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OPTIMIZATION AND SIMULATION OF AN AMBULANCE LOCATION PROBLEM

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ABSTRACT

The main Campus (Ciudad Universitaria) of the National University of Mexico (UNAM) has a population density of about 259,617 people who are attended by four ambulances and 10 technicians in medical emergencies (TME). At the present time the response time of the ambulances is, on average, from 5 to 6 min to the perimeter of the main campus. The National Fire Protection Association of USA recommends that basic life support services should arrive at the scene of an emergency within 4 minutes, while advanced life support providers should arrive within eight minutes for all TME calls. So the TME´s want to find the optimum locations for the ambulances so that they can get to the patients in the shortest possible time. For this job we used simulation and integer programming to find better ambulance locations and shorten the ambulance response time in the main Campus.

1 INTRODUCTION

Records of the treatment of injured or sick patients go back to biblical times. The National Autonomous University of Mexico (Universidad Nacional Autónoma de México UNAM) has been providing this service since 1982, using vehicles with enough capacity for a multidisciplinary team consisting of both professionals and technicians to provide basic and advanced life support.

The efficiency of the ES (Emergency Service) system is measured by the system's average response times, which is the time taken by the emergency medical technicians to arrive at the scene of the accident, attend to the patient and, if necessary, transfer him or her to hospital.

The purpose of the UNAM's Medical Services is: "To promote, protect and restore the health of university students as part of their overall development as well as promoting healthy living among the university community and the general public". Medical Services Bureau (D.G.A.S.) of the UNAM.

2 THE EMERGENCY SERVICE

The emergency service of the University Medical Center has resources to deal with mild to moderate cases, while only serious cases and ones requiring hospitalization are sent to other health institutions.

One of the achievements of the Bureau has been the introduction of pre-hospital care programs as one of the pivotal activities of the department. The purpose of pre-hospital care is to provide immediate first aid and emergency care in situ during the first 60 min, i.e. "the golden hour"; responding to the needs of the case by stabilizing, immobilizing, and moving the patient to the specialist service they require. Timely care gives the patient a better chance of life and lowers the incidence of invalidity or its sequels.

The medical emergency service operates 24 hours a day in the University Medical Center, with the support of the Emergency Care Headquarters. It has four ambulances, two of which have advanced life sup-

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port equipment and two that just have basic support equipment. At the present time the response time of the ambulances is, on average, 5 to 6 min to the perimeter of the main campus. They operate through guards who use phones or radios. However, in view of the rise in the population of students and faculty members, as well as administrative and service staff over the last few years, this service is no longer sufficient, which is why we have had to carry out this analysis to find a way to make it more efficient. It is worth mentioning that the flow of users is nonstop throughout the year and the service is still provided during the inter-year or inter-semester periods, with a 2012 population density of 214,364 students, and 45,253 faculty members (estimated). Floreset.al (2016).

3 METHODOLOGY

As has already been mentioned, the methodology was developed as follows: in the first place, we collected the following information: place, type of population requiring attention; what kind of service they need; the nature of injuries or accidents, and dates. As these data are stochastic, we used probability distributions to fit them. A discrete simulation model was the model that best fit and served to define the demand behavior. Once the simulation model had given us the demand information, we used it in a maximum covering model, experimenting with the parameters. Finally we used the results to create other scenarios.

3.1 Information Gathering

We used mathematical modeling to find a better location for the ambulances and one of the criteria for optimizing the location was based on maximizing the level of coverage and the other one was based on minimizing the distance between the place of the incident and the position of the ambulance. Therefore, the following information was collected: Demand, number of services, measurement of distance. We collected 1919 items of data, based on the control records of ES for the period from 2008 to 2011.

Data fitting

We did this using the EasyFit© software that lets us fit probability distributions, giving as a result the parameters to be considered in the simulation model.

3.2 Simulation Model

This section gives the simulation model that was used to determine the behavior of the stochastic demand for which the data was fitted. Considering a Poisson distribution for each of the zones, we proceeded to construct the simulation model where each zone is considered a source that generates a certain number of events (demand for service) throughout the simulation. These events in turn are attended by servers which are units of transport that also have their own operating parameters. As soon as the sources generate an event, it is attended by the servers and taken to a general sink. As the model is large, considering 12 sources, each one with its own time between arrivals, 4 ambulances (servers) and a single sink, the calculation by pencil of a six-month simulation would be a cumbersome task indeed, which is why we opted to employ the SIMIO software. In this model the values of events per zone were estimated considering a semester with ten repeated samples.

3.3 Location Model

In ambulance location cases, the aim is to locate them as close as possible to the demand sites in order to shorten the response time, when demands can be served by any available resource. One of these models is the set covering model, where the question to be answered is: When there are a given number of people who require the service, how many resources should be located? So that everyone who is to be served is within a given distance from the nearest resource. As it is, we already have a fixed number of ambulances and it is not very probable that more resources are going to be acquired, apart from the fact that these resources might not mean a significant reduction in the response time. Therefore we employed a variation in the set covering model which is the maximum covering model, where the objective is to maximize the coverage provided by the resources, given that the resources are limited to a certain number.

For the construction of this model, we need to know the number of ambulances to be located, the demands of the zones (nodes) and the distances between them. These data were collected, by dividing the campus into 12 zones (one node per zone), and checking that the distances between them were less than or equal to 2 km. The data were put in a Table of 12x12, and with this data the location model was constructed.

Using the location mathematical model we found a first optimal solution which was used to build scenarios to find the best one. As the mathematical model is integer, scenarios were developed with SIMIO software.

Experiments

The purpose of the experiments was to further improve the response time (reduction of transporting time) by making adjustments to the criterion for the selection of the constraints used to solve the model, bearing in mind that the first criterion used for a first approximation to the result was a distance between zones of less than or equal to 2 km, 3 more parameters are proposed below as follows: a) Distance between zones less than or equal to 1.7 km apart; b) The same but with 1.5 km, and c) with 1.1 km.

The best solution found using the parameters obtained through the experimentation offered by simulation is that the optimum range of criterion for a shorter time is located in the 1.5 km ≤ distance between zones and the≤ 1.7 km range, where the ambulances will perform better, demand will be covered, and the response time will be shortened by approximately 16%.

4 CONCLUSIONS AND RESULTS

To answer the questions of the previous section, the importance of systematizing the location of the ambulances is that it can save lives. The optimum social location was found in an interval of (1.5, 1.7) kilometers between zones. The location of the ambulances was found by using SIMIO simulation.
The location model was linked to a simulation model whose function was to identify demand behavior and analyze the results of the model in order to find the best possible solution within the limits set when creating different scenarios; while, at the same time, shortening the response time.

There is a high level of randomness in the ambulance services on the main campus of Mexico City, with the time taken for the jobs forming part of the routine of the system. Moreover, there are no clear rules for many of the jobs, so they depend on the people doing the job. However, discrete event simulation is a useful tool for the analysis of these systems, and it is possible to develop models that are capable of satisfactorily representing all the phenomena that form part of all the activities of the system. Therefore the combined use of optimization techniques, such as the location optimization technique, and simulation improves the search for optimum values for the system, making the simulation and analysis of a large number of alternatives possible.

REFERENCES

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