuzzy number. These three functions, known as *membership functions*, are the most famous representation types of fuzzy numbers, and they are all convex (the grade starts at zero, rises to a maximum, and then declines to zero again as the domain increases).

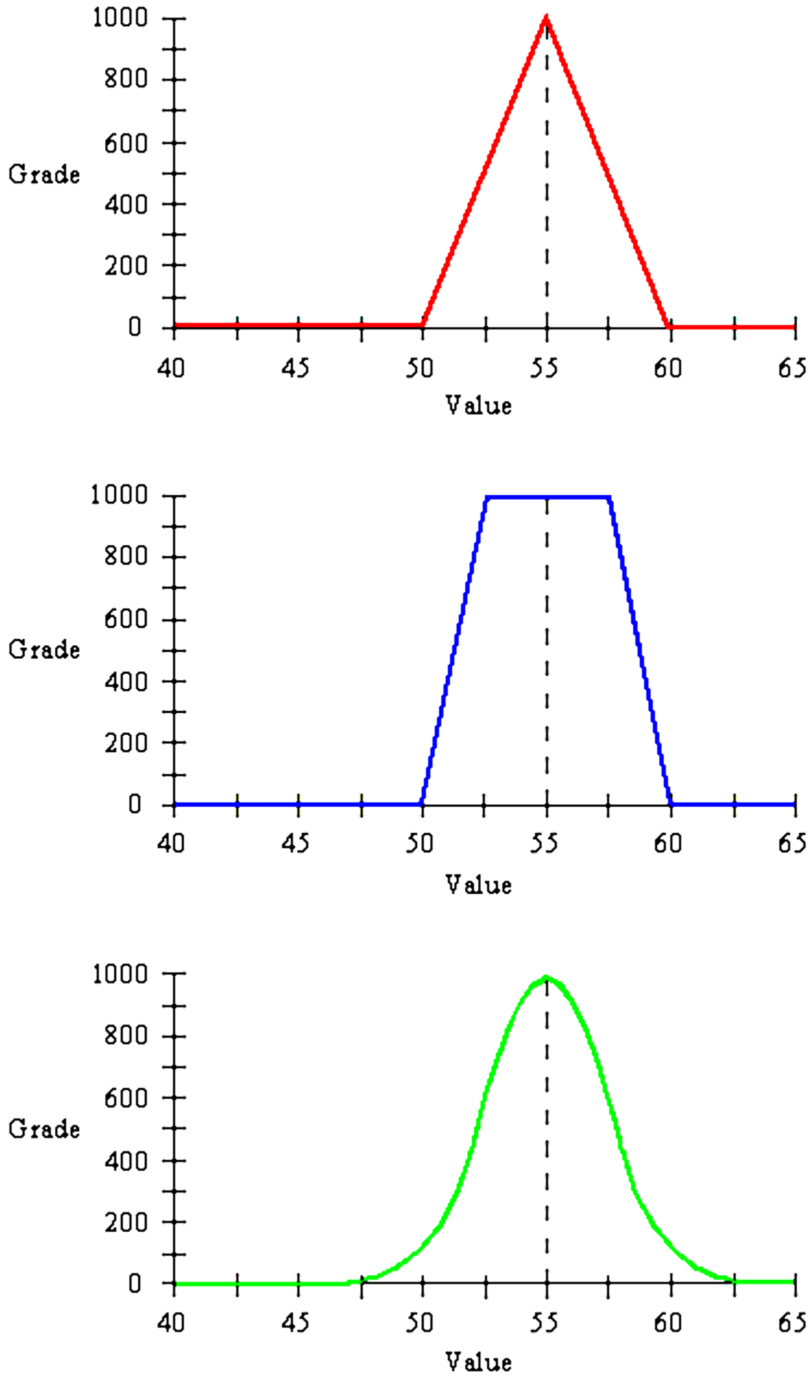

FIGURE 21. TYPES OF FUZZY NUMBERS

Fuzzy approach enables one to work in uncertain and ambiguous situations and solve ill-posed problems or problems with incomplete information.

APPENDIX 9: LIST OF SPECIALISTS

1. Prof. Dr. Bela Vizvari: Mathematician and Operation Researcher.
2. Assoc. Prof. Dr. Sadegh Niroomand: Expert in Optimization, System Modeling, Fuzzy Programming and Decision Support Systems.
3. Assoc. Prof. Dr. Ali Alimooradi: Expert in System Modeling and Fuzzy Programming.
4. Dr. Mahdi Shavarani: Expert in Optimization, Modeling, Expert Systems, and Location Analysis.
5. Dr. Mazyar Ghaidri Nejad: Expert in Optimization, Modeling, and Scheduling.
6. Dr. Mahmood Golabi: Expert in Simulation, Modeling, Programming, and Location Analysis.
7. Jan vaden Hogen: Real Estate Expert.
8. Saeid Mosallaeipour: Local real Estate Expert.
9. Pedram sheikh Hasani: Local Business Analyst.
10. Mr. Hashem Amiri: Director Manager at LGI company.

APPENDIX 10: THESIS PROGRESS FORM

University of Applied Sciences SAXION

UNIVERSITY of GREENWICH

Project progress form

Record the dates of consultations with the tutor, the action points resulting from the discussions, the tasks set for the next appointment and the date for the next appointment. Record telephone conversations (date etc.) and e-mail correspondence (attach copies of any requests and responses). Ensure your tutor initials the "Task Set" section at the end of each session, and keep copies of any notes/correspondence.

Student: Sam Mosallaeipour

Tutor: Dr. Adrienn Eros

Date	Kind of communication (email, phone, in person)	action points, task set	date of next meeting
12. January.2018	Personal Meeting	Problem formulation discussion	14.Feb.2018
14.Feb.2018	Email	Data collection discussion	10.April.2018
10.April.2018	Personal Meeting	Preparation for presentation and planning the final steps of thesis writing	30.May.2018
30.May.2018	Email	Prefinal corrections	11. July.2018
11. July.2018	Personal Meeting	Final Corrections	--

Signature student: ……………………………..……………..

Signature tutor: ..Dr. Adrienn Eros……..

STUDENT AND TUTOR ARE EXPECTED TO HAVE PERSONAL CONTACT AT LEAST FOUR TIMES DURING THE PROGRESS OF THE DISSERTATION.