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Prioritize target markets using combined method of Analytical Hierarchy Process/Monte Carlo simulation and Fuzzy AHP

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Abstract

Nowadays, most of Businesses have faced a great challenge for entering a new market. The existence conditions have forced the managers to apply the innovative methods for simultaneous analyzing of various factors for arrival to special markets. This paper prioritizes a few target markets using two methods. First, the problem is solved by the combined method of hierarchical analysis and Monte Carlo simulation, and then by the method of fuzzy hierarchical analysis and finally the results of both methods are compared. The considered problem in this study relates to a factory of prefabricated building components that is looking for establishing the sale agencies in appropriate towns in order to introduce and distribute the new products. In order to prioritize cities, desired criteria are determined through interviews with experts and investigating the previous studies. The research findings have shown that based on the four main criteria and seven related sub-criteria, the prioritization of selected cities as markets has been A-D-C-B respectively. In the end, it is concluded that based on the findings of this study, managers and stakeholders should pay attention to these priorities in choosing the target market. In this research, for the first time, the combined Monte Carlo technique and hierarchical analysis have been used to select the market. Market selection is one of the issues that has always been a concern of managers and has been associated with a lot of risk. Using Monte Carlo simulation algorithm and hierarchical analysis, by considering different decision intervals, greatly reduces the risk of selection, so this technique is recommended to managers of organizations as a practical method in market selection.

Keywords: Market, Business, Analytical Hierarchy Process, Monte Carlo, Fuzzy AHP.

1. Introduction

During recent decades, managers have faced global changes due to the advances in technology, globalization of the markets, and new conditions of political economy. The organizations have forced to improve their processes immediately in order to remain in global competition arena due to increasing number of world class competitors. A new approach which has been recently dominated on the operation management is the supply chain management. Supply chain is a network of facilities and distribution centers connecting different steps such as preparing raw materials, converting these materials to intermediate and final products, and distributing the final products to customers. In summary, we can say that the supply chain management consists of three main parts as following: preparation and provision, production, and distribution. In this network, choosing

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suitable supplier and distributor, and appropriate market is of those topics which have constantly attracted the attention of manufacturers to decrease costs and increase productivity (Chopra & Meidl, 2004).

Nowadays, most of the business units have faced a great stress for entering a new market. Opportunities and threats, competitors' evaluation, production ability, quality, and price are factors that create a complex puzzle for managers. Also, the most important point is that to enter a new market there is no place for trial and error, because failure in a special market may lead to overall bankruptcy. In total, the existing conditions have forced the managers to apply the complex methods for simultaneous analyzing of various factors (Sevkli, Koh, & Zaim, 2008). The purpose of this study is to prioritize and select the appropriate target market using a combined method of Analytical hierarchy Process (AHP) and Monte Carlo simulation with the aim of risk decrement in decision-making. Usually, in a supply chain the distributor is responsible for selecting an appropriate market, but the distributor's willingness to operate in current market and ignorance of the other markets position may cause the distributor to consider a limited workspace which has been involved in it. Furthermore, sometimes the manufacturers distribute their products by their own to decrease costs and enhance reputation. But the success in this step firstly requires identifying and selecting a suitable market.

Since our purpose in this study is to prioritize the markets (towns), select an appropriate market and decrease the risks of stablishing agencies in non-suitable markets, the combined method of MCAHP (Monte Carlo-AHP) is used to increase accuracy in decision-making. In doing so, the needed criteria are obtained from the existing factors of market selection in literature as well as the experts' opinions. In rest of the paper, we are going to investigate research background in Section 2. Then we introduce the intended problem of the current study in the third section. In section four, we discuss how to use the MCAHP and we conclude in the fifth section. One of the most important factors influencing the success of any organization is choosing the right target market. According to surveys of commercial companies, when the decision to select a target market is associated with a lot of risk, the probability of project failure is very high (Vanegas et all, 2021). To select the target market, many factors and criteria must be considered. Choosing the right method of weighing criteria and determining how much it affects the purpose of the problem is critical, as large organizations conduct extensive research for this purpose (Duong et all, 2021). A lot of research shows that there is a bigger issue for any organization before it enters the market, and that is the market choice. This is very important because for each product there are many factors that affect the choice of market. The abundance of these factors confuses managers. Therefore, choosing the right decision-making technique to choose the right target market has always been one of the constant concerns of managers (Park, 2020). In addition to the above, the work experience of the researchers in this research, who have been working in the field of marketing for many years, also confirms the existence of this decision.

2. Literature Review

Currently, the productions and services units of developed countries have found that their long-term profit depends on balance and integration of well-defined supply chain components, while traditional policies are no longer remedial (Morgan, Clark, & Gooner, 2002). The supply chain relates to suppliers a side and on the other hand, it adjoins the distributors. The optimal selection of suppliers and distributors would result in decreasing the costs and increasing the profits to a considerable extent. Many studies have been conducted with the purpose of supplier selection in a supply chain (Amid, Ghodsypour, & O'Brien, 2006), (Carter, Maltz, Maltz, Goh, & Yan, 2010), (Chen & Huang, 2006), (Gencer & Gurpinar, 2007), (Chan & Kumar, 2007), and (Micheli, 2008) can be mentioned but there exist a little studies and experiences about the distributor's selection. Among those works we can refer to (Ross, 1973), (Lindqvist, 1983), (Fram, 1992), and (Fonsson & Zineldin, 2003). But one of the key factors to increase the number of customers is to choose an appropriate market. Decision-making about selecting an appropriate market to establish a sale agency is a multi-criteria decision-making problem. Since the ultimate goal of any supply chain is to reach customer satisfaction, the market selection as a part of supply chain is so important. Keegan (1983) and Johansson (1983) have found a strong relationship between marketing systematic planning and the performance of different firms. Selecting of target market is one of the most important decisions in all the organizations which deal with marketing issues and strategic planning (McDonald, 1995). Doyle (1995), in his paper about Marketing in the third millennium suggests a combination of traditional and modern duties of marketers in the present and future. Detecting the attractions of a market or " strategic market

choice" according to Doyle, is one of these duties. Despite the existence of various viewpoints about the features of an attractive market, the relationship between market attractiveness and business success in no secret to anyone. CHANDLER, G. N. & HANKS 's study on 800 manufacturing company in the United States is a proof to truth of this claim. This study which indicates a positive relationship between market attractiveness and business growth, considers six factors in determining the attractiveness of a market. These factors are: ability to provide services to customers and marketing approaches, the difference of goods and services supplement between different firms, the number of main competitors with a same competitive position, the growth rate of industry, the number of established competitors, and the market need to products and services which still is unmet (Talukder, 2019). Many variables are involved in the selecting of a market and there are many disagreements among experts. In the following we provide some of these variables which attracted more attention:

- Market size: The estimation of market size is one of the most important decisions. The variables which are beneficial to estimate the market size are as follows: the geographical, demographical, and economical features (Rusta, 2004).
- The expected potential market growth (market potential): Although, the size of a market may be small but, the probability of its growth should be considered (Rusta, 2004).
- Cost: In this regard, the costs like those to gain a market section and transportation costs should be considered (Rusta, 2004).
- Anticipation of profit to investment ratio: The ratio of profit to investment should be high enough to firstly cover the expected profitability of the firm and secondly offset the unforeseen potential risks (Mirabi. V, 2004).

The various factors should be considered when the manufacturer is looking for a new town and market to offer new products. For instance, one of these factors is the consumption expenditures of considered population. Furthermore, the income level of people in each region and their consuming culture may be different (Onut & Efendigil, 2010). Identifying the most important criteria and determining their weight requires the use of multi-criteria decision-making method (Topcu & Burnaz, 2006). According to Douglas et.al. the market size, potential growth rate, amount of competition and risk of any market, criteria relating to market cost and distribution channels are the criteria for assessing and selecting of the best market (Douglas, Craig, & Keegan, 1982).Samli (1977) in his study introduces the criteria such as the amount of integration of and communication with destination market as a partner, the market potential, experiences, the respective economical programs and previous working relationship (credit obtained as a result of the previous works) as well. The market size and amount of growth are of factors which have attracted the most attention of researchers in the past (Samli, 1977). But, nowadays the criteria such as economic, cultural, and political factors, competitive advantages, trade capacities, cost, market structure and strategies relating to competitors are more emphasized (Rahman, 2003).

Yaraghi (2014) states in his article that both AHP and MCAHP methods are strongly influenced by individual or group preferences and therefore provide subjective rankings. Since the mere difference between their results does not necessarily guarantee superiority over one another, a reliable and robust ranking of options must be available as a basis for comparison in order to evaluate the results of the two methods. In his paper, he uses a simulation method to compare AHP results with MCAHP under different levels of uncertainty. The simulation results show that as long as the change in different pair comparisons is less than 0.24, the performance of AHP is statistically MCAHP performance is no different. MCAHP offers more accurate rankings when uncertainty about change grows beyond 0.24. Baylan (2020) did a research in that AHP and TOPSIS method are combined to developed novel method. In this hybrid method, Constructing AHP model is to prioritize work packages with respect to relative importance of project time, project output quality and project cost. Broken down structure of these work packages are used as input for weighted criteria for TOPSIS method. In second layer of this decision method, TOPSIS model is used for prioritizing predetermined activity risks according weighted project work packages success criteria. Results showed that application of AHP-Stochastic TOPSIS Hybrid Algorithm

provides a platform that project risks could be analyzed as quantitative and also at project activity level. Junaid (2020) wrote an article entitled" A Neutrosophic AHP and TOPSIS Framework for Supply Chain Risk Assessment in Automotive Industry of Pakistan"In this paper, neutrosophic (N) theory is merged with the analytic hierarchy process (AHP) and technique for order of preference by similarity to ideal solution (TOPSIS) to deal with complexity, uncertainty, and vagueness. Then the proposed methodology is practically implemented through a case study on the automotive industry. SC resilience, SC agility, and SC robustness were selected as criteria for managing supply chain risks and analyzed using N-AHP. Furthermore, seventeen risks were identified and assessed by using N-TOPSIS. Results suggest supply chain resilience is the most important criterion for managing supply chain risks. Moreover, supplier delivery delays, supplier quality problems, supplier communication failures, and forecasting errors are the most vulnerable risks that occur in supply chains of the automotive industry in Pakistan. As mentioned, in research in the field of marketing, many factors have been considered and in each of these factors has its own weight and impact, in order to determine the extent of this impact, multi-criteria decision-making techniques and sometimes a combination of different decision-making techniques is used. But despite the great importance of the subject, little research has specialized in the field of target market selection. Therefore, introducing a technique that can reduce decision risk to a very good extent and can be used in various industries is very important. For this purpose, this research has used the combined technique of fuzzy hierarchical analysis and Monte Carlo simulation algorithm.

3. Methodology

To do the evaluation and ranking markets we first use a combination of AHP and monte-carlo simulation. Then we will use the fuzzy AHP to prioritize the cities. Finally, we will compare the results with each other. In the following, we explain each procedure in more details.

3.1. Analytical Hierarchy Process-AHP

AHP has most widely used to solve the advanced problems with complex criteria as a method of multi-criteria decision-making (Saaty, 1977). The excessive use of this method in solving the various problems indicates its high capability and performance. In terms of using AHP to select the appropriate market we can refer to studies of Hortacsu and Tektas (Hortacsu.A & Tektas.A, 2009), (Abari, Nilchi, Nasri, & Hekmatpanah, 2009), and (Mohaghar & Fathi, 2012). The AHP is used to prioritize the considered alternatives of decision-making problem; the special vector obtained from AHP is used as a basis to prioritize the alternatives, but the possibility of personal views and opinions to influence this process is not considered. To solve this problem and to decrease this negative impact we can use the Monte Carlo simulation.

3.2. The combined method of AHP and Monte Carlo simulation

Rosenbloom (1996) suggested to add the Monte Carlo simulation to AHP method in order to increase its ability of alternatives screening. This model decreases the decision-making risk and provides the more reliable results. It also helps decision makers to make more flexible decisions than the usual AHP. In this method, the triangular distribution is used when decision maker is uncertain about his/her decision in which three points of minimum, maximum, and the most probable is determined. Although it has not passed a long time since this hybridization, many researchers have used this method in decision-making process. Among these researchers, we can refer to (Banuelas & Anton, 2004), (Hsu & Pan 2009), (Momani & Ahmed, 2011), (Li & Zheng, 2009), and (Zhang, 2020). In the following sections we explain the details of this method in more details.

3.2.1. Selecting appropriate city (market) to establish the sale agency

This paper is looking for the selection of appropriate market to distribute the products of a factory of prefabricated building components. In doing so, the four big towns are candidate for creating sale agency considering the firm's strategic plan and experts' opinions. After investigating of similar studies and using the opinions of competent experts, decision-making criteria and sub-criteria has been determined as shown in Table 1.

Table 1. Market selection criteria

Main criteria	Sub-criteria
Market size	Population
	Region economy
Cost	Transportation cost
	Advertisement cost
	Office and warehouse cost
Ratio of expected profit to investment volume	
Market potential growth	Level of competition
	Technology use

4. Implementing MCAHP to solve the problem

In this paper, the combined method of analytical hierarchy process and Monte Carlo simulation is used in order to minimize the decision-making risk. This model is composed of the following main steps:

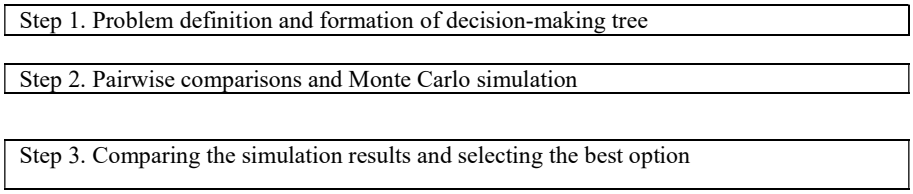

Figure 2. Steps of the combined method of MCAHP to solve problem

The first step is to define the market selection problem and form the hierarchical decision-making tree. To do so, we use Table 1 and depict the decision-making tree as shown in Figure 2. Then, we gather data relating to decision-making elements as random variables using paired comparisons questionnaires. The paired comparisons in AHP are usually determined as a definite number, but in this method the paired comparisons are random variables which follow a specific distribution (Almeida, 2020). The Monte Carlo simulation method represents the random combinations of possible states of uncertainties, which occur in a project. In the first step of Monte Carlo simulation method, the probability distribution function of uncertainties which were identified in previous stages is determined by the experts of project management team and sometimes by the experiences obtained from the past projects. In this regard, we have used the random variables with a triangular distribution function for the paired comparisons. to this aim, we ask the decision maker to assign a triple number to paired comparison, in which the first the second and the third numbers represent the minimum possibility, the most probable and the maximum possible amount for the preference of one element to another. In the second step of implementing Monte Carlo simulation, the simulation runs are determined which depends on the project dimensions, complexity, and importance of investigated risks (Cano, 2017). In this paper, for each of the paired comparison the related variable is simulated one thousand times. In the method used in this study, in each simulation run, a random number with a triangular distribution function is allocated to the paired comparisons which its bounds are determined by decision maker in advance then the alternatives are prioritized through AHP.

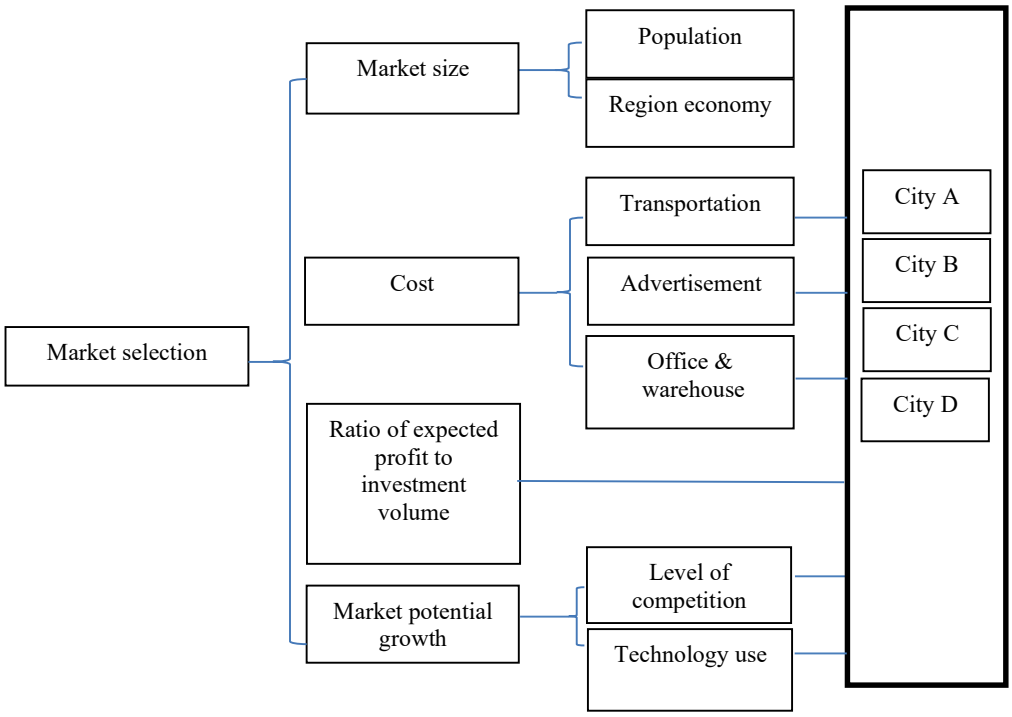

Figure 3. The Hierarchical structure for selecting the appropriate market

Since the Saati spectrum is used to compare the criteria as shown in table 2. The paired comparisons of criteria and the comparisons relating to alternatives were performed by triangular distribution at an interval from 1/9 to 9.

Table 2. Saati scoring of preferences

Definition	Score
Equal importance	1
More important	3
Much more important	5
Highly important	7
Very highly important	9

After gathering data, the Monte Carlo simulation is repeated one thousand times by excel software while the results are entered to the AHP in order to specify the weights of each alternative (town). The frequency chart resulting from simulations is provided in figure 4, while horizontal axis represents for the weights and the vertical axis shows the frequency of these weights among iterations of simulation. Also, the priority of towns along with means and standard deviations are represented in table 4.

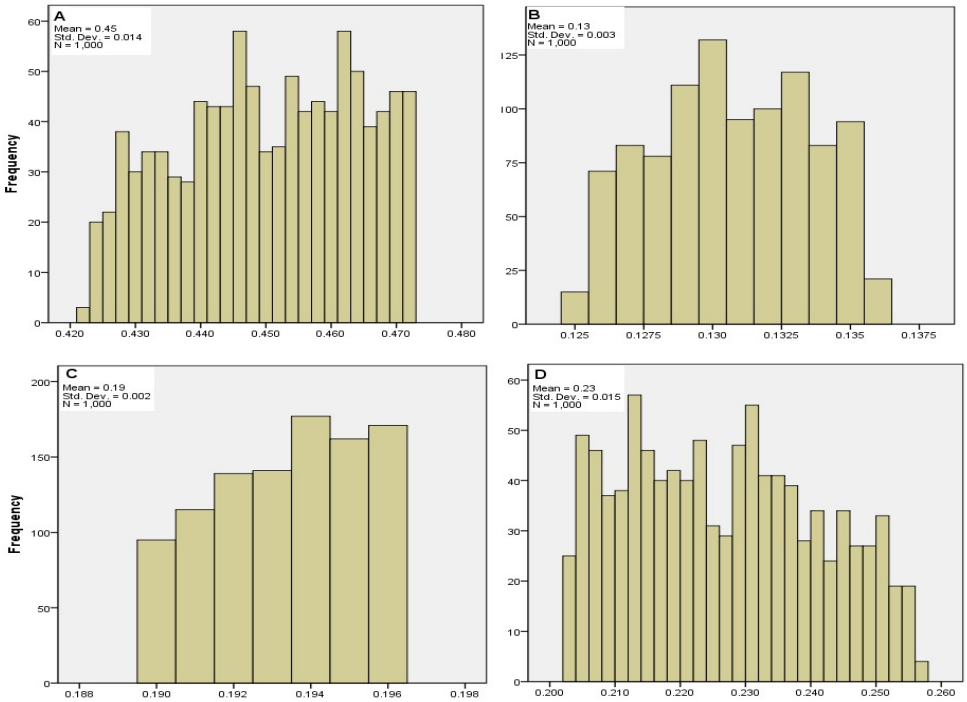

Figure 4. Frequency distribution of towns' scores in MCAH model

Table 4. The statistical output of MCAHP

		A	B	C	D
N	Valid	1000	1000	1000	1000
Mean		0.449690	0.130700	0.193360	0.226230
Std. Error of Mean		0.000436	0.000090	0.000061	0.000465
Mode		0.462000	0.130000	0.194000	0.204000
Std. Deviation		0.013794	0.002861	0.001921	0.014710
Variance		0.000190	0.000008	0.000003	0.000216

Given the information of table 4, it can be seen that the obtained prioritization is useful to a considerable extent, because the amounts of standard deviation and error of the average deviation are so trivial. The weights of criteria and sub-criteria resulting from both the FAHP and MCAHP are provided in table 5 in order to compare these two methods.

4.2. Fuzzy AHP

Chang in 1992 developed a simple method to expand the analytical hierarchy process to a fuzzy space (Chang, 1992). This method which is based on arithmetic average of experts' opinions and the normalization method of Saati and was developed using triangular fuzzy numbers was welcomed by researchers (Percin, 2008).

In this method, the probability of triangular fuzzy number of $\mu_2 = (l_2, m_2, u_2)$ is greater than triangular fuzzy number of $\mu_1 = (l_1, m_1, u_1)$ equals to:

$$V(M_2 > M_1) = \text{sub}_{y>x}[\min(\mu_{m_1}(x), \mu_{m_2}(y))]$$

That this equation is synonymous with:

$$V(M_2 \geq M_1) = \text{hgt}(M_2 \cap M_1) = \mu_{M_2}(d)$$

$$= \begin{cases} 1, & m_2 \geq m_1 \\ 0, & l_1 \geq u_2 \\ x, & otherwise \end{cases}$$

In which d is peculiarities of the highest point in common area and collision place of two functions of μ_{M_1} and μ_{M_2}.

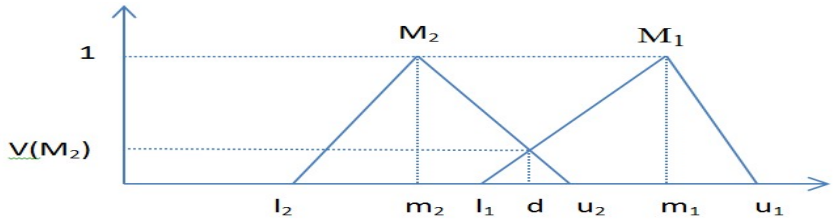

Figure 5. prioritization of two fuzzy number

To compare M1 and M2, the calculation of both amounts of V(M1≥M2) and V(M2≥M1) is necessary. In addition, the probability of convex fuzzy number of M is greater than the other convex fuzzy number of K is broken up as follows:

V(M≥M1, M2,….,Mk)=V[(M≥M1),(M≥M2),…,(M≥Mk)=min V(M≥Mi) i=1,2,…k

To facilitate the processing of expert's judgments, we can obtain their opinions in verbal phrases and then convert them to triangular fuzzy numbers. To gain more information about conversion methods of triangular numbers to fuzzy numbers could refer to Abdel-Kader and Dugdale (2001).

Here, we describe the steps of FAHP only for one table, as an example of applying this method.

Cost	Transportation			Advertisement			Office & warehouse		
	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max
Transportation	1	1	1	2	3.5	4	1	3	4
Advertisement	0.25	0.29	0.5	1	1	1	0.3	0.65	0.75
Office &warehouse	0.25	0.33	1	1.42	1.53	3.33	1	1	1

	Sum of Each Row				Fuzzy Number		
					l	m	U
Transportation	4.00	7.500	9.00	After Normalizing →	0.242	0.609	1.094
Advertisement	1.55	1.936	2.20		0.094	0.157	0.267
Office &warehouse	2.68	2.872	5.33		0.162	0.233	0.648
Total Sum	8.23	12.308	16.53				

in order to $V(M_2>M_1) = \begin{cases} 1, & m_2 \geq m_1 \\ 0, & l_1 \geq u_2 \\ x, & otherwise \end{cases}$

V	Trans..	Advert..	Office..	Min V_i	Normalized weights
Transportation		1.000	1.000	1.000	0.636
Advertisement	0.053		0.581	0.053	0.034
Office &warehouse	0.519	1.000		0.519	0.330

Table 5 indicates the same results for this problem using both two methods i.e. the towns are prioritized in the order of A, D, C, and B by these methods.

The weights obtained from MCAHP method are more accurate than FAHP, because if the upper bound of a triangular fuzzy number is less than the lower bound of one other number, probability of the former triangular fuzzy number than the latter triangular fuzzy number is considered zero. For example, it can be referred to weights obtained from the both methods for the main criterion of market potential which is .09 in the first method and is zero in the second. This shortcoming is rectified in MCAHP method by producing the random numbers based on triangular distribution between the upper and lower bound of triangular fuzzy number and repetition of this process.

Table 5. Comparison between the results of FAHP and MCAHP

criteria	Criteria & Alternatives	Weight base on MC-AHP	Weight base on FAHP
Main criteria	Market size		0.410
	Cost	0.160	0.160
	Ratio of expected profit to investment volume	0.410	0.420
	Market potential growth	0.090	0.000
Sub criteria	Population	0.213	0.259
	Region economy	0.116	0.148
	Transportation cost	0.098	0.105
	Advertisement cost	0.026	0.006
	Office and warehouse cost	0.040	0.055
	Level of competition	0.027	0.000
	Technology use	0.061	0.000
cities	A	44%	49%
	B	13%	9%
	C	19%	17%
	D	22%	25%

5. Discussion and conclusion

In this paper, a combined method of analytical hierarchy process and Monte Carlo simulation was provided in order to select the appropriate market. In fact, the Monte Carlo simulation method decrease the uncertainty of decision-making to a considerable extent through producing of random values between the lowest and the highest determined value, considering the highest possible probability by decision maker, and following the determined triangular distribution.

Since in this combined method, all the points of interval that determine the lowest and the highest probability are investigated, the percentage of its decision-making risk is so lower than conventional method of AHP. This result is consistent with the findings of Yaraghi (2014) research that uses a simulation method to compare AHP results with MCAHP under different levels of uncertainty. His research results show that as long as the change in different pair comparisons is less than 0.24, there is no difference between the performance of AHP and MCAHP. In this regard Baylan (2020) showed that application of AHP-Stochastic TOPSIS Hybrid Algorithm provides a platform that project risks could be analyzed as quantitative and also at project activity level. He noted the lack of a complementary technique for AHP to reduce risk. Also, Junaid (2020) merged neutrosophic (N) theory with the analytic hierarchy process (AHP) and technique for order of preference by similarity to ideal solution (TOPSIS) to deal with complexity, uncertainty, and vagueness. He emphasized that the AHP alone cannot meet the needs of decision-making under uncertainty.

In this paper to explain the practical application of this method, a real example was applied which results is provided in table 4. In order to compare this method with the conventional method of paired comparisons of fuzzy numbers (FAHP), the results problem solving using the both two methods are indicated in table 5. The comparison between two methods indicates that the MCAHP is a more accurate method and it can be said that

the MCAHP method can be good alternative for the relative old method of FAHP for such problems like one that exposed to discussion in this research.

In the end it is suggested: In order to reduce the risk, using Monte Carlo algorithm is safer and in cases where less reliability is considered, using of fuzzy hierarchical analysis algorithm is recommended.

As mentioned, many researchers have used various techniques such as AHP, TOPSIS, ANP, etc. to select the market, and sometimes combining one or more decision-making techniques, have created new techniques that sometimes result in nothing but more complex problems. The simplicity of these techniques has made them popular, but their use has always been associated with high risk of decision making. In order to reduce this risk, various researches have used the combination of the mentioned methods with the discussion of fuzzy logic and simulation algorithms. In this study, for the first time, two techniques, MCAHP and FAHP, were compared in terms of target market selection. Although the results of the two were very similar, in the case of the case in question, the results of the MCAHP technique were more favored by research experts. Therefore, it can be suggested to use the MCAHP technique to select the target market in the housing industry, if the number of options is high, which greatly reduces the risk of decision making with many repetitions and if the number of options was small, the FAHP technique is a faster solution for selecting the right target market.

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