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RESEARCH PAPER

Prevention of Cardiovascular Diseases by Combining GIS with Fuzzy Best-Worst Decision-Making Algorithm in Areas of Tehran

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ABSTRACT
The frequency of chronic diseases, such as cardiovascular diseases, has significantly soared in recent years; therefore, it is important to closely consider a number of factors, especially environmental factors, which contribute highly to the development of cardiovascular diseases. A long-term trend that has been adopted in several developed and developing countries to reduce the incidence of such diseases for patients is formulated in the form of health tourism. This study is a developmental research, which is categorized as descriptive-survey in terms of data collection method. The aim of this study is to prioritize 22 districts of Tehran for the purpose of preventing cardiovascular diseases. In the present study, after the extraction of the effective factors in the prevalence of cardiovascular diseases from previous studies, the weight of each factor with their specific data for each of 22 districts of Tehran (collected from relevant organizations) is obtained using two levels of Fuzzy Delphi method and one level of fuzzy best-worst method for confirming or denying factors and weighting them based on the opinion of 25 cardiologists, respectively. These date are transferred to Arc GIS software for prioritizing 22 districts of Tehran. The application of a combination of fuzzy best-worst method, which is one of the newest methods for making a multi-criteria decision, and GIS, for weighting parameters and prioritizing 22 districts of Tehran, gives an acceptable value to the present study. Obtained results after classification, drawing, and combination of maps indicated that the 8th district (except a small part in the west) is the best district, and the 16th and 19th districts (approximately the whole district) are in the last priority for the prevention of cardiovascular diseases. Other districts are respectively placed in the second to 21th places.

KEYWORDS: *Prevention, Cardiovascular diseases, GIS, Fuzzy decision-making algorithm, Tehran.*

1. Introduction

Cardiovascular diseases are the most frequent causes of death and disability in most of developed countries such as USA and the developing countries such as Iran [2,1]. Moreover, they are observed to be an important cause of disability for people. Despite fast progress in the detection and treatment realm, 1/3 of heart stroke cases result in death, and the remaining 2/3 may never experience a complete recovery and, thus, never return to the usual life. While the mortality rate in the western countries has gradually decreased over the last decades, it is still the cause of death in 1/3 of over 35-year-old people[1]. More than 54% out of 56.4 million deaths worldwide in 2015 occurred due to 10 essential causes. Cardiovascular diseases (CVD) and brain stroke are the strongest murderers worldwide, which caused 15 million death cases in 2015. These diseases have been the major causes of death over the last 15 years [3].

According to WHO, in 2017 in Iran, the probability of death caused by different kinds of CVD, cancer, diabetes, and CRD, between ages 30 to 70 years was 14.8% in 2015, which seems to have increased because of the lack of technological progresses, a decrease in the physical activities, and inappropriate nutrition. Moreover, based on the predictions of WHO, cardiovascular diseases will be the main cause of death worldwide until 2020. [4]

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Based on the definition of world atlas in the prevention and control of CVDs, cardiovascular disease is a group of diseases that involve heart and vascular systems, *e.g.*, coronary heart diseases, coronary artery diseases, and acute coronary syndrome. However, health professionals often use CAD and ACS and also CHD definitions, which are not similar, in the place of each other[1].

According to WHO, in 2017, ischemic heart disease, which is one of the frequent cardiovascular diseases worldwide, is also the second leading cause of death due to environmental effects[5].

It is estimated that outside air pollution and inside house air pollution (due to cooking using polluting fuels) result in 13% and 17% of cardiovascular diseases, respectively. Approximately 3% of cardiovascular diseases are associated with the second-hand tobacco smoke, and approximately 2% are related to the lead. Other environmental and work factors, such as the existence of arsenic in water, high level of noise pollution, and stressful workplace and work in turn, increase the risk of cardiovascular diseases [5].

Cardiovascular diseases incur significantly high costs for health and treatment organizations in a country. However, these diseases are preventable and non-contagious; for this reason, the recognition of factors that are effective in the prevalence of cardiovascular diseases (especially, environmental factors) is important for preventing them.

2. Research Background

First studies on the recognition of environmental factors that affect cardiovascular diseases performed by Brown and Pearson in 1948 assessed the effect of seasonal changes on CVD. Results of this study indicated that seasonal changes are conducive to the prevalence of cardiovascular diseases; the highest rate of mortality due to cardiovascular diseases has occurred in cold seasons. Therefore, temperature could be an environmental factor that affects cardiovascular diseases [6].

Hodgson in 1970 studied the relationship among mortality rate, air pollution, and some other meteorological factors during November of 1962 to May of 1965 in New York City. The results of this study indicated that the mortality rate due to cardiovascular and alveolar diseases in people of age under 64 years old and over 65 years old was highly influenced by high air pollution level [7].

Yamazaki (1973) compared 530 patients affected by heart infarction with 530 healthy volunteers to study hereditary and environmental factors, which are conducive to heart infarction progression. Results indicated that the frequency of heart infarction was higher in people with a history of related diseases in their family (*e.g.,* parents, brothers, or sisters affected by hypertension, apoptosis, ischemic heart disease, or sudden death). Moreover, it was shown that people with management, professional, and religious jobs were exposed to the greater risk of heart infarction. On the other hand, the frequency of acute heart infarction undergoes a significantly traction on a snowy day or in cold climate and under sudden temperature changes [8].

The study of Fodor, Pfeiffer, and Papezik (1973) showed that men's mortality rate due to cardiovascular diseases outside hospital was lower in districts with hard drinking water in newfound lands than those in districts with soft drinking water [9]. Totally, studies indicated that the mortality rate caused by cardiovascular diseases in districts with soft drinking water was higher than that in districts with hard drinking water. In this case, Keil (1973) performed a multiple regression analysis in England, which showed that social and economic conditions, as well as air pollution, could significantly affect the mortality rate caused by cardiovascular diseases [11].

The study of Nerbrand and colleague in 1991 indicated that environmental factors such as economic and social conditions and quality of water gave an impetus to the prevalence of cardiovascular diseases [11].

Dzik (1991) studied the effect of regional differences on mortality rate due to heart ischemic disease in USA using a multiple regression model. The results indicated that a combination of factors such as height, average family income, and air pollution included 46% of mortality rates due to the ischemic disease variance [12].

Omura prepared the first complete list of cardiovascular risk factors in 1982 in an article titled "96 cardiovascular risk factors", which is the most extended list of cardiovascular risk factors. Afterward, many studies were performed to recognize cardiovascular risk factors. Omura and colleagues (1996) presented approximately 177 cardiovascular risk factors (including 96 factors mentioned before) and categorized them into environmental factors such as air pollution, low air temperature, extremely high air temperature, electromagnetic fields (*e.g*., cell phones with 500-900 MHz of frequency and microwave with 2.4 GHz of frequency (2400 MHz)) that resulted in blood circulation disorders and cardiovascular diseases, joblessness, low levels of education, and literacy [13].

Results of the study of Nuzhdina (1998) in Kieve, Ukrain, showed that environmentally natural factors such as temperature, humidity, and atmosphere pressure affected the prevalence of cardiovascular diseases [14].

The study of Diez-Roux and colleague on environmental factors affecting the prevalence of cardiovascular diseases in 2001 indicated that low income, low job, and lower education levels could increase the risk of cardiovascular diseases [15].

Pope and colleagues in 2002 studied the relationship between air pollution and mortality caused by lung cancer and cardiovascular diseases in long term. Their results showed that for every 10 micrograms in mm^3 increase in micro particle air pollution, the mortality rate caused by renal, cardiovascular, and lung diseases increased approximately by 4%, 6%, and 8% [16].

Crawford, McCann, and Stout in 2004 studied the relationship between seasonal changes and mortality rate due to Myocardia infarcts (MI) in men and women during a 20-year period in north Ireland. The results indicated that low temperature increased the mortality rate due to Myocardia infarcts [17].

Wang and colleagues (2008) studied the relationship between changes in the number and density of food stores and nutrition behavior of 5779 men and women in California and their overweight. The study was performed using the data collected by Stanford cardiac disease prevention program in 4 sectional assessments from 1981 to 1990. Results indicated that the number and density of food pastries, fastfood restaurants (pizza), and small grocery stores significantly increased. During this period of time, the percentage of women over men that had healthy nutrition increased; however, the percentage of people with unhealthy nutrition behavior also increased. The percentage of fatness increased by 28% in women and 24% in men, too .[18]

Leal and Chaix (2011) attempted to recognize the geographic features of a living place that added an impetus to increasing the main risk factors and, eventually, the prevalence of cardiovascular diseases regarding the risk factors of cardiovascular diseases such as fatness, hypertension, type-2 diabetes, dyslipidemias, and metabolic syndromes. In this case, the features that were highly related to fatness and hypertension included housing density and accessibility of services, high levels of noise pollution, and high density of convenience stores [19].

Okello and colleagues (2012) studied the role of social-economic parameters in cardiovascular rheumatoid diseases in Uganda. Results indicated that the increased risk of cardiovascular rheumatoid diseases was directly related to population density, joblessness, and also distance from the nearest health center. This showed that population density with an increase in the distance from the nearest health center promoted the risk of cardiovascular rheumatoid diseases [20].

The study of Chum and O'Campo on 1626 adults in Toronto, Canada (2013) assessed the environmental risk factors, which have a part in cardiovascular diseases. The results indicated that lack of parks and entertainment facilities, as well as high levels of noise pollution in house and workplace, increased the risk of cardiovascular diseases [21].

While documents indicated that life style parameters contributed to the risk of cardiovascular diseases, the report of WHO in 2016 indicated that 35% of heart ischemic diseases occurred as a result of air pollution, high doses of arsenic in water, noise, and high temperatures [4, 22].

During the study of "India State-Level Disease Burden Initiative CVD Collaborators" in 2018 on "the changing patterns among cardiovascular diseases and their risk factors, between the years 1990-2016" in India, air pollution was introduced as one of the most important factors in the incidence of heart diseases [23].

On the correlation between the degree of noise pollution and the incidence of heart disease, Münzel et al. (2018) found that excessive noise could increase the likelihood of heart diseases [24].

With a study of cardiovascular disease burden from ambient air pollution in Europe, Lelieveld et al. found that air pollution was one of the most significant factors in the incidence of cardiovascular diseases [25].

3. Research Method

3-1. Introduction

This research is a comprehensive indicator of the results of the studies performed in the field of prevention of cardiovascular diseases; therefore, it can be considered as developmental research. This study is descriptive-survey in terms of data collection, and questionnaire was used for data analysis. The analysis was also performed by the mentioned methods and Lingo, Arc GIS 10.5, ENVI software. The statistical population of the study includes 22 districts of Tehran city.

Since the validity of questionnaire was assessed by 25 professionals at the first level and by 10 professionals at the second level, based on the opinions of professionals, the questionnaire enjoyed the validity. Obtained results from the first 25 questionnaires and second 10 questionnaires are expressed in the following sections.

Moreover, since the method used in this study is a paired comparison, for assessing the reliability of the threshold value, the mean difference between two sequential sequences in the fuzzy Delphi method and the calculation of compatibility rate in the fuzzy best-worst method were used. The results are explained in the following sections.

Screening of the parameters was performed at two levels of Delphi fuzzy. After the validation of parameters using this method, BWM fuzzy method was used for calculating the weight and importance of the approved criteria in Delphi fuzzy method. Weighting of the parameters was done using the issue model through Relation 8 and was solved by Lingo 17 software.

At the final level, after data validation, the information related to each parameter with its weight was transferred to ArcGIS software, and the priority of 22 districts of Tehran city was determined to prevent cardiovascular diseases.

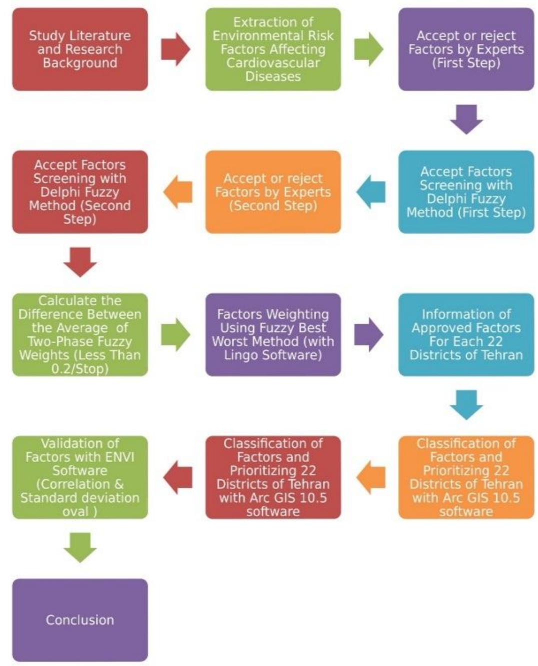

Fig. 1. Solving method process

3-2. Delphi fuzzy method

Delphi method was introduced by Dolky and Helmer for the first time in 1963. This technique is a survey method based on the opinions of professionals. In several real situations, professional judgments could not be expressed and interpreted as certain qualitative numbers; in other words, data and certain numbers are insufficient for modeling the real-world systems because of ambiguity and uncertainty in the judgment of decision-makers. In this case, "the theory of fuzzy sets" introduced by Lotfizadeh (1965) is an appropriate tool for coping with the problem of ambiguity and uncertainty in the decision-making process. Therefore, in this study, Delphi fuzzy method was used for approving and screening the detected parameters.

This method is the combination of Delphi and the theory of fuzzy sets, introduced by Ishikava and colleagues (1993). The steps of Delphi fuzzy method are as follows [26]:

1- Recognition of research parameters using a comprehensive review of theoretical basis of the research

2- Collection of the opinions of decision-making professionals: In this step, after the recognition of parameters and/or factors, the decision-making group including professionals in research subject formed. The questionnaires were distributed to determine the relevance of the identified parameters to the main topic of research and screening, in which the language variables of Table 1 are used to express the importance of each parameter. In this study, triangular fuzzy numbers are used.

Tab. 1. Language phrases and fuzzy numbers of the fuzzy delphi method [27]

Triangular Fuzzy Numbers	Language Phrases
(0 ,0 ,0.25)	very little
(0 ,0.25 ,0.5)	Low
(0.25 ,0.5 ,0.75)	medium
(0.5 ,0.75 ,1)	much
(0.75 ,1 ,1)	too much

3- Approving and screening the parameters: This was performed via the comparison of the acquired values of each parameter and the threshold value, *S*. The threshold value was calculated in several ways and was considered as 0.7 in this study. For this purpose, first, triangular fuzzy values should be calculated according to the opinions of professionals. Then, for calculating the average of opinions of *n* decision-makers, their fuzzy mean should be calculated. The calculation of fuzzy value τ for each parameter was performed by the following equations.

Equation (1)

$$\tilde{a}_{ij} = (a_{ij}, b_{ij}, c_{ij}), \quad i = 1,2,\dots,n \quad j = 1,2,\dots,m$$

Equation (2)

$$\widetilde{\tau_j} = (a_j, b_j, c_j)$$

Equation (3)

$$a_j = \left(\prod_{i=1}^{n} a_{ij}\right)^{1/n}$$

Equation (4)

$$b_j = \left(\prod_{i=1}^{n} b_{ij}\right)^{1/n}$$

Equation (5)

$$c_j = \left(\prod_{i=1}^{n} c_{ij}\right)^{1/n}$$

In the above relationships, i index indicates professional, and j index indicates a decision-making parameter. The diphasic value of the average fuzzy number is also obtained through the following equation.

Equation (6)

$$Crisp = \frac{a+b+c}{3}$$

4- The phase of consensus and completion of delphi fuzzy: In this step, if the mean difference between two sequential sequences of Delphi fuzzy is lower than 0.2, Delphi fuzzy is completed [28].

3-3. Fuzzy best-worst decision-making method

3-3-1. Explanation and definition

The-best-the-worst method was introduced by Jafar Rezai in 2015 and was promoted in another article in 2016. In this method, the best and the worst parameters were determined by decision-maker, and the paired comparison was performed between each of these parameters (the best-the worst) and other parameters; afterwards, a maximum-minimum issue was formulated and solved for determining the weights of different parameters; in this method, a formula was considered for the calculation of inconsistency rate to verify the validity of the comparison [29].

The model of Rezai's article was used in a certain environment; however, in 2017, Guo and Zhaeo assessed BWM model in fuzzy environment and introduced several examples to solve the model in fuzzy environment. The application of fuzzy numbers because of verbal ambiguities of respondents caused higher precision and better results in calculations [29, 30].

3-3-2. The reason for the superiority of the method

Despite multiple incompatibilities in the paired comparison matrix, when a paired comparison matrix is incompatible, it is recommended that the comparisons be revised in order to adapt the paired matrix. Although this approach is common, it has had some unsuccessful results. The main reason for the incompatibility mentioned above is the non-structured comparison method implemented by paired comparison methods.

In this study, due to the high sensitivity and dependence of the results on how factors determine weights, the method that solves the incompatibility challenge and other weaknesses in the process of analyzing the hierarchy in several other decision-making methods is the fuzzy best-worst method.

3-3-3. Steps of the method:

In this method, it is assumed that there are *n* criteria. Paired comparisons of these n criteria are done via verbal phrases in Table 2 with each other. In other words, verbal phrases of the respondents are converted to the corresponding fuzzy numbers based on Table 2.

Tab. 2. Language phrases and the corresponding fuzzy numbers

Corresponding Fuzzy Numbers	Language Phrases
(1,1,1)	equal importance
(0.67,1,1.5)	little importance
(1.5,2,2.5)	relatively important
(2.5,3,3.5)	very important
(3.5,4,4.5)	absolutely important

First step: Determination of a Set of comparative criteria

In this step, a set of parameters is defined as $\{c_1 . c_2 \dots c_n\}$ required for making a decision.

Second step: Determination of the best (*e.g.*, the most important, appropriate one) and the worst (*e.g.*, the least important, appropriate) criteria

In the second step, the best (the most important and appropriate) and the worst (the least important and appropriate) parameters are determined by collecting opinions of professionals, group meetings, and methods such as Delphi.

The best criterion is denoted by C_B and the worst one by C_W.

In this step, a decision-maker defines the best and the worst parameters and no comparison is performed.

Third step: Determination of priority of the best criteria over the other criteria

The priority of the best criteria to other criteria is determined in the form of numbers 1 to 5. The vector of superiority of the best criteria to other criteria is shown in the form of:

Equation (7)

$\tilde{A}_B = (\tilde{a}_{B\,1} . \tilde{a}_{B\,2} \dots . \tilde{a}_{B\,n})$

In the mentioned vector, $\tilde{a}_{Bj}$ indicates the priority of the best criteria (B) to the criteria (j). It is obvious that $\tilde{a}_{BB} = 1$. Moreover, the comparison of the best and the worst criteria should always be of the highest value related to the others.

Fourth Step: Determination of the priority of all criteria related to the worst criteria

The priority of all criteria to the worst criteria is determined by 1 to 5. The vector of the superiority of all criteria to the best criteria is shown in the form of:

$\tilde{A}_w = (\tilde{a}_{1\,W} . \tilde{a}_{2\,W} \dots . \tilde{a}_{n\,W})$

Equation (8)

In the mentioned vector, $\tilde{a}_{jw}$ denotes the priority of the criteria (j) to the worst criteria (W). It is obvious that $\tilde{a}_{ww} = 1$.

Fifth Step: Determination of weight of the parameters $(\widetilde{W}_1^* . \widetilde{W}_2^* \dots . \widetilde{W}_n^*)$ and calculation of compatibility rate

For determining the best weight for each parameter, pairs of $\frac{\tilde{w}_b}{\tilde{w}_j} = \tilde{a}_{Bj}$ and $\frac{\tilde{w}_j}{\tilde{w}_w} = \tilde{a}_{jw}$ are created, and for confirming this condition for all (j)s, a solvent should be found, in which maximum absolute differences ($|\frac{\tilde{w}_b}{\tilde{w}_j} - \tilde{a}_{Bj}|$ and $|\frac{\tilde{w}_j}{\tilde{w}_w} - \tilde{a}_{jw}|$) for all (j)s are minimum.

Since the weights and total of weights are not negative, the model can be formulated as follows:

Equation (9)

$$\min \max_j \{|\frac{\tilde{w}_b}{\tilde{w}_j} - \tilde{a}_{Bj}|, |\frac{\tilde{w}_j}{\tilde{w}_w} - \tilde{a}_{jw}|\}$$

s.t.

$$\sum_j R(\tilde{w}_j) = 1$$

$$w_j \geq 0. \quad l_j^w \leq m_j^w \leq u_j^w \quad . \; l_j^w \geq 0 \quad \text{for all j}$$

where $R(\tilde{a}_i) = \frac{l_i + 4m_i + u_i}{6}$.

The above model could also be converted to the following:

Equation (10)

$$\min \tilde{\xi}$$

s.t.

$$|\frac{\tilde{w}_b}{\tilde{w}_j} - \tilde{a}_{Bj}| \leq \tilde{\xi} \text{ . for all j}$$

$$|\frac{w_j}{w_w} - \tilde{a}_{jw}| \leq \tilde{\xi} \text{ . for all j}$$

s.t.

$$\sum_j \mathrm{R}(\tilde{w}_j) = 1$$

$$w_j \geq 0. \quad l_j^w \leq m_j^w \leq u_j^w \quad . \ l_j^w \geq 0 \text{ for all j}$$

By solving the above models, the best values as $(\widetilde{W_1}^*.\widetilde{W_2}^*.\ldots.\widetilde{W_n}^*)$ and $\tilde{\xi}^*$ are achieved.

In the following processes, the ratio of compatibility is determined using $\tilde{\xi}^*$.

Since $\tilde{\xi}^*$ value is higher, the compatibility is also higher and the comparisons have a lower confidence rate.

Sixth Step: Calculation of compatibility rate

The comparison of time is fully consistent with the following relation for all (j)'s:

$a_{Bj} \times a_{jw} = a_{BW}$, in which a_{Bj} , a_{jw}, and a_{BW} are the priorities of the best parameter to j parameter, priorities of the best parameter to the worst parameter, respectively. As $a_{Bj} \times a_{jw} = a_{BW}$ and $a_{BW} \in \{1.2.3.\ldots.9\}$, the maximum $\tilde{\xi}^*$could be achieved. By the application of compatibility parameter in the table below and its relation, the compatibility rate could be calculated. This compatibility rate is in the range of 0 to 1, and as it gets closer to 0, comparisons have higher stability and compatibility. In contrast, as it is closer to 1, comparisons have lower stability and compatibility.

Tab. 3. Compatibility index BWM fuzzy method

absolutely important	very important	relatively important	little importance	equal importance	a_{BW}
(3.5,4,4.5)	(2.5,3,3.5)	(1.5,2,2.5)	(0.67,1,1.5)	(1,1,1)	
8.04	6.69	5.29	3.8	3	Compatibility Index

Equation (11)

$$\text{Compatibility Rate} = \frac{\xi^*}{\text{Compatibility Index}}$$

4. Results Analysis

4-1. Results of delphi fuzzy method

In the first step of Delphi Fuzzy method, 24 parameters extracted of the previous studies in the form of a questionnaire were given to 25 professionals (cardiologists). Then, they were asked to determine the importance of each parameter based on Table 1. After the collection of opinions and their analysis, the fuzzy and certain means of opinions were calculated, as shown in Table 4. For screening, parameters with a mean lower than 0.7 were deleted; in this case, 14 out of 24 parameters were deleted.

The parameter of "economic-social status" includes living on the margin of a city, housing density, population density, the number of service centers, level of education and literacy (the number of educational and cultural centers, level of awareness, knowledge, and literacy), the number of administrative centers, the number of welfare and entertainment centers, the number of health and treatment centers, the number of economic and commercial centers, the number of banks and financial and credit institutions, employment rate (income), and the number of parks, entertainment equipment and green places. For a precise assessment of these parameters, their sub-parameters are separately placed in the questionnaire, designed for this study, to be proven or denied by the professionals (cardiologists).

Tab. 4. Fuzzy delphi first step results

Status	Final Average of the First Level	Fuzzy Average of the First Level	Index Name
REJECTED	0.330	(0.14,0.31,0.54)	very high temperature
REJECTED	0.350	(0.16,0.33,0.56)	very low temperature
REJECTED	0.470	(0.24,0.47,0.7)	living in margin of a city
REJECTED	0.490	(0.25,0.49,0.73)	housing density
ACCEPTED	0.737	(0.52,0.77,0.92)	population density
REJECTED	0.607	(0.38,0.61,0.83)	number of service centers
ACCEPTED	0.707	(0.48,0.73,0.91)	number of educational and cultural centers

ACCEPTED	0.763	(0.55,0.8,0.94)	level of awareness, knowledge, literacy
REJECTED	0.320	(0.13,0.29,0.54)	number of administrative centers
ACCEPTED	0.787	(0.57,0.82,0.97)	number of welfare and entertainment centers
ACCEPTED	0.767	(0.55,0.8,0.95)	number of health and treatment centers
REJECTED	0.300	(0.11,0.27,0.52)	number of economic and commercial centers
REJECTED	0.260	(0.09,0.22,0.47)	number of banks and financial and Credit Institutions
ACCEPTED	0.750	(0.53,0.78,0.94)	employment rate (income)
ACCEPTED	0.763	(0.54,0.79,0.96)	number of parks and entertainment equipment and green places
ACCEPTED	0.850	(0.66,0.91,0.98)	air pollution (CO-PM10-NO2-O3-SO2-PM2.5)
ACCEPTED	0.740	(0.52,0.77,0.93)	noise pollution
REJECTED	0.503	(0.29,0.49,0.73)	quality of drinking water
REJECTED	0.473	(0.24,0.47,0.71)	height
REJECTED	0.437	(0.21,0.43,0.67)	electromagnetic fields
REJECTED	0.353	(0.14,0.34,0.58)	humidity
REJECTED	0.450	(0.24,0.44,0.67)	atmosphere pressure
ACCEPTED	0.753	(0.53,0.78,0.95)	density of confectionery & fast food restaurants
REJECTED	0.383	(0.16,0.37,0.62)	density of shopping centers

In the second step of the Delphi Fuzzy Method, anew questionnaire was designed with 10 proven parameters. The means of the parameters of the first step were also provided in another questionnaire to give the mean of each parameter to the professionals. Questionnaire 2 is given to professionals, and the fuzzy and certain means of new opinions, listed in Table 5, showed the reproved 10 selected parameters.

Tab. 5. Fuzzy delphi second step results

Status	Subtract	Final Average of the First Level	Final Average of the Second Level	Fuzzy Average of the Second Level	Index Name
ACCEPTED	0.033	0.737	0.770	(0.56,0.81,0.94)	population density
ACCEPTED	0.016	0.707	0.723	(0.5,0.75,0.92)	number of educational and cultural centers
ACCEPTED	0.027	0.763	0.790	(0.58,0.83,0.96)	level of awareness, knowledge, literacy
ACCEPTED	0.01	0.787	0.797	(0.58,0.83,0.98)	number of welfare and entertainment centers
ACCEPTED	0	0.767	0.767	(0.55,0.8,0.95)	number of health and treatment centers
ACCEPTED	0.007	0.750	0.757	(0.54,0.79,0.94)	employment rate (income)
ACCEPTED	0	0.763	0.763	(0.54,0.79,0.96)	number of parks and entertainment equipment and green places

ACCEPTED	0.027	0.850	0.877	(0.69,0.94,1)	air pollution (CO-PM10-NO2-O3-SO2-PM2.5)
ACCEPTED	0.003	0.740	0.737	(0.53,0.77,0.91)	noise pollution
ACCEPTED	0.024	0.753	0.777	(0.56,0.81,0.96)	density of confectionery & fast food restaurants

At the end of the second step, the difference in means of parameters in the first and second steps was calculated to be less than 0.2. Therefore, the second step is the termination of Delphi Fuzzy Method.

4-2. Results of the best-worst fuzzy method

The first step in this method is the determination of the most important (the best) and the least important (the worst) parameters. Based on the results of Delphi Fuzzy, "air pollution including CO-PM10-NO2-O3-SO2-PM2.5" with a mean score of 0.85 was selected as the most important parameter, and "the number of educational and cultural centers" with a mean score of 0.707 was selected as the least important parameter. Afterwards, paired comparisons of the best parameter to the other parameters (BO) and the other parameters to the worst parameter (OW) were performed using a specific questionnaire method and by 10 professionals. Then, the answers were integrated using Geometric Mean Method that the obtained results are shown in Table 6. Compatibility rate is also 0.037 that indicates **High-Level Compatibility**.

Tab. 6. Weight and final rating of criteria

Rank	Definite Weight	Fuzzy Weight	Index Name
1	0.173	(0.16,0.176,0.176)	air pollution (CO-PM10-NO2-O3-SO2-PM2.5)
2	0.132	(0.112,0.133,0.148)	population density
3	0.132	(0.09,0.137,0.153)	number of health and treatment centers
4	0.118	(0.112,0.133,0.148)	noise pollution
5	0.098	(0.071,0.102,0.11)	number of welfare and entertainment centers
6	0.097	(0.075,0.097,0.121)	employment rate (income)
7	0.082	(0.064,0.082,0.097)	number of parks and entertainment equipment and green places
8	0.067	(0.062,0.062,0.092)	level of awareness, knowledge, literacy
9	0.056	(0.043,0.045,0.046)	density of confectionery & fast food restaurants
10	0.045	(0.043,0.045,0.046)	number of educational and cultural centers

4-3. Information of the approved parameters for each of 22 districts of tehran city

After approving the environmental parameters effective in cardiovascular diseases using the opinions of professionals (cardiologist) and their analysis using Delphi Fuzzy Method, and after weighting each one using Fuzzy Best-Worst Method, for prioritizing 22 districts of Tehran based on the prevention of cardiovascular diseases, this study collected the information relating to each parameter in 22 districts of Tehran separately and based on the latest statistical data. For this reason, the data were collected via different organizations and parameters related websites.

4-3-1. Population density

Population density is described as an average number of population in 1 km² of a target district.

Equation (12)

$$\textbf{Population density} = \frac{Population}{Area\ (km^2)}$$

To calculate population density in each of 22 districts of Tehran based on the latest statistical data, a reference is made to the statistical reporting system, statistics section of Tehran in 1395 (2016), and the websites of municipality of each of 22 districts of Tehran.

4-3-2. Literacy rate

Literacy rate is described as the ratio of literate people to the population of 6 years old or above.

Equation (13)

$$\textbf{Literary Rate} = \frac{Literate\ Population}{6\ years\ old\ population\ \&\ more} \times 100$$

This ratio is obtained in each age rate or group by dividing the number of literate people by the whole population (six years old or more) that are placed in that age rate or group, as denoted by percentage.

To calculate the literacy rate, information of literate population, and the population of 6 years old or more, separately for each of 22 districts of

Tehran, this study collected the required information from the Iranian statistical center and calculated the literacy rate separately for each district.

4-3-3. Employment rate

Employment rate is described as the ratio of employed people to the active population of 10 years old or above.

Equation (14)

$$\textbf{Employment rate} = \frac{Practitoner\ Population}{10\ years\ old\ active\ population\ \&\ more} \times 100$$

This ratio is obtained in each age rate or group by dividing the number of employed people by the whole active population (10 years old or more) that are placed in that age rate or group, as denoted by percentage.
To calculate the employment rate, information of employed population, and the active population that are 10 years old or above, separately for each of 22 districts of Tehran, this study collected information from the Iranian statistical center and calculated the employment rate separately for each district.

4-3-4. Number of parks and entertainment equipment and green places

Information of the number of parks and entertainment equipment and green places including the number and district of public gardens (counting urban forest gardens) and urban green places such as gardens, forest gardens, forestry, squares, refreshments, pavement trees, margins and the number, the district, and the capitation of each one were all collected from the latest statistical data in 2016 from the website of Organization of Gardens and Green Places in Tehran.
It is necessary to mention that as the capitation rate is appropriate, for the preparation of geographic maps, this parameter is used for final analysis.

4-3-5. Density of confectionery and fast food restaurants

The number of fast-food restaurants in each of 22 districts of Tehran was obtained from Tehran's Union of Food and Grocery Stores. The number of confectionery in each of 22 districts of Tehran was obtained from the IT Department of Tehran's Guildhall. Since the information about the 1st and 20th districts is not in the specific classifications of these two organizations, information of these districts is obtained from the Center for Statistics and Information of Iranian Chamber of Commerce.
Moreover, for the preparation of geographic maps, total rates of density of pastries and fast food restaurants are used.

4-3-6. Density of cultural and educational centers, density of welfare and entertainment centers, and density of health and treatment centers

The number of cultural and educational centers, the number of welfare and entertainment centers, and the number of health and treatment centers for each of 22 districts of Tehran were obtained from the Department of Social and Cultural Studies, Deputy of Social and Cultural Affairs of Tehran Municipality. It is important to explain that to prepare geographic maps, density of cultural and educational centers, density of welfare and entertainment centers, and density of health and treatment centers were used.

4-3-7. Air pollution including CO-PM10-NO2-O3-SO2-PM2.5

- ✓ **Air Quality Index (AQI)**

Air quality index is a parameter that serves as a daily notification and predicts air quality. This index shows the quality of air and indicates its relationship with the health level.
In other words, this index shows how much air pollution can be effective in the human health status, making it easier for citizens to understand this effect. Air quality index is calculated for 6 air pollutants including carbon monoxide (CO), ozone (O3), sulfur dioxide (SO2), nitrogen dioxide (NO2), micro-particles with a size less than 10 microns (PM10), and micro-particles with a size less than 2.5 microns (PM2.5).

Tab. 7. Pollution failure in the calculation of air quality index and pollution control guide and AQI indicator

	Breakpoints							
O3 (PPM) 8 hour	O3 (PPM) 1 hour	PM2.5 (µg $/m^3$) 24 hour	PM10 (µg $/m^3$) 24 hour	CO (PPM) 1 hour	SO2 (PPM) 24 hour	NO2 (PPM) 1 hour	AQI	Air Quality Classification
0-0.059	-	0-15.4	0-54	0-4.4	0-0.034	0-0.053	0-50	Clean
0.06-0.075	-	15.5-35	55-154	4.5-9.4	0.035-0.144	0.054-0.1	51-100	Healthy
0.076-0.095	0.125-0.164	35.1-65.4	155-254	9.5-12.4	0.145-0.224	0.101-0.36	101-150	Unhealthy for sensitive groups
0.096-0.115	0.165-0.204	65.5-150.4	255-354	12.5-15.4	0.225-0.304	0.361-0.64	151-200	Unhealthy
0.116-0.374	0.205-0.404	150.5-250.4	355-424	15.5-30.4	0.305-0.604	0.65-1.24	201-300	Very unhealthy
O3(8 hour)>0.374 AQI>300	0.405-0.504	250.5-350.4	425-504	30.5-40.4	0.605-0.804	1.25-1.64	301-400	Dangerous
	0.505-0.604	350.5-500.4	505-604	40.5-50.4	0.805-1.004	1.65-2.04	401-500	

To obtain the information of AQI, air quality control website, and archive of Air Quality Index in Tehran to select AQI parameter, information of all stations of 22 districts of Tehran municipality from 18/01/2013 to 18/01/2018 (a 5-year period) was extracted. Since no complete information existed in the reports of air quality control website, the information obtained from the stations of 22 districts of Tehran was approximately complete. The stations were placed equally in the districts of Tehran. For normalizing AQI data, the above-mentioned formula is used, and AQI parameter defined above is considered as the main parameter.

Equation (15)

$$s_{AQI} = \frac{\text{AQI} \times \text{Max Total Days}(1740)}{Total\ Days\ of\ That\ Station}$$

It is necessary to mention that the consequences of incomplete information in the assessment of air pollution include technical defect and power outage on some days of the year, which was also one of the limitations of our study.

4-3-8. Noise pollution

The latest statistical information about noise pollution was extracted from air quality control website. The yearly mean of noise assessed by constant stations and the noise pollution rate in 22 districts of Tehran that were defined as the terms of the noise level at the day-time period and the terms of the level of noise at the night-time period on the basis of unit dBA from 2009 to 2013 were calculated. However, this is considered as a limitation for this study because of the lack of newer information.

Of note, the mean terms of day/night-time noise levels are used in preparing geographic maps for using this information.

4-4. Classification of parameters and prioritization of 22 districts of tehran for each parameter by considering their effects on prevention of cardiovascular diseases

In this section, 22 districts of Tehran were prioritized in accordance with every parameter following their classification and considering their negative and positive effects using Natural break algorithm and Arc GIS 10.5 software.

According to this clustering algorithm and based on the values in the layers, classification is done such that, first, distributions in different classes are considered to be variable; second, total values of classes are variable. This method seeks to decrease the variance within classes and maximize the variance between classes. This method is also one of the best classification methods. **(Appendix 1)**

4-5. Validation of parameter and information related to each of them using standard deviation oval and correlation

In this section, to validate the parameters and the corresponding information, standard deviation oval parameters, Standard Deviation-gravity center, and credit value of correlation will be used and analyzed.

Standard deviation oval indicates the distribution pattern of each parameter in Tehran. In this parameter, as far as the outer diameter of the oval is concerned, the distribution of that parameter increases.

As Figure 2 shows, except the parameter of the capitation of green places, literacy rate, noise pollution, and density of health and treatment centers, other parameters have central and circular distribution.

ENVI (environmental software) provides satellite images for visualization and analysis. Moreover, using this software, it is possible to totally analyze different kinds of remote sensing data in a user-friendly environment.

Since the concordance of the correlation between parameters and results of Standard deviation oval parameter is higher, the validity and accuracy of archived data are more promising; to put it differently, research results are more accurate. **(Appendix 2)**

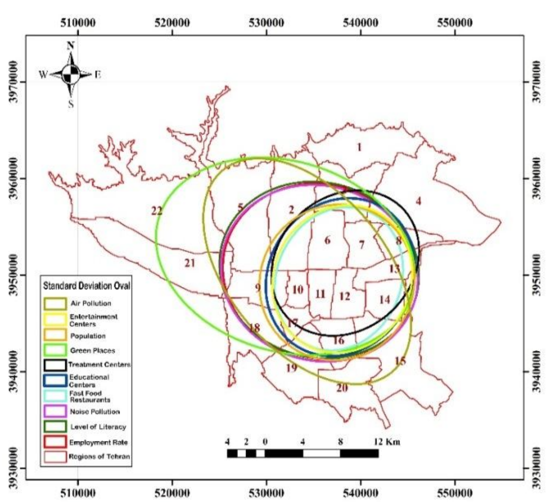

Fig. 2. Status of standard deviation oval of indicators contributing to cardiovascular diseases in tehran

In the analysis of parameters, as indicated in the matrix, air and noise pollution parameters have a positive correlation with density parameters such as population density, density of welfare and entertainment centers, density of health and treatment centers, and density of cultural and educational centers. In fact, given the increase of the mentioned parameters, the other parameter will experience an approximate increase. This is highly in agreement with the logic of environmental situations. In other words, density of the mentioned parameters in Tehran because of high traffic, especially personal cars, results in the enhancement and amelioration of air and noise pollutions. From this point of view, the high correlation and (positive) coordination between the aforementioned parameters shows the high validity of parameters and their related information in this study. The positive correlation between air pollution and capitation of green places appears to be logical; as for neutralizing the effect of air pollution, increasing the green places is highly required. On the other hand, in districts with higher population density, the need for green places is higher.

Furthermore, high population density needs many more health and treatment centers due to the greater need and demand for them. Therefore, the correlation between these two parameters is positive, too.

The significant point about the results of the correlation matrix is that there is a total correlation between population density and air pollution. For these parameters, Correlation 1 is archived, which indicates that these parameters have a close correlation with each other. However, this issue is not only not impossible, but also completely logical.

Regarding the results of the analysis of standard deviation oval parameter, correlation and maximum concordance of results with each other should receive greater notice and value; by the same token, regarding the environmental situations, validity and accuracy of parameters and the related information in and about each of 22 districts of Tehran are of highest value.

5. Conclusion

In the final section, considering weight for each parameter, the separated maps derived from the previous steps were aggregated. Finally, the priority map of 22 districts of Tehran for the prevention of cardiovascular diseases was drawn.

Tab. 8. Classification of aggregation of indicators using natural breaks algorithm

Classification of Aggregation of Indicators		
Lower Limit	Upper Llimit	Score
1.65368	2.15973	1
2.15973	2.448902	2
2.448902	2.77422	3
2.77422	3.087489	4
3.087489	3.352563	5
3.352563	3.593539	6
3.593539	3.870662	7
3.870662	4.292371	8
4.292371	4.726128	9

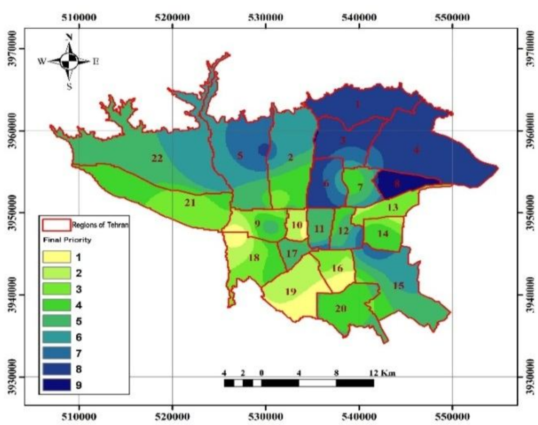

Fig. 3. Prioritizing 22 areas of tehran for prevention of cardiovascular dDiseases

As indicated in Figure 3, the 8th district (except a small part from the western side), the western half of the 6th district , a part of the east of the 5th district, the 1st, 4th, 3rd, 8th districts, marginal parts of the 12th, 14th, and 15th districts, a small part in the west of the 11th district , central and northern parts of the 2th and 5th districts, the eastern part of the 22th district, the northern and eastern parts of the 15th district, southern part of the 11th and 12th districts, parts of north-west, center, and south-east of the 15th district, southern-eastern (marginal) parts of the 20th district, central, western, and southern parts of the 22th district, southern part of the 5th district, north-west part of the 21th district, central parts of the 9th and 14th districts, central parts of the 7th district, southern part of the 2th district , eastern part of the 18th district, western part of the 15th district, approximately all parts of the 20th district except a part in south-east, northern parts of the 14th district, approximately all parts of the 13th district, central and southern parts of the 21th district, marginal parts of the 2nd, 5th, 9th, and 10th districts, a part in southern-western of the 12th district, central bar of the 18th district, and the north part of the 16th part are the best districts with respect to the prevention of cardiovascular diseases. Further, the 10th district, marginal part of the 9th and 18th districts (northern-western part of the 18th and southern-western part of the 9th districts), and the 16th and 19th districts (approximately the whole districts) are the last priorities for the prevention of cardiovascular diseases. In other words, the frequency of cardiovascular diseases is higher in these districts, which are considered as high-risk districts (Table 8 indicates the aggregated classification of parameters).

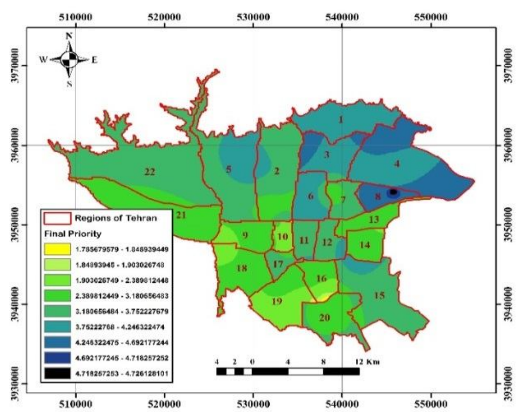

Fig. 4. Prioritizing 22 areas of tehran for prevention of cardiovascular diseases with the top priority of the area

For detecting the best district based on the prevention of cardiovascular diseases in Tehran, the classification of parameters is limited in order to increase accuracy. The results indicated that the eastern part of the 8th district (the black district) is the best district based on the prevention of cardiovascular diseases. The other district is prioritized respectively from blue to yellow (Figure 4).

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Appendix 1
Classification of indicators contributing to the prevention of cardiovascular diseases in tehran

Density of Welfare and Entertainment Centers		Noise Pollution		Density of Health and Treatment Centers		Population Density		
Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Score
20.459999	44.439999	61.974998	63.051595	42.978778	56	2998.590088	3623.370117	9
18.49	20.459999	63.051595	65	27.121164	42.978778	3623.370117	8799.950195	8
14.37	18.49	65	66.43	21.463702	27.121164	8799.950195	11081.59961	7
12.32	14.37	66.43	67.404999	16.670187	21.463702	11081.59961	12890.21973	6
8.7	12.32	67.404999	68.389999	13.242267	16.670187	12890.21973	16602.67969	5
6.77	8.7	68.389999	70.269997	9.507785	13.242267	16602.67969	20351.63086	4
5.54	6.77	70.269997	71.129997	3.683107	9.507785	20351.63086	24439.67969	3
2.17	5.54	71.129997	71.809998	1.899474	3.683107	24439.67969	35474.21094	2
2.11	2.17	71.809998	74.379997	1	1.899474	35474.21094	40038.55859	1

Density of Confectionery & Fast Food Restaurants		Level of Awareness, Knowledge, and Literacy		Density of Parks and Entertainment Equipment and Green Places		Employment Rate (Income)		
Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Score
0.374	0.757	97.75	98.07	43.700001	66	91.330002	93.190002	9
0.757	4.5	96.989998	97.75	29.6	43.700001	90.050003	91.330002	8
4.5	5.653	96.150002	96.989998	18.299999	29.6	88.610001	90.050003	7
5.653	6.823	95.349998	96.150002	15.6	18.299999	87.75	88.610001	6
6.823	8.983	94.459999	95.349998	14.2	15.6	86.639999	87.75	5
8.983	10.444	92.260002	94.459999	11.9	14.2	85.226423	86.639999	4
10.444	14.842	90.709999	92.260002	6.2	11.9	83.518325	85.226423	3
14.842	16.622999	90.150002	90.709999	3.7	6.2	80.959582	83.518325	2
16.622999	22.766001	89.629997	90.150002	2.8	3.7	79.760002	80.959582	1

Air Pollution (CO-PM10-NO2-O3-SO2-PM2.5)		Density of Educational and Cultural Centers		
Old	New	Lower Limit	Upper Limit	score
		35	42	9
		25	35	8
High : 887.997	9	21	25	7
		18	21	6
		16	18	5
		12	16	4
Low : 85.7543	1	10	12	3
		4	10	2
		3	4	1

Appendix 2

Correlation rate of indicators affecting cardiovascular diseases in tehran using ENVI software

Correlation	Noise Pollution	Level of Awareness, Knowledge, Literacy	Density of Welfare and Entertainment Centers	Population Density	Parks and Entertainment Equipment and Green	Density of Confectionery & Fast Food Restaurants	Employment Rate (Income)	Density of Health and Treatment Centers	Density of Educational and Cultural Centers	Air Pollution (CO-PM10-NO2-O3-SO2-PM2.5)
Noise Pollution	1	0.999786	0.999153	0.999736	0.999546	0.999597	0.999232	0.999514	0.999173	0.999736
Level of Awareness, Knowledge, Literacy	0.999786	1	0.999028	0.999626	0.999458	0.99944	0.99899	0.999451	0.999064	0.999625
Density of Welfare and Entertainment Centers	0.999153	0.999028	1	0.999619	0.998879	0.998728	0.999815	0.999844	0.999919	0.99962
Population Density	0.999736	0.999626	0.999619	1	0.9997	0.999676	0.99967	0.999789	0.999639	1
Density of Parks and Entertainment Equipment and Green Places	0.999546	0.999458	0.998879	0.9997	1	0.999883	0.999009	0.999176	0.998872	0.999699
Density of Confectionery & Fast Food Restaurants	0.999597	0.99944	0.998728	0.999676	0.999883	1	0.99898	0.999081	0.998742	0.999675
Employment Rate (Income)	0.999232	0.99899	0.999815	0.99967	0.999009	0.99898	1	0.999729	0.999825	0.99967
Density of Health and Treatment Centers	0.999514	0.999451	0.999844	0.999789	0.999176	0.999081	0.999729	1	0.99989	0.99979
Density of Educational and Cultural Centers	0.999173	0.999064	0.999919	0.999639	0.998872	0.998742	0.999825	0.99989	1	0.99964
Air Pollution (CO-PM10-NO2-O3-SO2-PM2.5)	0.999736	0.999625	0.99962	1	0.999699	0.999675	0.99967	0.99979	0.99964	1