# Determining Best Location of Emergency Stations in the Urban Area

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## SUMMARY

Emergency medical stations and fire stations play a key role in emergency management. An early primary attack will save more lives and properties in emergency cases. Response time is a critical component which includes alarm answering time, alarm processing time, turnout time and travel time in an emergency. Travel time is one of the most important elements of the response time and it is affected by various factors; such as traffic volume, road networks, the time of day, driver habits, and the location of the incident. The strategic locations of emergency medical stations and fire stations are of paramount importance in achieving a minimal travel time which is part of an effective and reliable emergency response system. In Turkey land readjustment projects are done in order to create a regular urban area. These projects depend on a land development plan. Land development plans includes residential area, commercial area, industrial area and technical infrastructures like road, park, car park, sport area, school and other public service areas. Emergency medical stations and fire stations are important public services for the residents. Determining best location of this kind of public services affects the performance of these services. In this study, the response time and in particular the travel time criteria were determined according to the previous studies in the literature, and then existing sites of emergency medical stations and fire stations in Samsun city were evaluated according to the location of emergency calls and the eight minute response time coverage area. In addition, necessity of new stations and locations of them were determined using the Geographic Information System.

## ÖZET

Acil durum yönetiminde ambulans istasyonları ve itfaiye istasyonları kilit rol oynarlar. Acil durumlarda hızlı müdahale can ve mal kayıplarını önler. Bu konuda cevap süresi önemli bir kriterdir. Acil arama ve cevaplama süresi, hazırlık ve çıkış süresi, ulaşım süresi ve müdahaleye başlama süreleri cevap süresini oluşturur. Burada en etkili faktör ulaşım süresidir ve yol durunu trafik vb. Pek çok koşuldan etkilenir.Acil müdahale istasyonlarının konumu da erken müdahale için çok önemlidir. Bunların konumlarının planlanması imar planları yapılırken iyi planlanmalıdır. Bu istasyonların konumları erken müdahaledeki başarıyı doğrudan etkiler. Bu çalışmada acil müdahale istasyonlarının konumlarının en ideal şekilde belirlenmesi için cevap süresi baz alınarak mevcut istasyonların konumları CBS yazılımı desteğiyle alan kapsama analizi ile irdelenmiş ve bu istasyonların konumlarına dair yeni öneriler getirilmiş ve ihyiyaç gönünen bölgeler için önerilerde bulunulmuştur. Samsun iline ait veriler örnek uygulama olarak kullanılmıştır.

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## 1. INTRODUCTION

Accidents and emergency medical cases are a part of the human life. Studies have shown that 10% of deaths following an accident or injury take place in the first 3–5 mins, and 54%–60% within the first 30 mins.(Demirhan, 2003) Thus, emergency services must send a vehicle to the scene of a medical emergency as fast as possible. The American College of Cardiology/American Heart Association guidelines specify that an electrocardiogram should be obtained and interpreted within 10 mins of arrival to the emergency department in patients with symptoms suspicious of acute coronary syndrome.(Zègre-Hemsey etal, 2011)

The locations of fire stations have paramount importance in order to achieve an effective and reliable emergency response system. In the literature a lot of studies existed which focused on the Emergency Medical Services (EMS) and ambulance location, peleg and Pliskin (2004), Sakaklı (2006), Pell etal, (2001), Cromley and Wei (2011) and Gümüş etal (2006).

Fire is defined as an uncontrolled burning. It is not possible to avoid fires completely; however, the harm and damage caused by fires can be reduced if it can be taken under control at the initial stage and effective fire management. The protection of people, property and the environment from fire has long been a major concern in urban (and rural) areas (Murray, 2013). There are few types of research areas about fire management in the literature. One of the research areas is related to fire station location, (Revelle and Snyder 1995; Xin etal, 2000) Some studies about the location of fire stations were reported by; Plane and Hendrick (1977), Schilling et al. (1980), Badri et al. (1998), Habibi et al. (2008), Yang et al. (2007), Chevalier et al. (2012), Challands (2010), Catay (2011), Nisanci et al. (2012) and Murray (2013).

This study present an evaluation of the locations of existing medical emergency and fire stations in relation to the location of emergency calls and response time coverage area using network analysis components, service area analysis and location allocation analysis. In addition the process of locating new stations using the Geographic Information Systems (GIS) is determined.

## 2. RESPONSE TIME AND COVERAGE AREA

In a medical emergency or fire, rescue case response time is a crucial parameter to measure the quality of the service. When dealing with the people involved in an emergency event the EMS personnel focus on cardiac, vascular, respiratory, trauma, and other clinical factors. Although many factors determine the quality of EMS, response time is an important EMS industry benchmark. At the same time the main purpose of the fire and rescue services should

be to reduce the damage and injuries that can result from a fire and rescue event. According to the NFPA "where feasible an early, aggressive, and offensive primary interior attack on a working fire is usually the most effective strategy to reduce loss of lives and property damage" (NFPA, 2010). When a fire is not contained in a single room or floor it develops rapidly into flashover phase, flashover time ranges from 5 minutes to 30 minutes (Kerber, 2012).

The response time is a critical component in the control and mitigation of an emergency incident (Hacıoğlu, 2010). The response time is the manageable segment of time within the entire sequence, it is includes alarm answering time, alarm processing time, turnout time, travel time and initiating action/intervention time (NFPA, 2010). In an emergency call the major factor is travel time, and travel time is affected by various factors; such as traffic volume, average travel speed, driver habits, road networks (main roads, residential roads), time of day (rush hour vs. non-rush hour), the season, and the location of the incident. Most of the factors affecting travel time cannot be controlled, but determining the best locations of medical emergency stations and fire stations for a particular area could reduce the response time.

The ambulance industry has suggested that emergent ambulance responses meet a response time criterion of ≤ 8 mins for at least 90% of all calls (Pons and, Markovchick, 2002). Pell et al (2001) calculated that a reduction in response time from 14 mins to 8 mins in 90% of all calls would increase survival following cardiac arrest from 6% to 8%. Response time is one of the most important indicators of preventing the damages and injuries caused by fire as in emergency cases. According to the NFPA after 8 minutes the fire starts to extend outside the room without sprinklers where it began (NFPA, 2010). Table 1 shows some response time criteria in the literature. In this study 8-minute response time was used.

**Table 1.** Studies on response time and average speed

| Reference | Response Time (min.) | Speed |
|---|---|---|
| Stiegel 2004 | 10 | ---- |
| Yang et al. 2007 | 5 to 8 | 60 mph |
| Habibi et al. 2008 | 3 to 5 | 40 km/h |
| NFPA, 2010 | 2 to 4 | ---- |
| Catay, 2011 | 5 to 8 | 40 km/h |
| Chevalier et al. 2012 | 8 | 15 - 80 km/h |
| Nisanci et al. 2012 | 3, 5, 7 | 45 km/h |
| Murray, 2013 | 9 | ---- |

## 2.1. Average Speed

Travel time is the major factor which affect the response time. But, travel time is affected by various factors; such as traffic volume, driver habits, quality of road networks, etc. Average travel speed is one of the most important factors which affect the travel time. In this study average speed of the different type of roads were determined using vehicle trace system data. The vehicle trace systems collect the position, speed, maximum speed, driver name of the

vehicles etc. Samsun Fire Department vehicle tracking data were collected and recorded periodically. Average speeds were determined using three months vehicle tracking data for four types of road; main road, street, branch road and alley. The average speeds of the fire and rescue vehicles were calculated as 40, 30, 25 and 15 km/h respectively and 50, 37.5, 31.25, 18,25 km/h were determined for the medical emergency system.

## 3. CASE STUDY

This study was undertaken in Samsun city, which consists of the three districts; Atakum, İlkadım and Canik (16789 ha) for the medical emergency cases and four districts; Atakum, İlkadım, Canik and Tekkeköy (28151 ha) for the fire and rescue cases (Fig. 1). The smallest administrative unit in the current study is the quarter. All the quarters belonging to the four districts were included in the study; however, the villages were excluded because of their separate locations, low population and low case rates.

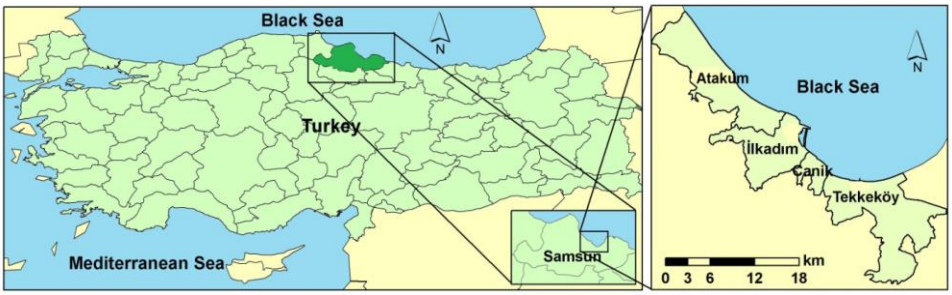


**Fig. 1.** The study area

### 3.1. Medical emergency cases

This study was included nine ambulance stations and 11506 emergency calls made in the Samsun provincial centre in 2009. The air ambulance was not part of this study. Detailed address data (i.e. local district and street) were obtained for all emergency ambulance callout locations. The positional data of the ambulance stations and emergency calls were also digitized (Fig. 2) and uploaded into the ArcGIS 10.1 software and evaluated together according to the response time coverage area. In the analysis phases of this study medical emergency cases evaluated using service area analysis.

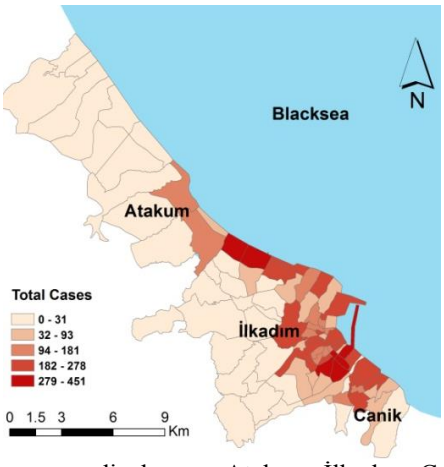


**Fig. 2.** Emergency medical cases, Atakum, İlkadım, Canik Districts

The response time is include alarm answering time, alarm processing time, turnout time, travel time and initiating action/intervention time. In this study alarm answering time, alarm processing time, turnout time was accepted two minutes and travel time is accepted five minutes, last one minute was taken by the activities at the scene. Average speeds were determined for four types of road; main road, street, branch road and alley. It was mentioned above the average speeds of the medical emergency vehicles was determined and all the average speeds were entered attribute data of this type of road for using in service area analysis. Service area analysis which is a network analysis tool was used to determine the coverage area of fire stations.

In the study area cases rates were different according to the population density of the quarters. Most of the population is concentrated in the central region of the İlkadım district and the coastal region of the Atakum district, according to the Turkish Statistical Institute (2014). In this study service area analysis was applied. Existing nine ambulance stations were cover a total a total of the 28.4% of study area and 81% of all cases according to 8-minute response time (5-minute travel time) coverage area (Fig. 3). According to the 11-minute response time (8-minute travel time) existing nine ambulance stations were cover a total of 46.7% of the study area, and 87.5% of all cases in the study area (Fig.4). Table 2 was present the total covered area and covered cases according to the existing medical emergency stations in the study area.

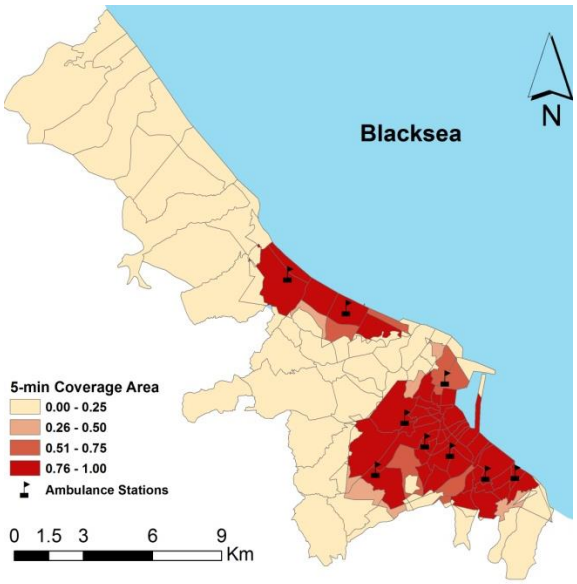


**Fig. 3**. 5-min travel time coverage area

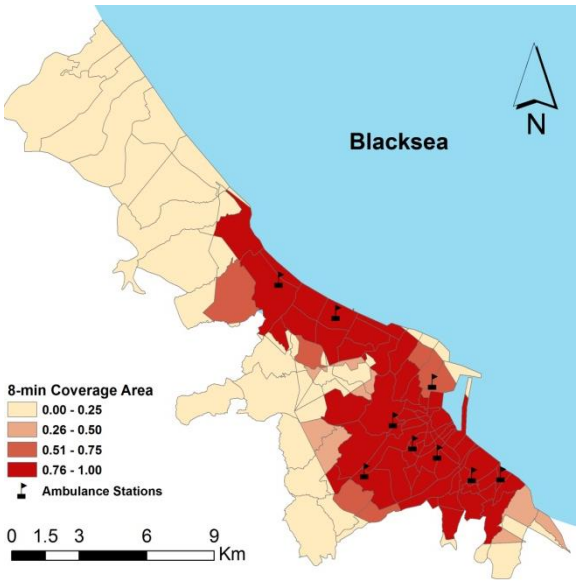


**Fig. 4.** 8-min travel time coverage area

**Table 2**: Total covered area and covered cases in the study area

| Travel Time | Total area | Total cases | Covered area | | Covered Cases | |
|---|---|---|---|---|---|---|
| | | | ha | ratio | cases | ratio |
| 5-minute | 16789 | 11509 | 4759 | 28.4 | 9286 | 81.0 |
| 8-minute | 16789 | 11509 | 7845 | 46.7 | 10064 | 87.5 |

## 3.2. Fire and Rescue Cases

In the study area 1014 fire and rescue cases were recorded by the Samsun Metropolitan Municipality Fire Service Department between January 01, 2013 and December 31, 2013. There were three fire stations in the study area (Fig. 4), one main station in İlkadım district, and two substations in the Atakum and Tekkeköy districts. The locations of fire stations and all fire and rescue cases were digitized and uploaded into ArcGIS 10.0 software and then evaluated together according to the determined response time coverage area.

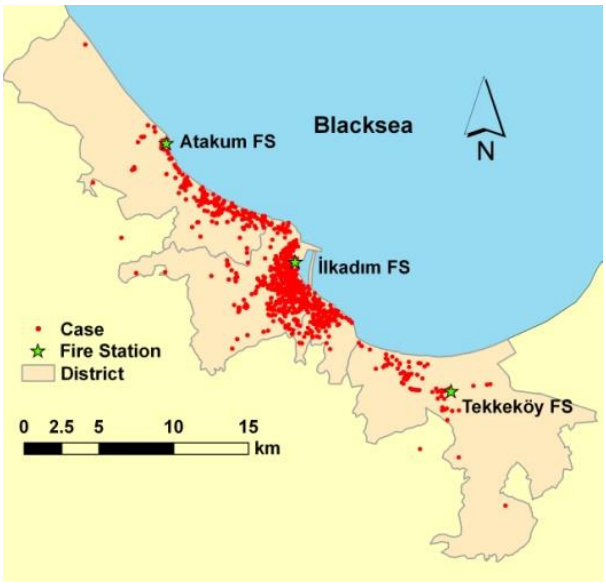


**Fig. 5.** Fire stations in the study area

**Table 2.** Fire and rescue cases

| District | Area (ha) | Population | People per ha | Cases | Cases Rate |
|---|---|---|---|---|---|
| Atakum | 9,265 | 149,226 | 16.10 | 201 | 19.82 |
| İlkadım | 6,128 | 312,248 | 50.95 | 572 | 56.41 |
| Canik | 1,414 | 93,721 | 66.28 | 158 | 15.58 |
| Tekkeköy | 11,344 | 51,124 | 4.50 | 83 | 8.18 |
| Total | 28,151 | 605,319 | | 1014 | |

In the study area all districts have different population and population densities (Table 2) and this is the same situation in the quarters, consequently the fire and rescue cases were concentrated in particular region, central Ilkadım and coastal Atakum (Fig. 5).

Response time was determined to be 8-minute on the basis of the literature presented in Table 1. The travel time was determined as five minutes as medical emergency cases. As it mentioned above that the average speed for fire and rescue vehicles was determined using Samsun Fire Department vehicle tracking system data. The average speeds of the fire and rescue vehicles in different type of roads are calculated as 40, 30, 25 and 15 km/h, and all the average speeds were entered attribute data of this type of road for using in service area analysis. Service area analysis which is a network analysis tool was used to determine the coverage area of fire stations.

In this study according to the 8-minute response time area (5-minute travel time), a total of 372 (36.7%) cases were covered by existing three fire stations (Fig. 6). İlkadım station covered 332 (32.7%) cases, Atakum station covered 23 (2.3%) cases and Tekkeköy station covered 17 (1.7%) cases.

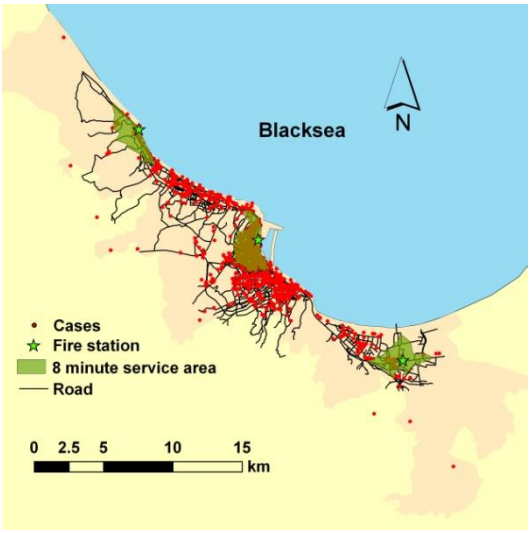


**Fig. 6:** 5-min travel time coverage area

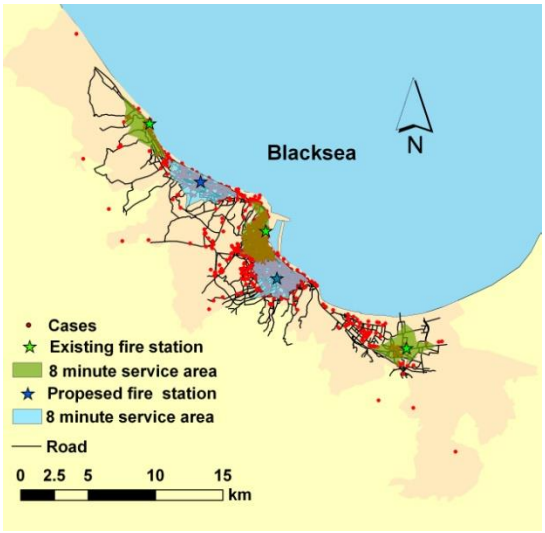


**Fig. 7:** 8-min travel time coverage area

In the current study area one main and two sub fire stations existed and a total of 372 cases were covered by three stations in 8-minute response time (5-minute travel time). In the study area a total of 642 fire and rescues cases were outside of the 8-minute coverage area of all the station. Thus, new fire and rescue stations were needed for an effective fire and rescue management, response to this need two locations were proposed based on uncovered cases according to the 8-minute coverage area. After determining the location of two new proposed stations, the total five stations covered a total of the 727 (71.7%) fire and rescue cases (Fig. 7) according to the 8-minute response time in the study area (Table 3). The proposed Station located in İlkadım covered 315 (31.1%) cases, 85 of which were from within İlkadım station coverage area, and the proposed Station located in Atakum covered 125 (12.3%) cases.

## 4. RESULTS and CONCLUSIONS

The primary goal of this study was to evaluate the coverage area of the existing medical emergency and fire stations and to determine the need for new stations according to the response time approach which was determined from the previous work in the literature. According to the service area analysis in the existing medical emergency stations is cover 81% of all cases according to 8-minute response time (5-minute travel time) coverage area and any changing in the location of the existing stations isn't recommended in the near future. The analysis of the location of fire and rescue stations, any changing in the location of the existing stations isn't recommended, but two new fire and rescue stations have been proposed taking into consideration the cost of investment. However, similar studies should be performed again in the long term to consider the future population increase, new settlement areas, new industrial areas and new main roads.

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