Evaluation of emergency medical service application from a geographical location perspective in Turkey

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Abstract

An important area of use of the geographic information systems in health is the organization of Emergency Medical Services (EMS). In this study, the EMS application offered in Turkey's 81 provinces, in particular, Istanbul metropolis, which has the highest population in the country, was examined with a statistical approach. It was determined that the correlation level between the number of EMS stations and the population of the 39 districts of Istanbul was higher compared to the land area and population density; the number of EMS stations in the Fatih District was significantly greater than the median value of the number of EMS stations in all districts of Istanbul. It was determined that the number of EMS stations, ambulances, and hospitals in Istanbul is significantly greater than the median value of all provinces in Turkey; the population density per hospital and EMS station in Istanbul is significantly greater than the median value of all provinces, and the area value is smaller than the median value of all provinces. Ambulance response time, hospital transfer time and reasons for delays at these stages were questioned through a survey. The most common reasons for delay were traffic congestion, followed by the few and far distances of ambulance stations. Considering the problems arising from the geographical location of EMS stations and hospitals, it is expected that taking population density into account when planning EMS station distribution would contribute to increased efficiency in EMS and equality in access to services.

Introduction

Geographic Information Systems (GIS) covers all tools and applications that collect, store, process, display, and present spatial data (Boulos, 2001). Health-related research has played an important role in the historical development of GIS. With regard to the cholera epidemics that occurred in England in the 19th century, Robert Baker's 1833 Leeds regional epidemic map, Thomas Shapter's 1848 Exeter epidemic density map and John Snow's 1854 map of the Soho area in London showing the spread of the disease constitute the first spatial thoughts in the field of health that evenually led to modern GIS applications (Musa *et al.*, 2013; Tulchinsky, 2018). Important functions of GIS today is its contribution to Emergency Medical Service (EMS) applications. Ambulance response time, defined as the time between an emergency call and the arrival of medical assistance, is one of the main factors indicating EMS performance. In urban areas, EMS station response time is affected by many factors such as the type and location of demand, the location and number of EMS stations and hospitals, the number of ambulances, EMS system density, and local traffic conditions. In such situations, population increases at the regional level make it necessary to reconsider the locational situation and administrative processes of health facilities. The most affected province in this regard in Turkey is Istanbul. The increase in population density, resulting in increased demand for emergency medical assistance and increased traffic congestion, negatively affects emergency ambulance response times. According to the statement by the Istanbul Emergency Health Station authorities, approximately 8-10 thousand ambulance requests come to the 112 Emergency Call Center every day, ambulances are sent to 2,500 of them and although expanding emergency ambulance stations is aimed to shorten the time to reach patients, it is becoming difficult for ambulances to reach patients on time due to traffic problems (Kavuncu, 2024). Since Cardiopulmonary Resuscitation (CPR) started within 4 minutes and advanced life support (primarily defibrillation) was applied within 8 minutes in cases of non-traumatic cardiac arrest would significantly reduce mortality, ambulance interventions try to reach victims within this interval. In contrast, however, it has been reported that exceeding the 8-minute time limit does not affect patient survival in trauma cases (Pons & Markovchick, 2002). To resolve this question, the Nuffield Trust, an independent health think tank in the United Kingdom (UK) aims to improve the quality of healthcare, has categorized and targeted ambulance response times according to the patient's clinical condition set by national standards. For category 1 emergency situations, *i.e.* life-threatening situations, such as life-threatening cardiac or respiratory arrest, airway obstruction, ineffective breathing, or unconsciousness a response time of 7 minutes is anticipated, while for less serious but still potentially serious cases requiring immediate on-scene intervention and/or emergency transport (category 2), a response time of 18 minutes is anticipated (changed to 30 minutes for 2023/24) (Nuffield Trust, 2024). The Resuscitation Council UK (RCUK) states that the average ambulance response time in the UK is 6.9 minutes (Perkins *et al.*, 2021). In the United States (US), the general approach is for this time to be 8 minutes or less, although there is no federal law regarding EMS response times. Considering response times, it is necessary to use GIS more effectively when planning emergency medical services. This situation necessitates that the number and geographical location of EMS stations are constantly monitored and renewed at certain intervals. In this study, the EMS application offered in the Istanbul metropolis and its districts, one of the areas with the highest population in Turkey, were examined in relation to the provinces in the country with a statistical approach, and the current problems were discussed in the light of literature data and suggestions that could contribute to the development.

GIS enable the planning of health services and the equal access of health services to different segments of society by utilizing data such as travel times, transportation networks, geographical barriers and population density (Neutens, 2015; Shaw & McGuire, 2017). This approach provides data analytics that make it easier for planners to make more effective and informed decisions in site selection and facility management for the establishment of new healthcare facilities. In cases of illness or trauma requiring emergency medical intervention, EMS is applied by selecting one of two basic models: "scoop and run", also called the "Anglo-American" model (Hanson & Burton, 2025) or "Stay and Play", also known as the "Franco-German" model (Biedrzycki *et al.*, 2023). The aim of the first one, which is implemented in many countries including Turkey, is to deliver the patient to the nearest and/or most appropriate hospital as soon as possible by providing basic life support at the scene by Emergency Medical Technicians (EMT) and/or paramedics (Kaim *et al.*, 2023; Lansiaux *et al.*, 2024). The aim of the latter, which is mostly applied in Central European countries, the team with physician participation reaches the scene as soon as possible with an ambulance with sufficient medical equipment, provides advanced life support and stabilization to the patient at the scene transporting the patient to the most appropriate hospital without rushing (Neeki *et al.*, 2021). Finally, in the "Hybrid" model, which is applied in 17 European countries, one of the "Scoop and Run" or "Stay and Play" models is selected using initiative according to the characteristics of the case (Rief *et al.*, 2023). In this case, the EMT arrive at the scene with the ambulance but can request the presence of a physician at the scene when needed. In all three types of EMS models, reaching the scene as soon as possible after the call for medical assistance is of great importance with regard to survival. Therefore, ambulance response time is an important criterion in evaluating the quality of EMS in countries (Cabral *et al.*, 2018). With respect to 4,278 adult "non-traumatic cardiac arrest" cases recorded arriving at hospitals between 2011 an 2015 in Taipei, the capital of Taiwan, it was shown that the average advanced life support response time was 9 minutes, with the survival rate decreasing by 7% and the favorable neurological outcome rate decreasing by 9% for each minute of delay (Chen *et al.*, 2022). Similarly, in London, the "Scoop and Run" model is being implemented, and according to the NHS Trust, Annual Report and Accounts 2023/24, it is stated that the reduction in ambulance response time was achieved by increasing the number of frontline staff, investing in the ambulance and emergency vehicle fleet, and focusing on introducing team-based working (Elkeles & Trotter, 2025). Since the "Scoop and Run" model has been widely chosen in Turkey, the approach of expanding EMS stations and increasing the number of ambulances has been adopted there. According to the statement of the Istanbul Emergency Health Station authorities, the emergency ambulance response is 8 to 9 minutes in the metropolis and less than 15 minutes in the rural areas, and it is stated that helicopter air ambulances and sea ambulances are used to reach cases in rural areas (Kavuncu, 2024). It is known that in countries with mountainous terrain conditions such as Switzerland, Norway and Austria, ambulances helicopters are used to urhegently reach patients in serious condition located far away within 15 minutes (Szabo *et al.*, 2023). GIS study analyzing EMS coverage and response times in Sukhothai Province, Thailand, found that densely populated areas are generally well served within a 20-minute response time, while remote and mountainous areas face significant access challenges, highlighting the need for targeted improvements in EMS infrastructure, resource allocation, and innovative solutions to ensure equitable access to emergency care across Sukhothai Province (Thipthimwong *et al.*, 2024). When the literature on the spatial organization of EMS is examined, it is seen that the existing studies mainly focus on issues such as reducing the ambulance response time and determining its minimum limits, the negativities caused by the extension of the response time, EMS modeling, determining the most appropriate ambulance routes and positioning EMS stations according to existing hospitals (Morova *et al.*, 2011; Tjelmeland *et al.*, 2020; Gürel *et al.*, 2021; Ahmadia *et al.*, 2024). In this study, it was determined which of the basic variables such as population, land area and population density, which have the main impact on the spatial positioning of EMS, should be given priority. This provides decision-makers with a different perspective that prioritizes population density and ensures equitable access to EMS when conducting GIS-based spatial planning for EMS access in urban or national contexts.

Materials and Methods

Study area, data source and variables used

The analysis covers EMS data from 39 districts of the Istanbul metropolis and the 81 provinces of Turkey. This study also includes the results of a survey study. The numerical distribution of EMS stations and ambulances in Turkish provinces was obtained from the Health Statistics Yearbook 2022 of the Ministry of Health (MoH) (Yılmaz *et al.*, 2022). The numerical distribution of EMS stations in the districts located on the European and Anatolian sides of Istanbul was obtained from the websites of Istanbul Provincial Health Directorate (Istanbul Provincial Health Directorate, European Regional Ambulance Service Directorate, 2023; Istanbul Provincial Health Directorate, Anatolia Provincial Ambulance Service Directorate, 2023). Area data for Istanbul districts and the provinces were obtained from General Directorate of Mapping website (https://www.harita.gov.tr/il-ve-ilce-yuzolcumleri). All of this data is publicly available. The variables were the number of EMS stations, population numbers, population density, and land area of all provinces in Türkiye and the districts of Istanbul. In addition, we used the number of hospitals and ambulances of the provinces; the population numbers and density there including land area for each EMS station, each ambulance and each hospital. Proportional variables for population, area and population density per EMS station, hospital, and ambulance were preferred over alternative access indicators because they are important variables reflecting regional health performance.

Participants in the survey were selected on a voluntary basis and through convenience sampling. Since no ready-made scale survey on the subject was available in the literature, the researchers developed the survey questions. To assess content validity, expert opinions were obtained from a medical professional and a social scientist. Applicability was verified with a pilot study of 15 participants. The survey was applied to two adult groups: 210 hospital employees and 401 patients and their relatives, via Google Forms. Since it was determined that some of the participants did not have experience with the response time (the time from receiving the call for help to arriving at the scene and providing the first emergency response), the time it took to transport the patient from the scene to the hospital, and the reasons for delays in these stages, only the responses of 339 participants with experience were used in this study.

Statistical analysis and visualization

Descriptive statistics were performed for the provinces and districts using the IBM SPSS Statistics 29.0.2.0 program to test the distribution of the data and determine whether it was normally distributed. Skewness; kurtosis; proximity of the mean-mode and median of the variables to each other; and presence of proportional variables were taken into account to determine whether the data were normally distributed (Table 1). Because the data were not normally distributed, nonparametric tests were employed. Additionally, statistical tests based on the normal distribution and

Table 1. Descriptive EMS statistics for Turkish districts and provinces.

	Mean	Median	Mode	Skewness	Kurtosis
Variables of Istanbul's districts					
Number of EMS stations	8.74	8.00	8	0.810	-0.358
Population	401433.95	409347.00	16325[a]	0.610	0.735
Land area	140.03	38.00	9[a]	2.817	7.745
Population density	13975.2833	12438.0000	60.6712[a]	0.574	-0.707
Population/EMS stations	44460.4235	49129.4000	2720.8333[a]	-0.865	0.560
Land area /EMS stations	21.8683	3.2857	1.5000	3.292	11.411
Population density/EMS stations	1599.4920	1137.0285	12.1342[a]	1.050	0.328
Variables of Turkey's provinces					
Number of EMS stations	40.62	27.00	19[a]	5.524	38.074
Population	1052833.99	557605.00	84241[a]	6.157	45.327
Land area	9630.12	7659.00	5717	2.087	6.512
Population density	133.8913	63.0392	11.1271[a]	7.870	66.778
Population/EMS stations	20309.12	18521.00	6516[a]	0.728	0.167
Land area /EMS stations	293.1205	292.3684	14.5239[a]	0.791	1.050
Population density/EMS stations	3.0435	2.0703	0.5780[a]	4.342	25.677
Number of emergency ambulances	70.80	52.00	48	5.623	38.970
Population/emergency ambulances	11385.96	10071.00	11654	0.831	0.201
Land Area/emergency ambulances	150.8122	144.2342	9.7344[a]	0.588	1.064
Population Density/emergency ambulances	1.6467	1.1347	0.3005[a]	4.070	22.101
Number of hospitals	19.20	12.00	8	6.264	47.011
Population/hospitals	47922.65	45677.375	14061.00[a]	0.602	0.608
Land Area /hospitals	733.0166	684.4285	23.3376[a]	3.083	17.787
Population density/hospitals	7.7397	5.4122	1.1271[a]	3.869	17.833

[a]Multiple modes exist. The smallest value is shown.

logarithmic transformation were applied for logarithmic transformation and robustness checks. The unsatisfactory results of these two control methods, and the fact that the logarithmic method caused dataset changes, supported the decision further to use nonparametric tests. Kendall's tau-b correlation was calculated separately for the variables in the districts and provinces categories (Tables 2 and 3). By applying the One-Sample Wilcoxon Signed Rank test (OSWSRT), a non-parametric rank test for the testing of hypoteses (Motlagh & Emrouznejad, 2022), between the Fatih District, which was established on the first settlement area of Istanbul, and all other districts of Istanbul, and between the Istanbul province and all other Turkish provinces, the existence of statistical significance between the median value obtained from the variables and the selected values of the variables was tested with the hypotheses that there either was no significant difference (H0) and that there was (H1) (Table 4).

Table 2. Distribution of EMS stations in Istanbul's districts

Correlation (n=39)		Land area (km²)	Population	Number of EMS stations	Population density	Population/ EMS stations	Land area/ EMS stations	Population density/ EMS stations
Land area (km²)	Coefficient	1.000	0.016	-0.048	-0.712**	0.035	0.855**	-0.783**
	Sig. (2-tailed)	.	0.885	0.685	<0.001	0.753	<0.001	<0.001
Population	Coefficient	0.016	1.000	0.658**	0.274*	0.601**	-0.105	0.179
	Sig. (2-tailed)	0.885	-	<0.001	0.014	<0.001	0.345	0.108
Number of EMS stations	Coefficient	-0.048	0.658**	1.000	0.309**	0.231*	-0.207	0.150
	Sig. (2-tailed)	0.685	<0.001	-	0.009	0.049	0.079	0.201
Population density	Coefficient	-0.712**	0.274*	0.309**	1.000	0.204	-0.783**	0.852**
	Sig. (2-tailed)	<0.001	0.014	0.009	-	0.068	<0.001	<0.001
Population/ EMS stations	Coefficient	0.035	0.601**	0.231*	0.204	1.000	0.014	0.185
	Sig. (2-tailed)	0.753	<0.001	0.049	0.068	-	0.904	0.097
Area/number of EMS stations	Coefficient	0.855**	-0.105	-0.207	-0.783**	0.014	1.000	-0.743**
	Sig. (2-tailed)	<0.001	0.345	0.079	<0.001	0.904	-	<0.001
Population density/	Coefficient	-0.783**	0.179	0.150	0.852**	0.185	-0.743**	1.000
EMS stations	Sig. (2-tailed)	<0.001	0.108	0.201	<0.001	0.097	<0.001	-

*Correlation significant at the 0.05 level (2-tailed); **Correlation significant at the 0.01 level (2-tailed).

Table 3. Distribution of EMS stations, emergency ambulances and hospitals in the Turkish provinces.

Kendall's tau-b		Number of EMS stations	Number of emergency ambulances	Number of hospitals	Population	Land area	Population density
Number of EMS stations	Correlation coefficient	1.000	0.847**	0.800**	0.815**	0.429**	0.415**
	Sig. (2-tailed)	-	<0.001	<0.001	<0.001	<0.001	<0.001
	Number	81	81	81	81	81	81
Number of hospitals	Correlation coefficient	0.800**	0.785**	1.000	0.781**	0.427**	0.400**
	Sig. (2-tailed)	<0.001	<0.001	-	<0.001	<0.001	<0.001
	Number	81	81	81	81	81	81

** Correlation significant at the 0.01 level (2-tailed).

Table 4. EMS presentation in districts of Istanbul and Turkish provinces.

Null Hypothesis	Total (n)	Test statistic	Standard error	Standardized test statistic	Asymptotic sig. (2-sided test)[a,b]	Decision
Comparison of Fatih district with all districts of Istanbul province						
Median of EMS stations Number = 14	39	1.500	60.776	-5.158	<0.001	Reject H0
Median of Area/number of EMS stations = 1.07143	39	776.000	71.658	5.387	<0.001	Reject H0
Median of Population Density/ number of EMS stations =1695.3600	39	315.000	71.659	-1.047	0.295	Retain H0
Comparison of Istanbul province with all provinces of Türkiye						
Median of EMS stations Number = 376	81	0.000	208.459	-7.771	<0.001	Reject H0
Median of Number of Emergency Ambulances =561	81	0.000	208.461	-7.771	<0.001	Reject H0
The median of the number of hospitals = 234	81	0.000	208.422	-7.773	<0.001	Reject H0
Median of Area/number of hospitals = 23.3376	81	3321.000	212.392	7.818	<0.001	Reject H0
Median of area/number of EMS stations = 14.5239	81	3321.000	212.392	7.818	<0.001	Reject H0
Median of population Density/ number of Hospitals =12.4488	81	406.000	212.392	-5.907	<0.001	Reject H0
Median of population Density/number of EMS stations = 7.74737	81	98.000	212.392	-7.357	<0.001	Reject H0

Test by the One-Sample Wilcoxon Signed Rank Test; HO = no significant difference.

The Chi-square test was applied to determine whether there was a significant difference between the responses of participants who are hospital employees and those who are not hospital employees in the survey study. The survey participants' responses regarding the ambulance response time, the time it takes to transport the patient from the scene to the hospital, and the reasons for delays at these stages are presented in Figure 1. The location of Istanbul and the boundaries of its districts are visualized in Figure 2a, with further thematic maps showing the distribution of EMS stations in Istanbul's districts by number (Figure 2b), population (Figure 2c), area (Figure 2d) and population density (Figure 2e). The base of the maps in Figure 2 was obtained from the Humanitarian Data Exchange website (https://data.humdata.org).

By evaluating the descriptive EMS statistics for the districts of Istanbul (Table 1) and thematic maps (Figure 2), we aimed to determine the distribution of EMS stations in the districts of Istanbul based on different variables, thus creating strategic data that will ensure easy and equal EMS access. The heatmap showing the distribution density of hospitals offering EMS in Istanbul (Figure 3) was used because it is a good indicator of unbalanced concentration (the regional differences), even if it does not reflect the exact quantitative values.

Different EMS stations were selected for three different districts located in the periphery of Istanbul, and the distribution of hospitals providing emergency medical services within 1, 3, 5 and 10 km radius from these stations was determined by Buffer Analysis (Yang *et al.*, 2020) that is shown in Figure 4. Buffer analysis was preferred because it is a powerful tool in understanding geographic relationships, although it does not reflect variables such as topography and obstacles, travel times and traffic. In this study, ambulance station coordinate data were obtained from the Google Earth website database (https://earth.google.com/). Hospital coordinates were obtained from the OpenStreetMap website (https://www.openstreetmap.org/#map=6/39.03/35.25). OverPass Turbo was used to download the data (https://overpass-turbo.eu/), and then buffer analysis and a heatmap were created in QGIS program. OpenStreetMap map was used as the map base in the QGIS program (https://qgis.org/).

Results

As mentioned earlier, the mean, median and mode values of the variables (Table 1) were not close to each other. Skewness was outside the range of -0.5 to +0.5, and some kurtosis values were outside the range of -2 to +2, while some of the variables were obtained proportionally (population/land area, population/EMS stations, area/EMS stations, etc.), led us to apply the non-parametric correlations Kendall's tau-b test of the districts of Istanbul (Table 2), which showed that the correlation between the number of EMS stations and land area was at a small, not significant level (-0.048). It was thus determined that the number of EMS stations did not increase proportionally with the increase in the service area. Istanbul has a geographical location that connects the Asian and European continents, and although the land areas of its districts are relatively small in the central settlement, while the expanse of the districts increases significantly towards the periphery (Figure 2a). Thematic maps showing the numerical distribution of emergency medical services stations in Istanbul's districts by population, area, and population density illustrate the variation in Emergency Medical Services (EMS) provision across various variables (Figures 2b-e). The distribution of EMS stations varies numerically according to the districts, with a concentration in the city centre (Figures 2a,b). When the distribution of EMS stations according to land areas on the thematic map is examined, it can be seen that the area per EMS station increases in proportion to the distance from the city centre (Figure 2d). On the other hand, it was determined that there was a strong correlation between the number of EMS stations and population (0.658), and a medium level correlation between the number of EMS stations and population density (0.309) and that both these correlations were significant. The correlation between the number of EMS stations and population density was lower than the correlation between the number of EMS stations and population, but higher than the correlation between the number of EMS stations and area. These results show that EMS services are most compatible with the population on a

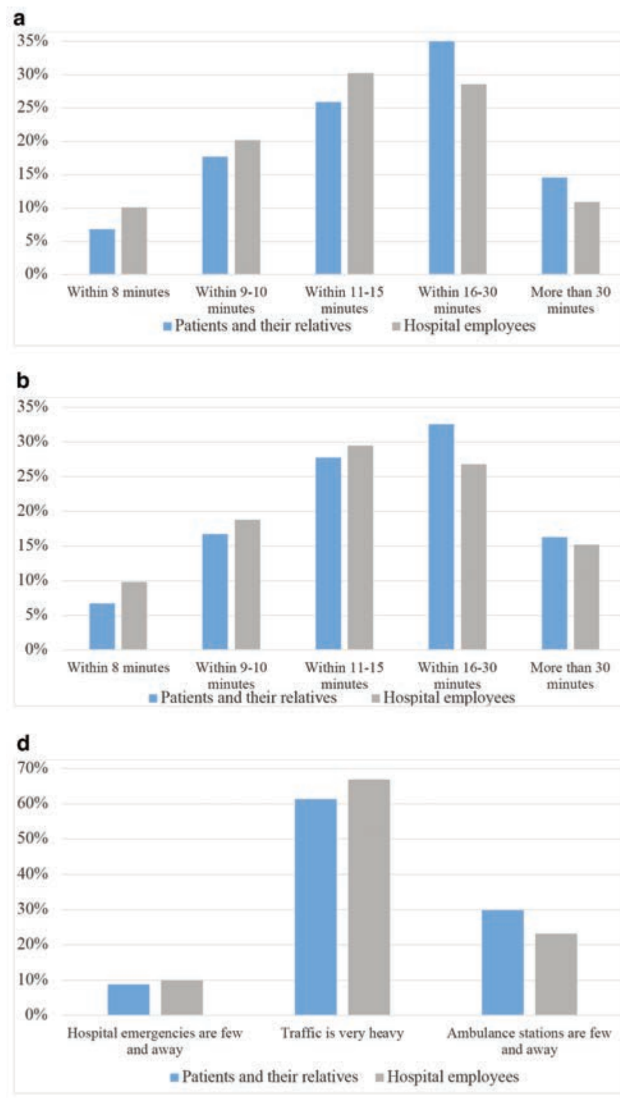

Figure 1. Outcome of the survey of time delays before medical care. Responses regarding **a**) the ambulance response time; **b**) the transportation time to the hospital following the first medical intervention; **c**) late arrival of the ambulance to the scene or the reason for the delay in transportation to the hospital.

district basis. When the thematic maps showing the distribution of EMS stations according to population and population density are examined, it can be seen that there are proportional increases as one approaches the city centre (Figure 2c,e). According to the results of Kendall's Tau-b non-parametric test for the Turkish provinces (Table 3), there were large correlation between the number of EMS stations and the number of ambulances (0.847); large correlation between the number of EMS stations and the number of hospitals (0.800); large correlation between the number of EMS stations and population (0.815); medium correlation between the number of EMS stations and land area (0.429); medium correlation between the number of EMS stations and population density (0.415); large correlation between the number of hospitals and the number of ambulances (0.785); large correlation between the number of hospitals and population (0.781); medium correlation between the number of hospitals and land area (0.427); and medium correlation between the number of hospitals and population density (0.400), with all correlations significant at the 0.01 level (2-tailed). A large correlation was found between the number of EMS stations and the number of ambulances and hospitals at the provincial level, while a medium correlation was found between the number of EMS stations and population density in both the district and provincial statistics. According to the OSWSRT results conducted between Fatih district and all districts of Istanbul (Table 4) there was a statistically significant difference in terms of the number of EMS stations and the area that an EMS station is responsible for (H1), while there was no statistically significant difference in terms of population density per EMS station (H0). As further seen in Table

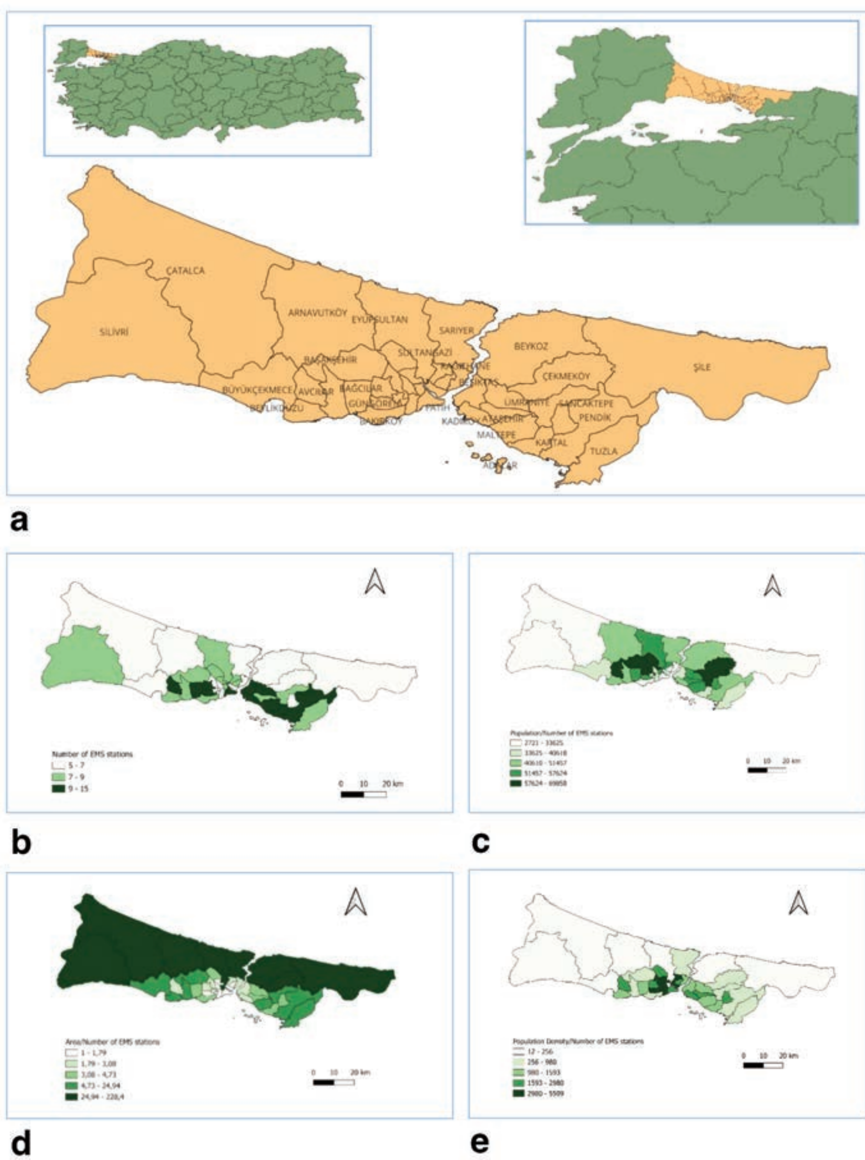

Figure 2. Distribution of EMS stations in districts of Istanbul. **a**) Localization of Istanbul province and its districts, **b**) Numerical distribution of EMS stations in districts, **c**) Distribution of EMS stations according to the population of the districts, **d**) Distribution of EMS stations according to land area, **e**) Distribution of EMS stations according to population density.

4, when this test was applied for Istanbul and the Turkish provinces, there was a statistically significant difference (H1) with respect to the number of EMS stations, the number of emergency ambulances, the number of hospitals as well as area and population density, both per hospital, and EMS. When the ambulance response time was questioned in the survey study (Figure 1a): 6.8% of patients and relatives and 10.1% of hospital staff responded that medical intervention was initiated within 8 minutes following the ambulance call; 17.7% of patients and relatives and 20.2% of hospital staff responded that it was initiated within 9-10 minutes. The rate of intervention within the first 15 minutes was 50.45% according to the responses of the patient and relatives, and 60.5% according to the responses of the hospital staff. It was determined that 49.6% of patients and their relatives and 39.5% of hospital staff stated that intervention took more than 16 minutes (16-30 minutes + more than 30 minutes). No statistically significant difference was found between the responses of patients and relatives and hospital staff ($p>0.05$). To the question of how long it took for the patient to be transported to the hospital by ambulance after the first medical intervention (Figure 1b): 6.7% of the patients and their relatives and 9.8% of the hospital staff responded as within the first 8 minutes; 16.8% of the patients and their relatives; and 18.8% of the hospital staff responded as within 9-10 minutes. The total rate of those who stated that intervention was received within the first 15 minutes was 51% for the patients and their relatives and 58% for the hospital staff. The total response of 16-30 and more than 30 minutes was 49% for the patients and their relatives and 42% for the hospital staff. No significant difference was found between the responses of the patients and their relatives and the hospital staff ($p>0.05$). To the question of reasons for delay in ambulance response time and hospital transfer (Figure 1 c): The answer “there are few and away hospital emergency services” was given by 8.8% of patients and their relatives and 9.9% of hospital staff; the answer “there is very heavy traffic” was given by 61.4% of patients and their relatives and 66.9% of hospital staff; the answer “there are few and far away ambulance stations” was given by 29.8% of patients and their relatives and 23.1% of hospital staff. No significant difference was found between the answers of patients and their relatives and hospital staff ($p>0.05$). When the heatmap of hospitals offering EMS in Istanbul was examined (Figure 3), it can be seen that there was an increase in the density of hospitals offering EMS in districts such as Fatih, Beyoğlu, Beşiktaş, Şişli, Üsküdar and Kadıköy, which are situated close to the two sides of the Bosphorus, and that the density of hospitals decreases significantly as one moves away from the city center. According to the results of the buffer analysis showing the distance of EMS stations to hospitals (Figure 4); in the Fatih district, which is located in the city centre, there is no hospital within 1 km of a station, while there are 7 hospitals within 3 km, 17 within 5 km and 72 within 10 km. In Küçükçekmece District, which is located towards the periphery of the city, there is no hospital within 1 km of an emergency station, but there are 3 hospitals within 3 km, 6 within 5 km and 26 within 10 km. In Beylikdüzü District, which is located more peripherally, there is no hospital within 1 km of an emergency station, but there are 3 hospitals within 3 km, 9 within 5 km and 14 within 10 km.

Discussion

While the survey results provided insight into EMS performance assessments, more reliable inferences are needed for decision-makers. Therefore, in addition to survey results, statistical assessments based on reliable data and GIS-based applications are gaining importance. In our study, statistical assessments were conducted using data from the MoH and supported by GIS-based applications such as thematic maps, heat map, and buffer analysis.

The time between an event and response time after call was an important part of our study. Naturally, the length of the ambulance response after the call varied (Figure 1a) but within the first 15 minutes, the rate was determined to be 60.6%. With regard to the duration of transfer to the hospital within the first 15 minutes following the first intervention (Figure 1b) the rate was 58% of the total. No statistically significant difference was found between the responses of the patients and their relatives and the hospital employees ($p>0.05$). According to a retrospective analysis of 12,722 adult out-of-hospital cardiac arrest cases in British Columbia, the average on-scene response interval for the emergency ambulance team was determined to be 6.4 minutes, and the time to emergency advanced life support was provided following hospital transport,

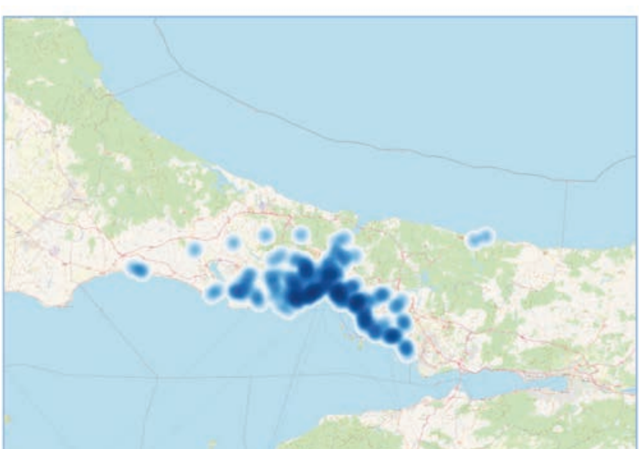

Figure 3. Heatmap of hospitals providing EMS in Istanbul.

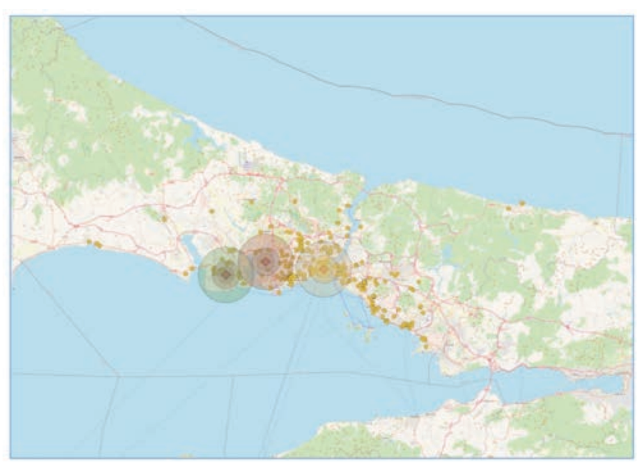

Figure 4. Display of buffer analysis for hospitals in Fatih, Küçükçekmece and Beylikdüzü districts of Istanbul. Radii used were of 1, 3, 5 and 10 km of the EMS stations.

11.8 minutes (Grunau *et al.*, 2019). Reaching the scene and providing advanced life support is important in terms of survival and positive neurological outcomes, so being able to do it within 10 minutes (≤10) after the emergency call must be considered a measure of quality (Grunau *et al*., 2019). In our survey, when the reasons for delays in ambulance response time and hospital transfer were questioned (Figure 1c), it was clear that traffic density, which is directly related to population density, plays an important role. Apart from population density is the fact that the city is located on both sides of the Bosphorus with one connecting bridge (Figure 2a). Although Istanbul only constitutes 0.68% of Turkey's total area according to 2024 data, 18.3% of the country's population of 15.7 million live there (TÜİK, 2024). Further, Istanbul is ranked 2nd in the Top 10 Cities in International Arrivals-2024 ranking (Euromonitor International, 2024). This high population density and mobility create the need for an EMS station organization that also considers hospital location. It is stated that one of the problems experienced in EMS service provision in Wuhan, China is poor accessibility to EMS due to population growth and traffic density, and another important problem is the spatial inequality in access to EMS between urban and rural areas (Luo, 2022). It has been noted that the South Korean government has made efforts in recent years to increase geographic accessibility to emergency care facilities through the selection of vulnerable areas, rather than a population-based approach in accordance with the Public Health and Medical Services Law (Jang *et al.*, 2021). In the survey (Figure 1c), 23.1% of hospital staff responded that ambulance stations were few and away as the reason for delay, while 29.8% of hospital staff responded that hospital emergency departments were few and away. No statistically significant difference was found between the responses of patients and their relatives and hospital staff (p>0.05). It was determined that the correlation level determined between the number of EMS stations in 39 districts of Istanbul and the population of the districts is higher than the correlation levels made according to the number of EMS stations, land area, and population density (Table 2). This situation is likely related to several factors. The first of these may be that decision makers prioritize the population of the district rather than its area when planning emergency station distribution (Figures 2b-e). The second reason may be that EMS implementation is planned at the provincial level, with a centralized structure under the MoH, ignoring district boundaries. This approach may have aimed to save on significant financial expenses such as establishing EMS station facilities, the number of ambulances, crews, and equipment. Another important reason is that when determining the geographical distribution of EMS stations, the geographical location of the hospitals to which the patients will be transported is also taken into consideration. The best example of this is the Fatih District, which is located on the first settlement area of Istanbul. The value of the number of EMS stations in this district was found to be significantly higher than the median value of the number of EMS stations in all districts of Istanbul (Table 4). The reason for this is that there are three university hospitals, two training and research hospitals and five private hospitals within the borders of Fatih District, and in parallel with the increase in the number of hospitals (Figure 3), the need for EMS stations also increases. According to the results of the buffer analysis showing the distance of EMS stations to hospitals (Figure 4); while there are 72 hospitals within a distance of 10 km in the Fatih District located in the city centre, there are 26 hospitals in the Küçükçekmece District that is located towards the periphery of the city and 14 hospitals in the Beylikdüzü District located further to the periphery. The land area for which an EMS station in Fatih District is responsible was found to be significantly smaller than the land area median value of all districts of Istanbul. Although this situation is considered a positive indicator in terms of workload, the real situation is different. Namely, due to the relatively high service quality in hospitals located in Fatih District, emergency patient transfer from surrounding districts to hospitals in the area increases significantly, which can lead to an increase in the total service area served by Fatih District and therefore lead to increases in ambulance response times. The fact that the OSWSRT results (Table 4), conducted between Fatih District and all districts of Istanbul, showed that the difference in terms of population density per EMS station was not significant, can be considered a positive indicator for EMS application. As obvious from the thematic maps, there is a large correlation between the number of EMS stations and the number of ambulances and hospitals at the provincial level. This may be due to the interrelationship between the functionalities of EMS stations, ambulances, and hospitals. As with the district statistics, a large correlation was found between the number of EMS stations and the population variable in the provincial statistics, while there was a small correlation was found between the number of EMS stations and area in the district statistics, and a medium correlation in the provincial statistics. On the other hand, a medium correlation was found between the number of EMS stations and population density in both the district and provincial statistics. These results suggest that administrators prioritized the population variable when determining the number of EMS stations at the provincial and district levels, ignoring the area variability within the districts. While a large correlation was found between the number of hospitals and EMS stations, the number of ambulances, and the population number at the provincial level, a medium correlation was found between the number of hospitals and the area and population density variables.

In Turkey, the provision of EMS stations is planned and carried out at the provincial level by a central organization affiliated with the MoH. When the EMS application is examined at the provincial level, it can be found that the number of EMS stations, emergency ambulances and hospitals in Istanbul is significantly greater than the median value of all the provinces in the country (Table 4). On the other hand, the population density per hospital and EMS station in Istanbul was also found to be significantly greater than the median value of all provinces (Table 4). In addition, the area value per EMS station and per hospital in Istanbul was found to be smaller than the median value of all provinces, a statistically significant difference. This situation is closely related to the population and land area value of the provinces. Namely, according to 2024 data, Istanbul ranks 1st among the 81 provinces of Türkiye in terms of population and population density, while it ranks 66th in terms of land area size (TÜİK, 2024). According to the 2024 internal migration statistics, it was determined that 4% of the Turkish population migrated between provinces, and Istanbul was the province that received and emitted the most migration (İPA, 2024). For Istanbul, while some criteria (number of hospitals, number of EMS stations, number of ambulances, area value per hospital and EMS station) have more positive results than the median value of all provinces, some criteria (population and population density per hospital and EMS station) have more negative results. Undoubtedly, when determining regional and nationwide health strategies, which of these variables will be used to determine the strategy depends on the decision of the relevant institutions of the MoH.

Limitations

This study proposes a statistical approach that prioritizes population density considering both population and land area for equitable EMS access. However, while the study uses a survey as primary data, it is primarily based on secondary data. Ambulance response time and hospital transport time constitute two important components of the "Scoop and Run" EMS model, which are widely implemented in Turkey. Survey participants are expected to recall these time frames quantitatively based on their past experiences. It should not be overlooked that there may be a recall bias due to the participants' level of proficiency in recall, the length of time that has passed, the excitement created by the event, and similar reasons. Questions regarding the time it takes to access healthcare services and the location of EMS stations and hospitals, which play a role in this process, aim to determine a general perception of EMS adequacy. Since our study did not include the Global Positioning System (GPS) or time-stamped ambulance data, some limitations in spatial analyses could not be avoided. Future GIS-based new studies, such as spatial network analysis, space-time accessibility, and real-time ambulance tracking integration, are expected to contribute to equal access to EMS.

Conclusions

The increase in population density and the inevitable resultant increase in traffic density negatively affect ambulance response time. Approaches that solve urban population growth and traffic problems are expected to contribute positively to EMS provision. Although increasing the number of EMS stations and ambulances is considered as a solution to reduce ambulance response time, this approach is not a frequently preferred option due to the significant costs that will arise and the difficulties in providing medical personnel. Instead, it is of great importance that EMS stations are positioned in the most appropriate way, taking into account the geographical location of the hospitals, with the contributions of the GIS database. Considering the correlations of EMS stations at district and province levels according to population, land area and population density, the fact that the correlation is high according to population, but the correlation is lower according to land area, suggests that the desired level of equality in access to EMS in spatial terms has not been achieved. When planning the geographical distribution of newly established hospitals and EMS stations at the level of provinces in Turkey and districts of Istanbul, considering population density, which takes population and land area into account together, will constitute an important approach in terms of ensuring equal access and efficiency to EMS. In this context, GIS-based tools, such as thematic maps, buffer analysis and heatmaps, provide significant contributions to understanding the problems in equal access to EMS and creating solutions.

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