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Improvement of Barranquilla's EMS response time with the use of GIS

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Abstract

The global emergency medical services (EMS) are complex systems characterized by significant differences in service providers, care pathways, patient care, and quality of care indicators. Therefore, analyzing and improving them is a challenge. Since EMS systems vary from country to country, it isn't easy to provide common standards and methods for EMS planning. However, the common goal of all service providers is to provide medical care to patients who are critically ill or injured as quickly as possible. This research analyzes the location of ambulances of the emergency medical system (EMS) of Barranquilla through a statistical and geographical study. This analysis considers the accident rate, ambulances' geolocation, service areas, and accident to hospital driving times. ArcGIS was used for data processing. The aim was to give an adequate response to accidents in the city of Barranquilla, Colombia.

Keywords: emergency medical services, location, service area, statistical analysis, ArcGIS.

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1. Introduction

The emergency medical service (EMS) of Barranquilla articulates the different actors of the health general social security system to ensure timely response to victims of disease, traffic accidents, trauma, or cardiorespiratory arrest requiring emergency medical care. It includes, among others, the mechanisms for notifying medical emergencies, the actions of the first responder, the tasks of the regulatory centers for crises and troubles in the management of requests, the provision of pre-hospital and emergency services, primary and medicalized transport modalities, hospital care, educational programs, and surveillance processes. An efficient EMS would help reduce the historical effects of emergencies associated with diseases such as cardiovascular diseases. These diseases represent costs of more than 900 billion euros worldwide per year for care, hospitalization, and various services. These costs represent a current concern because there is also a pyramidal inversion. This pyramidal inversion may cause the taxes to increase to afford the system's cost [1]. At the same time, records show an increase in the mortality rate of cardiovascular diseases, which, within medical emergencies, ranks first in terms of severity because, within medical emergencies, the one that ranks first in terms of severity is the case of cardio-respiratory arrest [2]. The importance of time is crucial since the average time that brain tissue can last without suffering irreversible neurological damage because of lack of airtight oxygen supply is 4 minutes [3]. It has been suggested that increased pre-hospital time is a factor that negatively affects rural vehicular trauma mortality rates. In this sense, it is estimated that about 1.35 million people die each year because of road traffic accidents, and these, in turn, cost most countries 3% of their GDP [6], [7]. Furthermore, many media report on the existing problems with the current EMS, showing that the system still shows a substantial weakness in the response of emergency medical services, generating a higher mortality rate, worsening the quality of life of people, and increasing the costs of the health system. [8]

Therefore, an optimized and efficient system is required to help reduce the current mortality rate and the costs involved, meet international standards of response times, and improve the service's quality and equity.

This article is focused on the analysis of the Barranquilla EMS through the study of databases provided by the Barranquilla Mayor's Office to identify if the existing locations are efficient in complying with the response standard time. The paper is divided into four sections. Section 1 introduces the study area; section 2 contains a statistical analysis through trend graphs of a database of accidents that occurred in 2015-2020; section 3 presents a geo analysis that includes heat maps and Thiessen polygons concerning the location of the studied databases. Finally, in section 4, some conclusions and analysis of results with the research gaps identified in the process are described.

2. Study area

Barranquilla lies in the northeastern corner of the department of Atlántico, on the western bank of the Magdalena River, 7.5 km from its mouth at the Caribbean Sea. It has an area of 154 km². The city's population is 1,274,250, making it the fourth most populated city in the country.

According to the National Administrative Department of Statistics (DANE) forecast, the total population of the Atlantic region in 2009 was 2,284,840. This population was split into 95% urban and 5% rural [9]. According to DANE sources, the population was close to 2.6 million inhabitants by 2020, which means that a total of 320,000 new citizens must be served in all aspects of human needs.

In Barranquilla, the existing ambulance locations have been empirically determined, meaning locations have been assigned through intuition. The decision-making process tried to locate ambulances in high service request districts. Nevertheless, the current ambulance location does not guarantee meeting the service standard for all emergency calls. A database containing accident reports from 2015 to May 2020 was used to identify the city's higher accident rate areas.

2.1. Statistical analysis

The statistical analysis of accidents reported from 2015 to May 2020 began by identifying certain behaviors that allow knowing the number of accidents annually, monthly, and by time slot to understand the existing demand for ambulances. The analysis helped to identify peaks and drops in the need depending on the hour, day of the week, and month of the year.

2.1.1. Annual performance

The data show a significant increase in accidents per year since 2017. For example, 482 accidents were already reported by May 2020, representing more than half of the total accidents reported in 2015 and 2016. This number is very high considering that the city was under quarantine due to COVID 19 pandemic since March 2020.

The increase in the accident rate makes it necessary to assess Barranquilla's EMS location policy and response times (see Fig. 1).

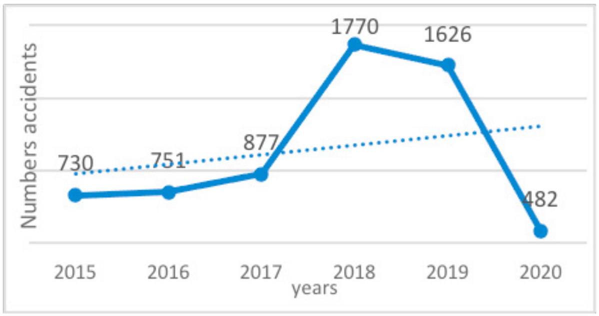

Fig. 1. Total number of accidents reported per year.

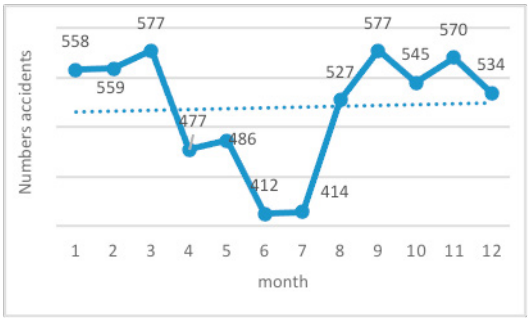

Fig. 2. Number of accidents per month

2.1.2. Monthly performance.

When analyzing the number of accidents per month, it is observed that there is a tendency of increase in the first semester in February and March, which can be associated with the festival celebrated in the city 'Carnival of Barranquilla', and in the second semester of the year in August and September (see Fig. 2).

2.1.3. Performance by time slot.

The time slots and days of the week analysis showed that approximately 21% of accidents occur between 6 pm and 9 am from Monday to Friday. On the other hand, 18% of the accidents occur from 12 pm to 3 pm. Finally, from 3 to 6 pm occur 16% of the accidents (See Fig. 3).

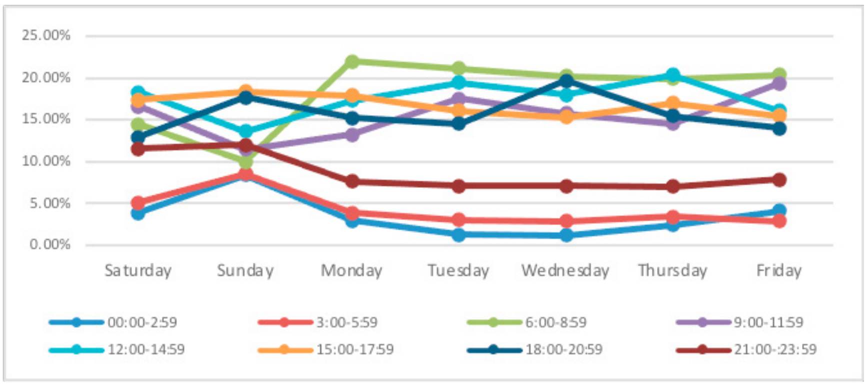

Fig. 3. Percentage of accidents reported in time slots by day of the week.

Nevertheless, the behavior on weekends differs from weekdays. In this sense, the data showed a drop in accidents from 20% to 12% between 6 pm and 9 pm. Other significant changes in the distribution of accidents in time slots during weekends can be observed in figure 4. There are significant drops in three time slots and significant increases in two time slots.

2.2. Geoanalysis

Once the descriptive statistical analysis was fulfilled, there was also necessary to perform a Geoanalysis to determine the neighborhoods with greater accident incidence. The ArcGIS Tool ® was used in this process during the construction of heat maps, Thiessen Polygons, and service areas. In constructing these tools, all the accidents and hospitals offering trauma services, neurosurgery, and maxillofacial surgery were considered. This information is helpful to analyze the response time of ambulances and estimate the impact of different ambulance locations.

2.2.1. Geoanalysis of Accident Database.

A heat map was built with the help of ArcGIS to determine the districts in which the accident rates are higher. This heat map also shows the city neighborhoods (see Fig 4).

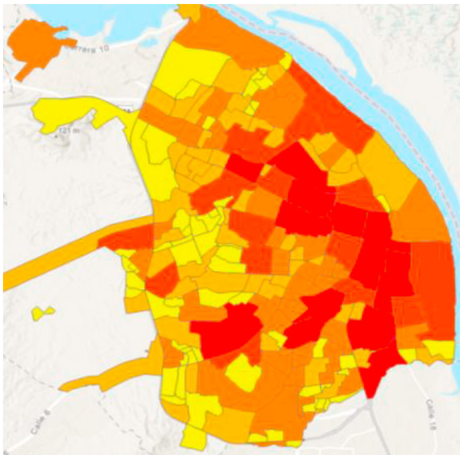

Fig. 4. Heat Map by areas of incidence in neighbourhoods.

Fig. 5. Thiessen polygons delimiting the areas of influence of the 20 ambulances at the service in Barranquilla

Figure 4 shows in red the districts with the highest accidents incidence (red areas). These red areas are important demand points for the EMS.

2.2.2 Geoanalysis of Ambulance Database.

Another critical study variable that was analyzed with ArcGIS tool ® was the current position of the ambulances. The addresses corresponding to each accident were converted into coordinates with the help of Bing Maps. Then these coordinates were supplied to ArcGis ® to build the Thiessen Polygon (see Fig. 5).

Thiessen polygons can establish mathematical relationships between elements generating a zone of influence with specific mathematical premises[10]. The main rule set in this case is that the sides of the generated polygon are equidistant from the adjacent points, trying to find the smallest possible distance. The margin of each polygon is the same distance from one point to another.

Therefore, in figure 6, it is possible to observe the existing distribution of the ambulances in Barranquilla and their areas of influence concerning the equivalent distance between them.

Fig 6. Ambulances service areas with current locations, Response time < 7 min.

Fig 7. Ambulances service areas with proposed locations, Response time < 7 min.

3. Analysis of results

After observing the current Barranquilla's EMS situation and the districts with the higher incidence of traffic accidents, where traffic accidents occur and where they present high peaks, the areas of services covered by ambulances are analysed, observing that the statistical analysis identifies some months show more accidents than others. For example, there is an increase in the number of accidents in March and September (see Fig. 2), which have a higher incidence of accidents. The cause of this behavior may be celebrations such as "Carnival" and "Love and Friendship" celebrations, respectively, in which people drink more alcohol than usual.

In the same way, it is possible to determine the hours in which the most significant number of accidents per day and week occur. This analysis showed that accidents usually happen at the beginning of workdays (6:00 am-8:59 am) and afternoons and evenings (12 pm- 6 pm).

Figures 7 and 8 show the comparison between services areas obtained with the current and proposed ambulance locations. The ovals and arrows indicate the new places that are reachable in less than 7 min. With the new distribution, 100% of the city is reachable in less than 7 minutes. With the previous ambulance locations, 98% of the city was reachable in less than 7 minutes. The additional districts that are reachable within 7 minutes are La Playa, Juan Mina, and Villas de San Pablo (see Fig. 6 and Fig. 7).

The threshold value was set considering a 10 minute response time of the system [11]. In this sense, it was estimated that the dispatcher takes approximately one minute to talk with the caller. The crew could take two additional minutes to get ready once the dispatcher notifies the emergency. Therefore the travel time from the ambulance site to the emergency must take less than 7 minutes. Once the 22 available ambulances are located in the proposed sites, 100% of the city is reachable in less than 7 minutes (See Fig. 7).

4. Conclusions

This research shows that the current ambulance locations in Barranquilla cannot serve in less than 7 minutes in 2% of the cases. Nevertheless, with ArcGis, it was possible to identify a better distribution for the ambulances. This new ambulance distribution allows serving all accidents in less than 7 minutes (travel time).

Nevertheless, it is essential to point out that the EMS task does not finish reaching the patient in a short time. It is necessary to take the patient fast to the hospital. Therefore for future research, it would be interesting to verify the impact of ambulance location not only the travel time to the emergency but also the travel time from the hospital to the ambulance base.

Another prominent line of research is the use of machine learning to estimate travel times and demand. Forecasting where the next accident is most likely to occur can help decision-makers allocate ambulances better, particularly in dynamic scenarios. This is especially relevant in the cases where different types of ambulances are available in the system. In these cases dispatching the closest server may not be the best option.

Finally, it is essential to address the problem considering the variability of travel times, the probability that ambulances are busy or unavailable, and other metrics such as coverage and equity.

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