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Original article

An analysis of Emergency Medical Services demand: Time of day, day of the week, and location in the city

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ABSTRACT

Objective: Effective planning of Emergency Medical Services (EMS), which is highly dependent on the analysis of past data trends, is important in reducing response time. Thus, we aimed to analyze demand for these services based on time and location trends to inform planning for an effective EMS.
Materials and methods: Data for this retrospective study were obtained from the Izmir EMS 112 system. All calls reaching these services during first six months of 2013 were descriptively analyzed, based on time and location trends as a heat-map form.
Results: The analyses showed that demand for EMS varied within different time periods of day, and according to day of the week. For the night period, demand was higher at the weekend compared to weekdays, whereas for daytime hours, demand was higher during the week. For weekdays, a statistically significant relation was observed between the call distribution of morning and evening periods. It was also observed that the percentage of demand changed according to location. Among 30 locations, the five most frequent destinations for ambulances, which are also correlated with high population densities, accounted for 55.66% of the total.
Conclusion: The results of this study shed valuable light on the areas of call center planning and optimal ambulance locations of Izmir, which can also be served as an archetype for other cities.

1. Introduction

Almost all cities in developing or developed countries have Emergency Medical Services (EMS), which consists of pre-hospital medical care and transport to a medical facility such as a hospital.[1] An EMS is defined as consisting of the sequence of events from the dispatcher's notification of a medical emergency, to the transfer of patients to hospital.[2] There has been an increase in demand for such services throughout the world.[3,4] In the United States, almost all EMS demand is made by calls to an emergency number, 911; the corresponding number is 112 in Turkey and some European countries.

The primary role of ambulance services is to provide rapid access to those in need. In Turkey, this process flow is as follows: An emergency call is made to 112, a member of the call center staff responds and determines whether the call is an emergency or not, based on information given, which is assessed according to the dispatch protocols. When a call center staff member is uncertain about the status, the call is directed to the appointed doctors. If it is considered an emergency, the call center member checks availability, and directs the nearest ambulance to the emergency event location. While the exact definition of EMS time intervals is a point of a debate in the literature, the interval from dispatch to ambulance arrival has generally been defined as the response interval.[5–7] Thus, one of the main goals of ambulance services is to minimize the response interval or time.[8] Many studies have analyzed the

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problem of how to best deploy or locate the ambulances to minimize response time and cost.[9–11] The solution depends on the number of emergency calls reaching the 112 center at a specific time interval, from a specific location, thus it is important to retain and analyze past data. This paper aims to produce an analysis of 112 calls, based on time and location characteristics, as a basis for the effective planning of EMS in further studies.

2. Material and methods

In this retrospective study, data was taken from the EMS 112 services of the third most populous city of Turkey, Izmir. The city's large geographical scale, dense population and the extensive network of surrounding small towns create a need for the large number of ambulance and health personnel (around 3300 ambulances are divided between the 81 towns in the area, of which 90 are reserved for the city itself). The demand for 112 services in Izmir during the first six months of 2013 was evaluated. The main variables used to describe the data are: time, location, and the status of the calls. From the operations planning and management perspective, status differentiates between emergencies, which require ambulances, and non-emergencies, which do not. Although, both types of the call are important in planning and managing the call centers of 112 ambulance services, just the calls which require ambulances, those we define as emergency calls, are important in planning and managing the ambulances. Differentiation of emergency and non-emergency calls are made by dispatcher physician, according to pre-determined protocols. Thus, in the data that we obtained, we already had an attribute of data regarding whether the ambulance is directed to the call or not.

In analyzing the time variable of the data, weeks were differentiated into days, and days were divided into three 8-h intervals, namely, p_1 as 00:00–08:00, p_2 as 08:00–16:00, and p_3 as 16:00–00:00, where p_1, p_2, and p_3 respectively represent the night, daytime, and evening periods. To analyze location, Izmir was divided into 30 areas based on local district boundaries, numbered according to alphabetical order of the district names.

Population of all these 30 districts or locations of Izmir were obtained from Turkish Statistical Institute data from 2013 statitiscs.[12]

The results were statistically analyzed using Statistical Package for Social Sciences -SPSS- 22.00 (IBM, IL,USA) to calculate significant differences, where $p < 0.01$, illustrating the 99% confidence level, was considered statistically significant.

3. Results

In the first six months of 2013, a total of 123,239 real calls reached the 112 system. 85,853 or 69.66% were emergency calls, which required ambulances. The remaining 37,386, or 30.34%, were non-emergency calls.

We first represent the result based on call time. In this part, both emergency and non-emergency calls were considered, since both require the attention and consume the time of the call center staff. The distribution of call volume for each day of the week for periods p_1, p_2, and p_3 is given in Table 1, where average number of calls are defined based on the 99% confidence interval, and the variations are defined based on the standard deviation. In Table 1, it is observed that average call volume was lower in p_1 compared to p_2 and p3 for each day of the week. On weekdays (Monday to Friday), the average call volumes were approximately equal during the day in p_2 and p_3. In p_2, call volumes were higher during week-days compared to weekends (Saturday and Sunday), whereas the opposite pattern was seen in p_3. When the average call volumes were compared with the standard deviations, considerable fluctuation between the different periods in each day were observed.

In order to analyze the statistical comparison between the average call volumes in each period of days of the week, we build up three hypotheses, such as:

H_0: $\mu_{p1} = \mu_{p2}$ for each day of the week, H_1: $\mu_{p1} \neq \mu_{p2}$ for each day of the week

H_0: $\mu_{p1} = \mu_{p3}$ for each day of the week, H_1: $\mu_{p1} \neq \mu_{p3}$ for each day of the week

H_0: $\mu_{p2} = \mu_{p3}$ for each day of the week, H_1: $\mu_{p2} \neq \mu_{p3}$ for each day of the week

We test these hypotheses by using two independent sample *t*-test based on 99% confidence interval, where $p < 0.01$ is considered as statistically significant. We summarize the p-values of these tests for each day of the week in Table 2.

Based on the p-values of Table 2, we additionally observed that average call volume of p_1 significantly differed from p_2 and p_3 for each day of the week, statistically significant difference was observed between p_2 and p_3 at the weekend, whereas no significant difference between p_2 and p_3 was seen in weekdays.

We then summarize the results based on call location. Ambulances are involved only in case of emergency thus non-emergency calls were excluded from this analysis. In Table 3, the districts or locations are represented by the given numbers or ID, and this table shows the population of each location based on 2013 statistics, percentage of the population for each location, number of ambulances currently located in each district, and the number and percentages of the emergency calls originating from each district.

According to Table 3 values, a significant correlation was observed between the population of each location, and the number or percentage of calls arriving from these locations ($r = 0.924$; $p = 0.000$). Similarly, a significant correlation was observed between number of currently deployed ambulances and number of calls arriving from locations ($r = 0.885$; $p = 0.001$). The five locations with the highest volume of emergency calls, as shown by the darker areas in Fig. 1, were Konak, Karabaglar, Buca, Bornova and Karsiyaka, locations numbered 21, 15, 8, 7, and 17 respectively, where the populations of these locations are also the highest as represented in Table 3. These percentages show that the more than half the emergency calls (55.66%) originated from these five locations where the total percentage of population of these five location is also more than half of the total population (50.73%).

According to distribution of number of calls given in Table 1, we concluded that weekdays have a similar pattern, and Saturday and Sunday also have a similar pattern which differentiates from weekdays' pattern. Thus, in order to observe the distribution of calls based on the locations at different time intervals, Monday and Saturday were selected to represent weekdays and the weekend respectively. Figs. 2 and 3 represent the average number of calls from each location in periods p_1, p_2 and p_3 for Mondays and Saturdays respectively.

These two Figures also showed that, in each of the three periods, the majority of calls were from the mentioned five locations: Konak, Karabağlar, Buca, Bornova, and Karsiyaka, although, within this group of five, the location generating the most calls varies between time periods. For example, in p_2 for Monday, there were more calls from Bornova than Buca, whereas in p_3, this situation was reversed. Similarly, higher numbers of calls originated from Bornova compared to Karşıyaka in p_1 on Saturdays, while the reverse was seen in p_2.

4. Discussion

In world –wide literature, it is well mentioned that the call

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