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Location of Road Emergency Stations in Fars Province, Using Spatial Multi-Criteria Decision Making

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ABSTRACT

Objectives: To locate the road emergency stations in Fars province based on using spatial multi-criteria decision making (Delphi method).
Methods: In this study, the criteria affecting the location of road emergency stations have been identified through Delphi method and their importance was determined using Analytical Hierarchical Process (AHP). With regard to the importance of the criteria and by using Geographical Information System (GIS), the appropriateness of the existing stations with the criteria and the way of their distribution has been explored, and the appropriate arenas for creating new emergency stations were determined. In order to investigate the spatial distribution pattern of the stations, Moran's Index was used.
Results: The accidents (0.318), placement position (0.235), time (0.198), roads (0.160), and population (0.079) were introduced as the main criteria in location road emergency stations. The findings showed that the distribution of the existing stations was clustering (Moran's I=0.3). Three priorities were introduced for establishing new stations. Some arenas including Abade, north of Eghlid and Khoram bid, and small parts of Shiraz, Farashband, Bavanat, and Kazeroon were suggested as the first priority.
Conclusion: GIS is a useful and applicable tool in investigating spatial distribution and geographical accessibility to the setting that provide health care, including emergency stations.

Keywords: Analytical hierarchical process; Road emergency stations; Geographical information system; Spatial autocorrelation.

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Introduction

Availability of the healthcare is a complex concept with multiple dimensions [1] and different definitions have been provided for it, but in most definitions the provision of services and geographical availability are considered [2,3]. Although investigating the geographical availability to healthcare services in all communities, or even in one country can be difficult [4], Geographical Information System (GIS) is useful in exploring the geographical dimension of availability [5]. By

combining and analyzing complicated data from different sources based on spatial information and data bases, and by using geographical parameters and then presenting them in the form of text maps, GIS can effectively contribute to understanding the distribution and the way of accessing [6-8]. Until now, many studies have used GIS in measuring the accessibility to primary and secondary_ health care services_ in order to estimate the spatial inequalities [9-11]. Moreover, this system has been used in developing countries in order to investigate the accessibility of health care facilities and also to plan and locate new healthcare centers [12,13].

Another important application of GIS is in emergency and it leads to recognizing the critical places for fast help and choosing the best place for emergency stations [14]. A review of the literature on using GIS in the field of pre--hospital care has demonstrated that in these studies geographical accessibility to these services and the time of this accessibility has been most investigated [15-20]. In Iran, most of the studies on the field of healthcare are related to spatial distribution of healthcare centers [21-23] and a few studies have been conducted on the spatial distribution and accessibility to emergency stations and pre-hospital centers [14,24]. By reviewing the statistics of the accidents, the importance of considering the pre-hospital services and emergency become clear.

Road accidents by causing 50 million injuries per year are one of the most important problems of public health in the world [25,26]. Iran is one of the countries that have the highest rate of road accidents. After cardio vascular diseases, accidents are the most important cause of death in Iran, so that there are almost 28000 deaths and 800000 injuries because of the accidents in roads and city streets per year [27,28]. This figure is also true about Fars province, one of the vast southern provinces of Iran, in a way that after cardiac arrest, traffic accidents have the highest number of deaths and with respect to the years of life lost they have the first rank in this province [29]. By providing fast and adequate pre-hospital services in accidents scene, we can prevent a large number of 1.2 million death cases and 50 million injuries that happen in the world yearly [30, 31]. Also, evidence has shown that pre-hospital services with good quality can significantly reduce the number of deaths caused by trauma brain trauma resulting from accident [32]. Therefore, examining the geographical distribution of the existing emergency centers and also providing appropriate arena for establishing new centers can be helpful in providing timely and fast services at the time of traffic accidents; Using GIS, the present study has assessed the distribution of the emergency stations and by identifying the existing limitations, the Province's emergency stations have located.

Materials and Methods

This study has been conducted in Fars province, which is located in the south of Iran, with an area of 122,400 km^2. This province is in longitude of 27°31 to 31°42' north and latitude of 50°37 to 55°38' east [33]. The population of this province is about 4.6 million and according to the country division in 1392, this province comprises 29 counties (Figure 1A). The total number of cars in this province based on the census data in 1390 was 532155, which means 0.11 per person and that of motorcycle per capita is 0.9 [34]. Based on the obtained data from Fars province's medical emergency center, in 2012 there were 92 road emergency stations in the province. The present study aimed at location road emergency stations in several stages: At the first stage, the criteria affecting the location of road emergency stations were identified; At the next stage, these criteria were

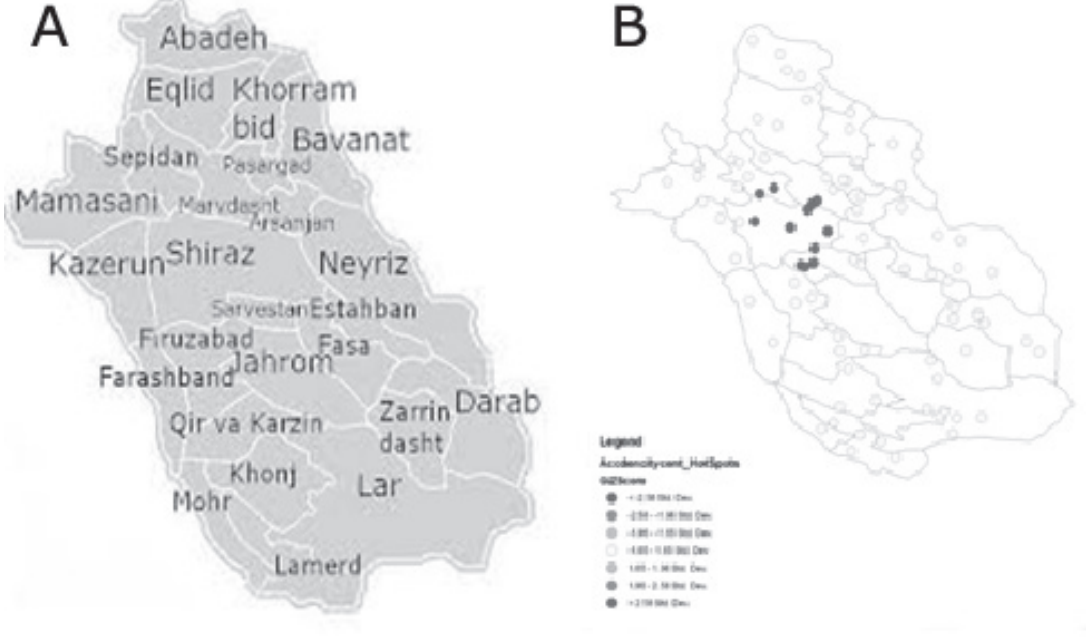

Fig. 1. Countries of Fars province in 2012 (A); Distribution of road emergency stations dispatched duty number in Fars, 2012 (B).

classified based on their importance and at the final stage, using these weighted criteria by experts and GIS, was recognized the appropriate arenas to initiate the emergency stations.

At the first stage of this study, the criteria affecting the location of emergency stations were identified. To this purpose, 22 criteria in 6 main groups were elicited by a review of previous studies. Delphi method which, was done in one round, was used to achieve an agreement on the elicited criteria. Therefore, a list of criteria was presented to 20 experts by email or by attendance. Seven individuals were expert in geography and urban planning, 6 in management and the rest in emergency medicine and disaster management. In the survey form of the criteria, the individuals were asked to determine the importance of the given criterion location the road emergency stations by using 1 to 10 numbers, and if there were any other important criteria, add it to the form. After collecting the forms, the data resulting from these forms were analyzed in SPSS 19 and the percentage of individuals' agreements on the importance level of each given criteria was determined. Scores7 and higher were considered as the criterion for selection in Delphi. The results indicated that in 81.82% of criteria, the group members' agreement was on the importance level of criteria. With respect to the fact that the condition for stopping the Delphi rounds was 80% agreement level, the rounds were stopped. The criteria that were in agreement level of higher than 80% were considered as criteria and those that were not at 80% agreement level were excluded from the study.

In order to prioritize the obtained criteria from the first stage, Analytical Hierarchical Process (AHP) was used. Therefore, measuring the relative importance of criteria-affecting the location of emergency stations questionnaire by using the criteria obtained from the previous stage was compared using pairs matrixes and sent to the experts in order to determine the relative importance of the criteria and sub-criteria by using numbers 1 to 9. Then, the results of the 18 completed questionnaires were analyzed using Expert Choice 11 software and at last the relative weigh of each criterion was obtained.

At the final stage of this study, Moran's Index was used in order to explore the distribution pattern of the existing road emergency stations in Fars province. Due to the work load of the stations. This index considers the spatial autocorrelation based on the location of the forms and also their complications and values. This index by considering the forms and related- characteristics analyzes the spatial distribution pattern in cluster, dispersed and random ways. Moran's index is between _1 and +1, which _1 shows dispersed state, +1 shows cluster scatter and zero denotes random pattern [35,36]. Then, for the descriptive data which was collected based on the criteria Excel software and GIS were used to create a data base in the software. At last Arc GIS 9.3 was used in spatial analysis.

Results

Based on the data obtained from emergency centers and medical emergency department of Fars province, in 2012 the number of the reporte road accidents in this province was 8886 which resulted in 831 death cases and 2851 injuries. The number of the missions by road emergency stations in Fars was 11225. The highest number of missions, regarding the time was related to September. The highest number of missions was related to Kazeroun road emergency station, with 332 missions and to Darab road emergency_ with_330 missions. Regarding the time, the highest average time of arrival to the accident scene was related to Kushkak station and the lowest average time to Alamarvdasht. Moreover, the investigation of continental factors indicated that the highest number of glacial days and the highest average of monthly rain in Fars province were related to February. The highest rain was related to Sepidan and the highest glacial days to Safashahr.

Table 1 shows the criteria affecting the location of road emergency stations in experts' views. Based on this table, 4 criteria of field space, stream, field price and the cost of establishing an emergency station; had an agreement of less than 80%; therefore, they were excluded from the list. According to the expert's opinion, the variables of Table 1 were divided into 5 main categories. The accidents (0.318), placement position (0.235), time (0.198), roads (0.160), and population (0.070) respectively had the highest importance on deciding about the location of the emergency station in Fars province (Table 2).

Distribution pattern of emergency stations based on Moran index was 0.3 (z=6.8) which shows the clustering distribution of the current emergency stations in Fars province (map 2). As it is seen in Figure 1B these stations are more focused in some parts of Shiraz, Sepidan, Marvdasht and Kavar, and they are highlighted in red. Figure 2 and 3 show the appropriateness of the existing road emergency stations in Fars with population, roads, accidents, placement position and time criteria, respectively.

In Figure 2A, the existing road emergency stations in arenas which have been highlighted with green, with regard to the population, the criterion have been located in appropriate places. These arenas have a high population with a high density. In Figure 2B, the existing road emergency stations in arenas highlighted in green, with regard to the road criterion, have been located in appropriate places. These arenas have a higher road and automobile per-capita than other areas and are near the main road. In Figure 2C, the existing road emergency stations in arenas which have been highlighted in green, with regard to the accidents criterion, have been installed in appropriate places. These arenas have a higher rate of accidents, deaths and ulcerous than other areas. In

Table 1. The experts' agreement percentage on the importance of the criteria affecting the location of road emergency stations [a]

Criteria	Agreement percentage*	Criteria	Agreement percentage
1. Population number	85	12. Distance from other stations	100
2. Population density	90	13. Distance from hospital	100
3. Tourist population	80	14. Parcel area	65
4. The length of the communication roads based on the type	90	15. Climate factors (snow, wind)	80
5. Adjacency to the main road	100	16. Stream	75
6. Road per capita based on type	80	17. Station Service Area	85
7. Automobile per capita	90	18. Parecal price	40
8. The number of accidents	100	19. Cost of establishing an emergency station	60
9. The number of ulcerous/ ulcerous per capita	100	20. Average time of helper arrival	100
10. The number of killed/killed per capita	100	21. Time of accident (night, day)	80
11. The accidents focus	100	22. Time of tourists presence	80

*100 agreement percentage means all the participating experts assigned [a] score higher than 7 to that criteria.

Table 2. The relative final weighs of the factors affecting the location of the road emergency stations

Row	Main criteria	Weigh	Variables	Weigh	Final weighs
1	Population	0.079	Population number	0.251	0.0198
2			Population density	0.452	0.0357
3			Tourist population	0.298	0.0235
4	Roads	0.160	The length of the communication roads based on the type	0.223	0.0356
5			Adjacency to the main road	0.288	0.046
6			Road per capita based on type	0.153	0.0244
7			Car per capita	0.342	0.054
8	Accidents	0.318	The number of accidents	0.220	0.069
9			The focus of accidents	0.430	0.136
10			The number of deaths	0.172	0.054
11			The number of ulcerous	0.178	0.056
12	Placement position	0.235	Distance from other stations	0.512	0.12
13			Space under cover	0.194	0.045
14			Field space	0.089	0.020
15			Continental factors	0.192	0.045
16	Time	0.198	Average time of helper arrival	0.503	0.099
17			Time of accident(night and day)	0.246	0.048
18			Time of tourist presence	0.251	0.049

other words they are the center of accidents.

In Figure 3A, the existing road emergency stations in arenas which have been highlighted in red, with regard to the placement position criterion, have been installed in appropriate places. These arenas have a higher number of glacial and rainy days than other areas, therefore it is more likely that the accidents occur. In Figure 3B, the existing road emergency stations in arenas which have been highlighted in green, with regard to the time criterion have been installed in appropriate places. These arenas have a lower average time of help than other areas. Figure 3C has been created by a combination of layers related to 5 investigated criteria and shows the three priorities for establishing new road emergency stations in Fars province. The first priority has been shown in dark brown, the second priority in light brown and the third priority by yellow.

Discussion

The study and need for assessing appropriate places for establishing healthcare facilities can be effective in appropriate distribution of these stations based on need. The findings indicated that the number of accidents, placement position, time, roads and population were respectively the most important criteria in deciding about establishing new emergency stations. Ashley and Schuurman also used population, emergency position and arrival time criteria in order to examine the geographical accessibility to emergency and investigate the optimal position modeling for emergency helicopter [37,38]. More over Saeedian has suggested population, space

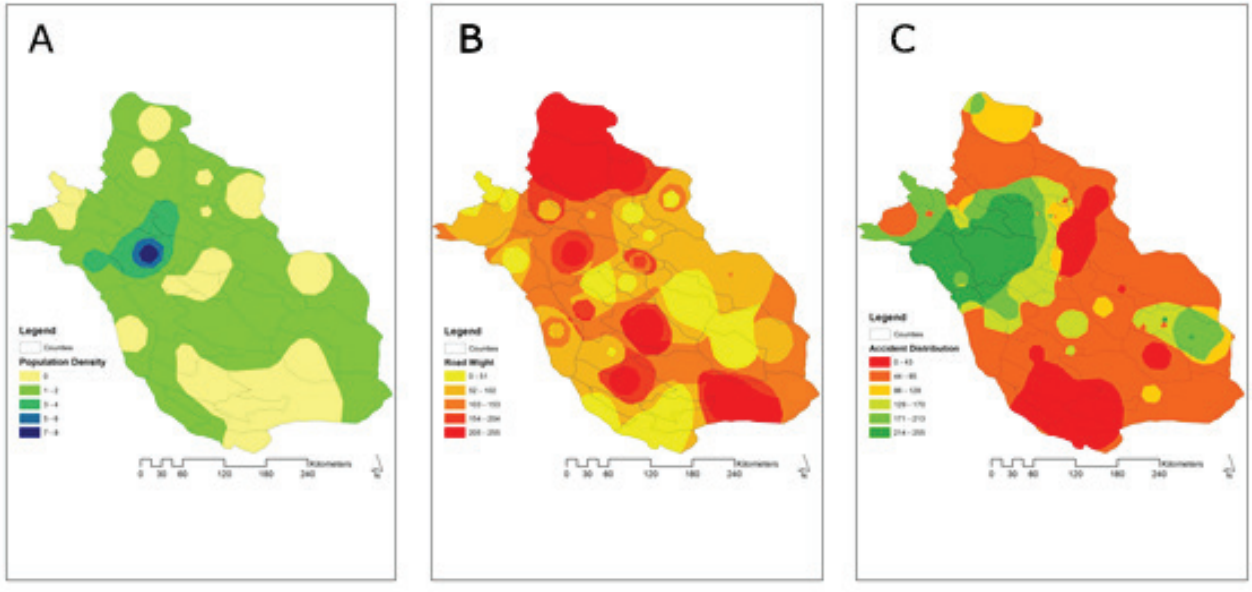

Fig. 2. Spatial distribution of population density criteria in Fars, 2011 (A); Spatial distribution of roads weight criteria in Fars, 2012 (B); Spatial distribution of accident criteria in Fars, 2012 (C)

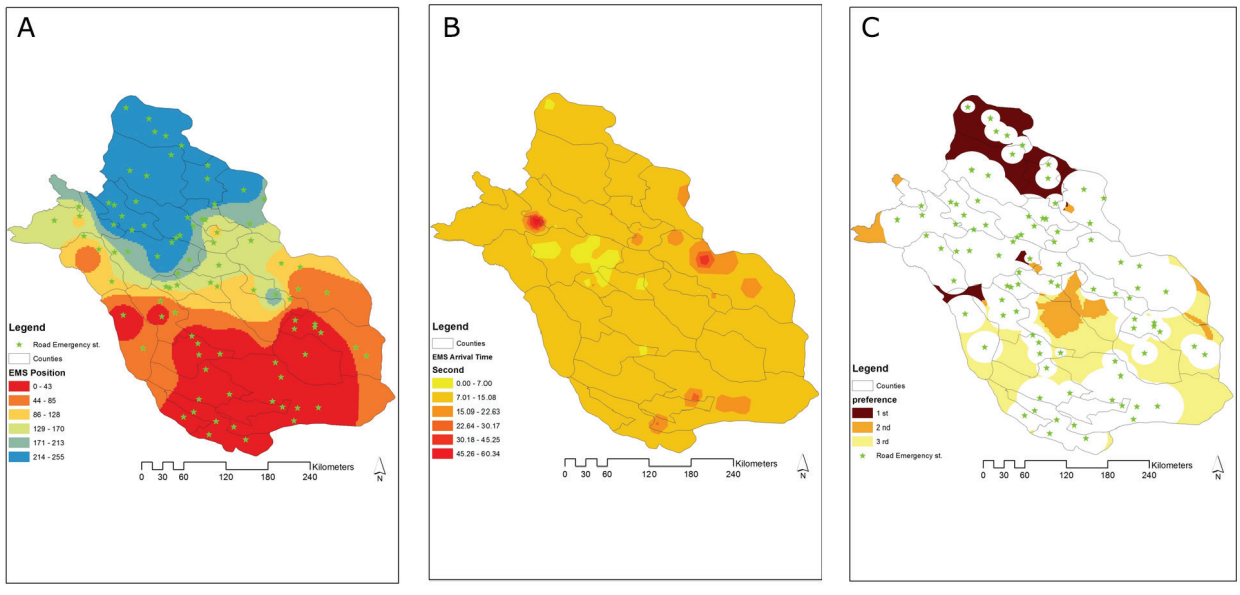

Fig. 3. Spatial distribution of EMS accessibility in Fars, 2012 (A); Spatial pattern of EMS average time arrival criteria in Fars, 2012 (B); Complimentary areas to locate a new EMS in Fars, 2012 (C).

under cover, traffic network, land application, and the potential danger as the major criteria in location the urban emergency station [14].The common criteria in all these studies and the present study is population, which has received a lower final weight in comparison to other criteria. In other areas of health, except emergency, Ebrahimzade (2012), Feli (2012), and Azimi (2011) in separate studies for location healthcare centers and aerial help sites considered placement position criteria and some variable including accessibility to the main communication network as criteria [23,39,40]. Parker *et al*., [15] for measuring accessibility to primary cares considered population, travel time and distance to the service provider center criteria. Yigit in distribution of local medical clinics considered population criteria [41]. Schuurman *et al*., [1] and Lars [42] in order to examine accessibility to hospitals considered such criteria as travel time, under cover space, and the location of hospital. It is obvious that the roads condition and the placement position in location pre-hospital stations are more important than other healthcare centers. Haynes *et al*., [43] suggested the importance of individuals' selection and patients' behavior as some important factors in geographical distribution. However, it seems this factor is not that much important in emergency services in which the individuals are in life-threatening states and usually the injured do not decide about the healthcare centers.

Among the given variable, accidents focus, distance from other help centers and the average time of helpers' arrival respectively obtained the highest

final weight. Therefore, identifying the appropriate locations to establish emergency stations is mostly influenced by these three criteria, and the arenas in which the accidents have occurred, and also the existing emergency stations in them had more distance from other, help-centers including hospitals, and other road emergency centers and with a higher average time arrival time at the accidents scene. Therefore it is more likely that they are in the first priority for establishing new emergency stations.

Results of Moran index demonstrated that the stations had a clustering distribution pattern. Since work load has been a base in the computation, i.e. the work load of emergency stations has been central izedin particular parts of Fars province, so; there have been more stations in this part of the province. Taghvaei and colleagues' study [44] on analyzing the spatial distribution of hospital services, Flabouris's study [45] on investigating the Australian accessibility to special care beds, Tanimura's study [46] on accessibility to child care facilities in a part of Japan and Sanni's study [47] on examining the distribution pattern of healthcare facilities in one of the Nigeria's state showed that the distribution pattern of all the above mentioned cases is clustering. It means these facilities have been centralized in particular areas. But the important point in geographical distribution of the healthcare facilities is considering the need index. Therefore, the clustering distribution of the emergency stations does not necessarily mean inequality in the of distribution stations, in case these clusters are in the priority of the agreed criteria among the experts. As the findings of this study indicated in Fars province, arenas including Shiraz, some parts of Marvdasht, Kazeroon, Sepidan, Mamasani, Firoozabad, Farashband and Kavar have had a higher number of population and a higher population density than other areas and with regard to the population criteria, the existing stations are located in appropriate places.

Arenas including Abade, Eghlid, some parts of Khorambid, Shiraz, Jahrom, Khonj, Larestan have had a higher road and automobile per capita in comparison to other areas, and the existing stations are located in appropriate places with regard to the roads criteria. It seems we can point to the dominant urban population in Abadeh, Shiraz and Jahrom as one reason for a high automobile per capita in these cities.

Arenas including, Shiraz, Marvdasht, Kazeroon and some parts of Mamasani, Sepidan, FiroozAbad, Darab and Eghlid have had a higher rate of accidents, deaths and injuries than other areas. Also, they have been the center of accidents and the existing stations in them have been located in appropriate place. We can point to factors such as high population density, high traffic, and high automobile per capita in cities like Shiraz as some reasons for being the center of accidents.

With regard to the position criterion, existing stations in Abade, Eghlid, Khoram bid, some parts of Sepidan and Marvdasht have had higher glacial and rainy days than other areas. And their distance from the nearest hospital was more than other parts and since in glacial and rainy days, the number of accidents increases they are located in an appropriate place with regard to the position criterion.

Areas including Shiraz, Abade, Sarvestan, Kavar, and some parts of Khorambid, Marvdasht, Eghlid, Darab, Kherame, Firoozabad, Kazeroon, Sepidan and Marvdasht have had a higher time than other areas and since one reason for death after accidents is delayed arrival of the help arriving at accidents scene, the existing stations in these areas are appropriate with regard to the time criterion.

But a question which may arise for the decision makers is that which area (mentioned above) is in the priority of establishing new emergency station in Fars province. Therefore, by creating a combined layer of the data related to the criteria and the application of criteria weights, the three following priorities were elicited for establishing new stations.

First priority includes Abade, north of Eghlid, Khorambid, and small parts of Shiraz, Firoozabad, Farashband, Bavanat, and Kazeroon. Second priority includes some parts of Fasa, Jahrom, Neyriz, Mamasani, Darab, Rostam, Bavanat, Kherame, Shiraz, and Firoozabad. Third priority is related to some parts of Darab, Larestan, Neyriz, ZarinDasht, Fasa, Jahrom, Ghir o Karzin, Khonj, Mohr, Farashband, Lamerd and Firoozabad. Abade, Eghlid and Khoram Bid which were chosen as the first priority, almost with regard to all the criteria, being accessibility time, placement position, accidents, roads, with exception of population, have had priority I in comparison to other parts of the province. It means these areas have had more glacial and rainy days, and more traffic and communication and hence have cause more accidents and with regard to accessibility to other healthcare facilities they had a more distance. Therefore, at first decision, some measures should be taken in establishing new emergency stations in these areas.

Like other studies, this study had some limitations including lack of information related to Fasa and Jahrom which made the software do the priority process by assuming no station in these two cities.

The results confirm the fact that geographical Information System is a useful and applicable tool in exploring the spatial distribution and geographical accessibility to the centers and stations that provide healthcare including emergency stations. It seems the decision makers in the field of health, when location the stations, can use this system and decide based on that in order to have an appropriate spatial distribution.

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