Spatial Analysis of Access and Transfer of Emergency (Asthma) Patients to Medical Centers; Case Study on District 3 of Tehran, Iran

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Date of submission: *08 Dec. 2018,* ***Date of acceptance:*** *04 Aug. 2019*

Original Article

Abstract

INTRODUCTION: The short resuscitation time for patients with asthma is one of the most urgent medical conditions with a high importance. In this study, the geographic information system (GIS) is used to analyze the access and transfer of emergency patients to health care centers (resuscitation, specialized, and health care services) to patients with respiratory problems with moderate and acute symptoms as the statistical sample.

METHODS: Identifying the service area of the eligible health centers based on two factors of time and distance, the districts and streets covered by these centers were identified. Then, by spatial analysis, the appropriate service area available to the medical emergency centers and patients of this category was determined to facilitate their access to these areas. In addition, by calculating the time and distance cost matrix of the location of the patients with asthma attack relative to the treatment centers, the best treatment center for patient transfer was identified. After summarizing the appropriate model to calculate the service area for these patients, the spatial and descriptive data were collected in the study area (District 3 of Tehran, Iran) and their thematic maps were produced. Then, the time and distance matrix of transfer of patients was calculated for the spatial analysis and facilitation of their access to treatment centers related to respiratory diseases based on the two above factors.

FINDINGS: Geospatial information system (GIS) and analysis of network access to appropriate respiratory care providers could save time and costs considerably.

CONCLUSION: Establishment of time and location management systems for ambulances and identification of specific types of diseases at the moment of contact with the emergency departments of the medical care units can also play an important role in the rapid transfer of the patients to these centers.

Keywords: Respiratory Diseases; Asthma; Geospatial Information System; Spatial Network Analysis

How to cite this article: Heidari-Mozaffar M, Pak A. **Spatial Analysis of Access and Transfer of Emergency (Asthma) Patients to Medical Centers; Case Study on District 3 of Tehran, Iran.** Sci J Rescue Relief 2019; 11(2): 103-10.

Introduction

Most decisions regarding the health care and planning are related to location, for example, deciding where the telecommunication-based health centers should be established based on the number, density, and health priorities of the people, and what services should be provided to effectively respond to the health requirements in the region. Therefore, since the healthcare network is dealing with a large amount of information, containing a huge amount of spatial data, there is a remarkable need to use the geospatial information system (GIS) for better management. What distinguishes GIS from other systems is its analytical capabilities, highlighting the increasing need for the use of GIS in all fields, particularly in the field of health care (1,2).

Asthma and respiratory diseases are considered as a major medical problem for all developed and developing societies (3). Asthma is a complication

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[DOI: 10.52547/jorar.11.2.103]

that results from narrowing of the airways and bronchitis due to allergens or by edema in infectious lung diseases or any other factor that can disrupt the opening and closing of the lungs. Asthma is an acute and chronic pulmonary disease that is often associated with inflammation of the airways and can cause respiratory problems. Chronic means that the disease is always present even when the patient does not feel unwell and if the airways are triggered in an individual with asthma, symptoms including wheezing, coughing, shortness of breath, and chest tightness emerge, making easy and natural breathing difficult for the patient (4). When the asthma symptoms become more intense than usual, this is called an asthma attack. Not all asthma attacks are similar, rather they have different intensities, with some of them being severe enough to cause the patient to die, thus asthma is one of the medical emergency cases (3).

Symptoms of a severe asthma attack include severe shortness of breath, rapid breathing, progressive wheezing, use of auxiliary breathing muscles as stretching the chest skin and use of intercostal muscles, inability to express even a single word, decreased level of consciousness and drowsiness, decrease in the number of breath recorded by the spirometer to less than the normal value for the patient, and bruising of the lips and toes (3).

The prevalence rate of asthma is respectively 13% and about 9-10% in Iranian children and adults, with 34% of children studied in Tehran metropolitan suffering asthma symptoms including coughing, wheezing, and shortness of breath (5).

Given the need to make quick decisions about patients with asthma, the use of spatial analysis tools can be helpful in decision making, including health care and planning. Besides, the health problems and needs of people vary in different places, necessitating the use of an analytical, yet flexible tool such as the GIS. In addition, the health care authorities can use maps produced by this system as a useful tool in monitoring and optimizing services as well as assessing the service provision status. Using these tools and analyses, one can evaluate the spatial distributions and changes made to various areas such as access, facility status, staffing conditions, and the health care network (6). Moreover, today, given the increase in population and increasing environmental pollution as well as changing lifestyle of individuals, there is a significant increase in the number of people with asthma. The present study investigated the most important environmental factors intensifying asthma and modeling the medical characteristics of patients with asthma. In this regard, it was attempted to use as an intelligent system to monitor patients with asthma using the extended GIS (6).

Various studies have been accomplished regarding the analysis of access and equitable distribution of medical centers for patients. Heydari Chianeh et al. analyzed the fair distribution of therapeutic uses in Tabriz, Iran (7). Rahnama and Amirfakhriyan analyzed the spatial access to health services in Mashhad, Iran (8). Additionally, regarding service provision to a specific community, such as patients with asthma, studies been conducted to design, implement, and improve the service delivery system in the form of an extended GIS (5). Karimipour and Kananisadat investigated the association of occurrence of asthmatic allergy with the environmental characteristics using fuzzy association rule mining (9). Kaffash Charandabi and Alesheikh examined improvements in the support vector machine (SVM) classification in extended GIS to monitor patients with asthma (10).

In a nutshell, it can be said that previous studies have mainly focused on issues such as the location of treatment centers and measuring contamination elements around the patient, but the way of delivering and transferring these patients to care centers has received little attention. Therefore, this study deals with the spatial analysis of health care centers delivering services for patients with asthma with the help of GIS. In the following, the study area is introduced first, then the method of the spatial analysis of the treatment centers is presented. Finally, after developing an analytical mechanism, the potential to choose an appropriate treatment center for each incident site is introduced.

Methods

The present study was applied in terms of objective and descriptive-analytical in terms of nature. The statistical population included the medical uses providing services for patients with asthma in District 3 of Tehran. This area was selected to continue and complete similar studies on patients with asthma.

[DOI: 10.52547/jorar.11.2.103]

Table 1. Classification of health centers by type of services provided to patients with asthma

Group	Emergency	Specialized wards[1]	ICU	Number	Description
A	*	*	*	6	People in need of intensive care
B	*	-	-	6	People who do not need intensive care - at least with a specialist.
C	*	-	-	4	Cardiopulmonary resuscitation by a GP
D	-	-	-	24	Others

ICU: Intensive care unit; GP: General practitioner

[1] A specialized ward refers to the pulmonary, asthma and allergy, and rhinolaryngology wards where patients can be treated.

Implementation of Method of Analysis of Access to Health Centers: As listed in Table 1, the criteria for grouping the health care centers were adopted based on the services needed for the patients. The descriptive and spatial information of the centers was extracted from their information websites and confirmed through contact with the centers.

In urban studies, the network of passageways plays a significant role in the delivery of services across the city. The quality of this delivery is measured by two factors of distance and time according which the network analysis tool analyzes the passage network behavior. Obviously, the behavior of the passage network varies at different times and places. This is especially important in metropolises. Therefore, the complex network system must be controlled and planned with a powerful and holistic tool. In this regard, the network analysis tool available in Arc GIS software can be used as an important tool in this field.

Planning to provide different services such as firefighting, emergency, and public transportation is strongly influenced by the behavior of the passage network and its characteristics. The network analysis tools can perform routing analysis and planning, implement specialized service delivery patterns, and also specify the service coverage areas for the structure of the urban passage network. In this regard, Arc GIS software, which benefits from the Network Analyst accessory tool, has many capabilities in analyzing the passage network and associated urban elements, including the analysis of the service area of uses based on “distance” and “time”. The passage network behaviors and characteristics such as the vehicle traffic volume, one-way or two-way streets, and the presence of public transport routes along the route are also examined in the Network Analyst tool. As a result, it can be claimed that the Network Analyst tool is currently applicable for various studies on the passage network. There are various applications for Network Analyst in the field of urban studies. In this study, two tools, including the service area function and the allocation function for network analysis and treatment centers were utilized.

Service Area Function: Service applications have specific and standard access areas, which can be defined based on time or distance to reach those services. For example, the standard distance a citizen has to travel to reach the nearest neighborhood park is 500 m, or the time for an ambulance to reach the incident place is 3 minutes (9).

The useful service area is determined given the passage network taking into account the network-based data and the service use layer of the hospitals and service centers. For instance, the 500-m radius of a clinic means all points with a distance of less than 500 m away from the clinic based on moving on the passage network. The same applies to the time radius. Given the average speed of vehicles, the time to travel the passage network can be calculated using a simple mathematical equation. Then the desired radius can be plotted and analyzed based on time.

Findings

District 3 of Tehran with an area of 2945.3 hectares is located in the northeast zone of this city. This area is limited to Shahid Chamran highway and from Seoul intersection to Valiasr street, Shahid Moddares highway to Sadr intersection, and Sadr highway to Pasdaran intersection from north, Pasdaran street from Shahid Moddares intersection to Zarrabkhaneh intersection, and Shariati street from Zarrabkhaneh intersection to Resalat highway from east, Resalat highway from Shariati street to Shahid Moddares highway intersections, Shahid Moddares highway to Shahid Hemmat highway intersection, and Shahid Hemmat highway to Shahid Chamran highway intersection from south, and Shahid Chamran highway from Shahid

[DOI: 10.52547/jorar.11.2.103]

Hemmat highway intersection to Seol intersection from west. Figure 1 demonstrates the location of the study area in Tehran.

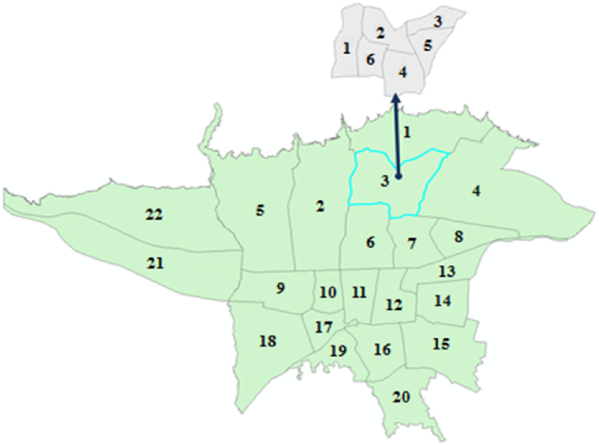

Figure 1. Location of the study district and its various areas on the general map of Tehran, Iran

It should be noted that this district consists of 6 regions and 12 neighborhoods and according to the statistics reported by Statistical Center of Iran (SCI) in 2006, it has an estimated population of 290726 people in 91,981 households. Of these people, 141186 and 149549 are men and women, respectively. The population growth rate, literacy rate, and employment rate in the district are 1.57%, 95.5%, and 95.5%, respectively. This district is one of the highlights in terms of high literacy rates. The area of the gardens in the district is 1161106 m^2, with green space reaching 21 m^2 per person. According to the international standards and the prevailing standard in Tehran, this district is in a very favorable position. The location of 66 embassies and ambassadors' residency centers has made the district a diplomatic area.

Currently, there are 100774 residential units and 18341 commercial units in the district and the highest rate of surface area of the units in the district is between 101 and 150 m^2. The presence of major commercial and economic centers, government agencies, Islamic Republic of Iran Broadcasting (IRIB) departments, higher education centers, trans-regional gardens (Mellat, Behesht-e Madaran, Taleghani), libraries and cultural and entertainment centers (Farhang Cinema, Water museum garden, Money museum, Dafine Museum, Imam Ali Religious Arts museum, Tamashagah-e Raz museum, Honar cultural center, Tabarestan museum, and Resistance museum), sport centers (Kowsar, Enghelab, Esteglal, Seoul Shooting Hall), and specialized hospitals (Khatam al-Anbia, Baqiyatallah al-Azam, Children's Specialized Hospital of Mofid, Ali-Asghar Children's Hospital, Burns and Incidents Hospital), mosques and hosseiniehs(Qoba, Al-ghadir, Husseiniyeh-i Ershad, holy shrine of Imamzadeh Ismail, Imamzadeh Qazi al-Saber), and also broad urban passgaes such as Shahid Sadr, Shahid Moddares, Shahid Chamran, Shahid Hemmat, and Resalat highways, as well as VanakMadar, and Ehteshamiyyeh main squares, while connecting the northern and southern parts of the city, bring a huge flood of population into the area daily, causing traffic congestion in this area. The public transport vehicles as well as Shahid Haqqani subway station facilities help reduce traffic congestion in this area of Tehran. Accordingly, this district with these features was considered to evaluate the access of patients with asthma to health centers.

In the study area, 39 treatment centers were identified in the form of health centers, hospitals, clinics, and health homes, with the information and classification illustrated in Table 2.

Table 2. Medical centers of the study area

Row	Code	Center type	Medical center name	Type of activity	Specialty	Group
1	3	Training, research, and treatment	Shahid Rajaee cardiovascular center	24-hour	Cardiovascular	A
2	1	Training and treatment	Ali-Asghar Children's Hospital	24-hour	Children	A
3	13	Training and treatment	Children's Specialized Hospital of Mofid	24-hour	Children	A
4	11	Hospital	Hedayat Gynecology Hospital	24-hour	Gynecology	A
5	5	Training and treatment	Shahid Motahari Burns and Incidents Center	24-hour	Burns and Incidents	A
6	4	Hospital	Khatam Al-Anbia	24-hour	General	A

[DOI: 10.52547/jorar.11.2.103]

Table 2. Medical centers of the study area (continue)

Row	Code	Center type	Medical center name	Type of activity	Specialty	Group
7	8	Clinic	Mirdamad	24-hour	General	B
8	2	Clinic	Raouf	24-hour	General	B
9	12	Clinic	Dorous	24-hour	General	B
10	10	Clinic	Ekhtiyariyyeh	24-hour	General	B
11	7	Hospital	Moheb Mehr cardiovascular center	24-hour	Cardiovascular	B
12	9	Hospital	Ayatollah Sadr Psychiatric Hospital	24-hour	Acute psychiatry	C
13	15	Hospital	Hasheminejad Hospital	24-hour	Urology	C
14	6	Hospital	Iran Mehr Hospital	24-hour	General	C
15	14	Hospital	Baqiyatallah al-Azam	24-hour	General	C
16	-	Hospital	Negah Eye Hospital	Morning and evening	Eye	D
17	-	Hospital	Noor Eye Hospital	Morning and evening	Eye	D
18	-	Clinic	Milad Salamat	Morning and evening	Opioid withdrawal	D
19	-	Clinic	Roza	Morning and evening	Plastic surgery	D
20	-	Clinic	Arman	Morning and evening	Rehabilitation	D
21	-	Clinic	Zafar Rehabilitation	Morning and evening	Rehabilitation	D
22	-	Clinic	Zafar Thalassemia	Morning and evening	Thalassemia	D
23	-	Clinic	Oximode	Morning and evening	Hyperbaric oxygen therapy (HBOT)	D
24	-	Clinic	Tabib Pasdaran	Morning and evening	Dentistry	D
25	-	Clinic	Dowlat	24-hour	General	D
26	-	Clinic	Vanak	24-hour	Dentistry	D
27	-	Clinic	Hojat	Morning and evening	General	D
28	-	Clinic	Clinic	-	-	D
29	-	Clinic	Clinic Gharb	Morning and evening	General	D
30	-	Clinic	Atlas	-	-	D
31	-	Clinic	Aria	Morning and evening	Rhinolaryngology, Rehabilitation	D
32	-	Clinic	Jaber Ibn-e Hayyan	Morning and evening	Dentistry	D
33	-	Clinic	Salman- Farsi	-	-	D
34	-	Clinic	Ibn-e Sina	Morning and evening	Infertility	D
35	-	Clinic	Municipality of District 3	Morning and evening	General	D
36	-	Clinic	Seddiq	-	-	D
37	-	Health and treatment center	Sabarou	Morning	General	D
38	-	Health and treatment center	Sheybani	Morning	General	D
39	-	Health and treatment center	Torab	Morning	General	D

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Figure 2 demonstrates the distribution of health centers across the district.

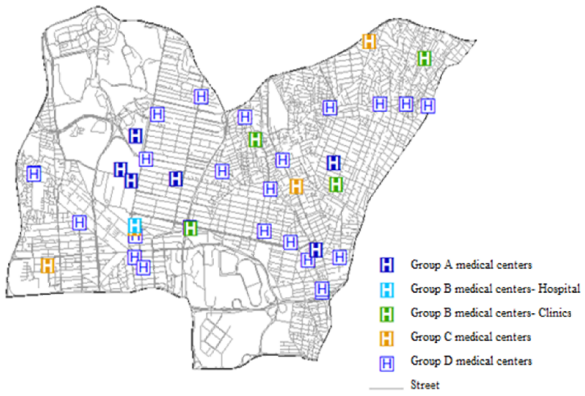

Figure 2. Road network and distribution of different groups of medical centers

The time index is very effective regarding services such as emergency. The area of function of the medical centers was defined as 650-750 and 1000-1500 m for the clinics and hospitals, respectively. Accordingly, the thematic maps were provided to exhibit the status of access to health centers in the study area. Figures 3 and 4 depict the access to health centers by the time and distance factors, respectively.

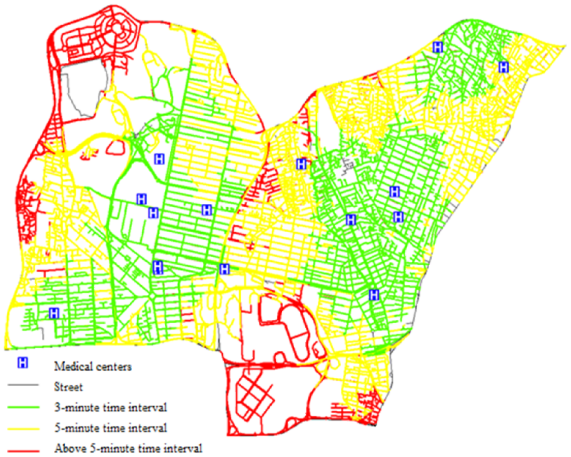

Figure 3. Radius of access to treatment centers by time interval

Finally, in order to analyze the network, two hypothetical points (A, B) were selected and each medical center was assigned a code from 1 to 15, as seen in Figure 5.

Routing is demonstrated in figure 6 for a better understanding of the multi-path optimization problem.

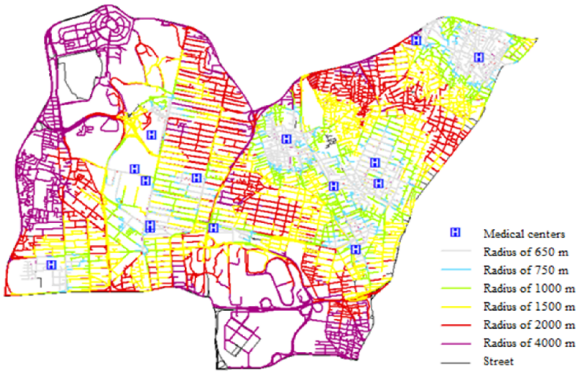

Figure 4. Radius of access to treatment centers by time distance

The routing results among the 15 target hospitals with the location of two patients are indicated in Table 3.

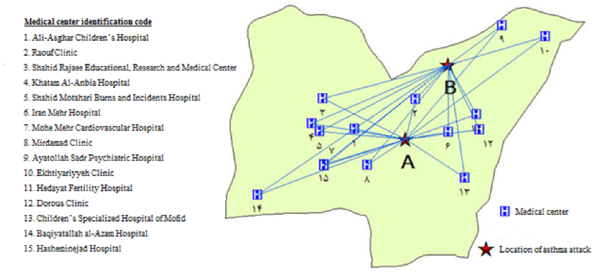

Figure 5. Origin-destination (OD) cost matrix analysis map of communication of all origins with all destinations based on distance and time

As shown in figures 5 and 6, the best hospital for patient A is the medical center with code 8, i.e. Mirdamad Clinic, and the medical center with code 11 for patient B, namely Mofid Hospital, which are ranked first. The optimal paths between the accident site and the treatment centers are shown in Figure 7.

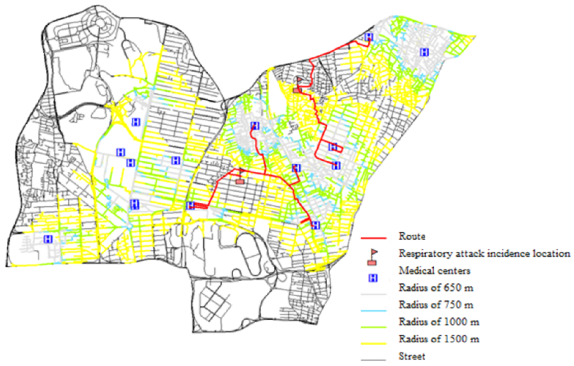

Figure 6. Routing of three treatment centers close to the asthma attack incidence location

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Table 3. Origin-destination (OD) cost matrix analysis map of communication of all origins with all destinations based on distance and time

Distance (m)	Time (minutes)	Priority of selection	Center name	Center code	Patient
1825.14	3.66	1	Mirdamad Clinic	8	A
1952.93	3.92	2	Iran Mehr Hospital	6	A
1980.11	3.97	3	Raouf Clinic	2	A
2405.68	4.82	4	Hasheminejad Hospital	15	A
2525.28	5.06	5	Children's Specialized Hospital of Mofid	13	A
2802.15	5.62	6	Moheb Mehr Hospital	7	A
2836.47	5.69	7	Dorous Clinic	12	A
2885.26	5.79	8	Ali-Asghar Children's Hospital	1	A
3158.65	6.34	9	Hedayat Gynecology Hospital	11	A
3213.9	6.45	10	Khatam Al-Anbia Hospital	4	A
3318.74	6.66	11	Shahid Motahari Burns and Incidents Training and Treatment Center	5	A
4280.46	8.59	12	Shahid Rajaee Educational, Research and Medical Center	3	A
4515.06	9.06	13	Baqiyatallah al-Azam Hospital	14	A
4823.68	9.68	14	Ayatollah Sadr Psychiatric Hospital	9	A
5387.86	10.81	15	Ekhtiyariyyeh Clinic	10	A
2106.6	4.22	1	Hedayat Fertility Hospital	11	B
2140.09	4.29	2	Ayatollah Sadr Psychiatric Hospital	9	B
2175.6	4.36	3	Dorous Clinic	12	B
2345.52	4.7	4	Raouf Clinic	2	B
2517.79	5.05	5	Iran Mehr Hospital	6	B
3019	6.05	6	Ekhtiyariyyeh Clinic	10	B
3600.12	7.22	7	Children's Specialized Hospital of Mofid	13	B
4488.3	9	8	Mirdamad Clinic	8	B
5068.84	10.17	9	Hasheminejad Hospital	15	B
5465.31	10.97	10	Moheb Mehr Hospital	7	B
5548.42	11.13	11	Ali-Asghar Children's Hospital	1	B
5877.06	11.79	12	Khatam Al-Anbia Hospital	4	B
5981.9	12	13	Shahid Motahari Burns and Incidents Training and Treatment Center	5	B
6943.62	13.93	14	Shahid Rajaee Educational, Research and Medical Center	3	B
7178.22	14.4	15	Baqiyatallah al-Azam Hospital	14	B

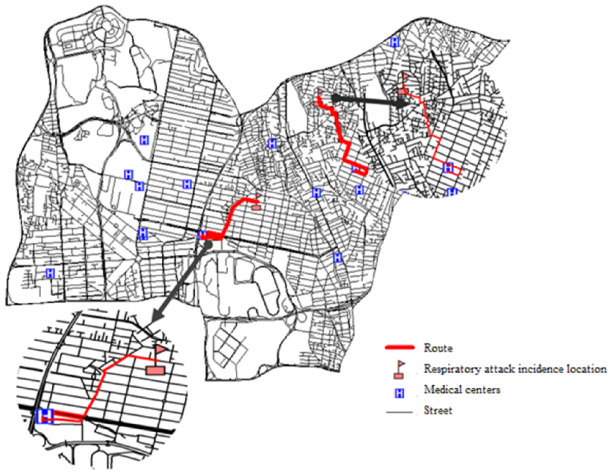

Figure 7. Routing of the asthma attack incidence site to treatment centers

Discussion and Conclusion

As mentioned earlier, the service area of the health care centers can be determined by the two factors of time and distance. In this way, the information of the areas and streets covered by the medical centers suitable for referral can be provided to the emergency medical centers and patients of this category to facilitate their access to these centers. This type of information can be employed to determine the shortest route and time for the patients to reach the appropriate treatment centers and receive medical care at the time of a respiratory attack. Based on the time and distance values, one can select the nearest centers and dispatch or transfer the patient to the selected center.

This service can be provided to patients

[DOI: 10.52547/jorar.11.2.103]

through GIS. Given the importance of the subject, it is recommended to utilize the capability of the GIS in combining different information and providing desired outputs for providing health services to patients. As mentioned earlier, the patients' access to medical centers can be considered in two ways; the distance dimension is of particular importance to transport the patient on foot or by personal vehicles. Using a routing system can help greatly in transferring the patient to medical centers at the time of the attack given the high stress on the patient and the companions as well as the lack of proper decision making and even temporary forgetfulness of individuals.

Choosing a treatment center appropriate to the condition of patients with asthma, particularly at the time of a respiratory attack, can be of great importance in saving the lives of these patients. The creation of the ambulance location and time management systems and identification of specific types of illnesses at the time of contact with emergency departments can also contribute to the rapid transfer of the patients to medical centers.

Acknowledgments

None

Conflict of Interests

Authors have no conflict of interests.

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[DOI: 10.52547/jorar.11.2.103]