OPTIMAL AMBULANCE LOCATION, AT UNIVERSITY OF MEXICO, EMPLOYING SIMULATION

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ABSTRACT

This study was undertaken to make more efficient the ambulance service at the University of Mexico in terms of response time and their location through a simulation model, programmed in SIMIO, which represents the real system and allowed us to propose a strategic location of these ambulances, provided by a location model.

Keywords: ambulance location, simulation, location model.

1. INTRODUCTION

The University of Mexico provides the population located on its main campus with various services, including libraries, general store, medical service, sports and recreation, to name a few. On the other hand, the medical service also counts with an emergency center, which provides ambulance service, being responsible of addressing any circumstances required. The service covers an approximate area of 3.5 square miles, as shown in Figure 1, with a daily population greater than 258.617 people, according to table 1. Considering the above, the response time plays an important role to provide care and protect human life, stating the reason of this research, proposing a strategic location of the ambulances, improving the response time, and bringing this service at the time when it is required.

Table 1. Population Statistics from the main campus

Year	Undergraduate Student	Graduate Student	Professorate
2008	167,891	22,527	43,151
2009	172,444	23,875	43,252
2010	179,052	25,036	44,348
2011	180,763	25,167	44,869
2012	187,195	26,169	45,253

This paper presents a combination of tools: discrete event simulation and integer programming. Discrete event simulation was used because of its power to simulate complex and detailed systems. (Perez Cardona Gomez Olarte, Escudero, 2008).

Figure 1. Aerial View of main campus

The following sections give a brief description of the simulation model and its methodology; as well as the location model, and the conclusions achieved.

2. SIMULATION MODEL

This section gives a brief description of the model building, along with the methodology used, and the results obtained.

2.1 Methodology

The methodology (Flores, Cortez, 2006) conducted for this article was as shown in Figure 2.

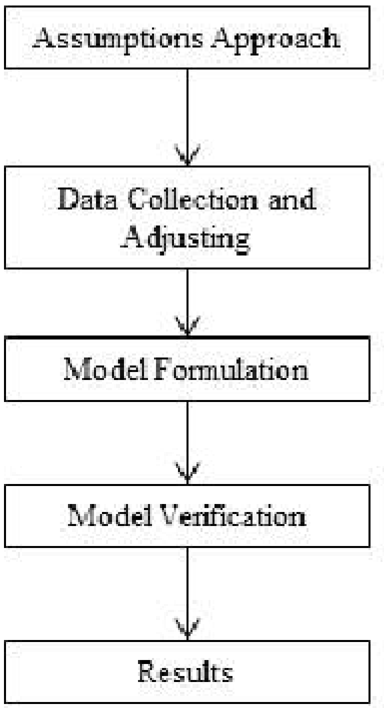

Figure 2. Methodology Followed

2.2 Assumtions Approach

Several assumptions were raised for this project, such as:

- Free circuit traffic.
- Constant ambulance speed of 60 km / h.
- Students, workers, and externals are the only affected population.
- Events occur only on the main buildings of each of the faculties.

It was proposed to work with an ambulances location zoning by considering the proximity areas between faculties, as shown in Table 2.

Table 2. Suggested Zones

Zone	School	School	School
1	Law	Economics	
2	Medicine	Dentistry	
3	Engineering	Languages	Architecture
4	Philosophy	Central Library	
5	Political Sciences		
6	Sciences		
7	Accounting		
8	Psychology		
9	Chemistry		
10	Social Labor		
11	Veterinary	Animal Husbandry	
12	Engineering Annex		

2.3 Data Collection and Adjusting

The data was extracted from the formats conducted by emergency medical technicians at the University of Mexico, considering information from 2008 to 2011, including all the days of the week. The collected data specified place, day of week of the event, and person served; information concentrated in Table 3 and Table 4.

Table 3. Total number of events per day and zone

Weekday / Zone	1	2	3	4	5	6	7
1	44	55	48	49	69	15	8
2	52	44	49	51	51	15	10
3	37	52	37	47	34	9	7
4	31	39	30	43	38	15	11
5	16	23	8	19	27	10	3
6	35	43	62	49	39	9	2
7	29	29	34	37	34	9	3
8	12	10	17	14	14	2	1
9	18	23	24	29	32	4	2
10	4	7	11	11	10	0	1
11	10	22	19	12	11	4	3
12	11	11	18	12	10	3	0

Table 4. Total number of people served per zone

Person served / Zone	Student	Employee	Other
1	194	56	38
2	130	72	70
3	121	60	42
4	112	49	46
5	67	18	21
6	154	67	18
7	136	25	14
8	45	17	10
9	83	30	19
10	29	6	9
11	37	21	23
12	41	16	8

These data was fitted using EasyFit software, which allows the adjustment of probability distributions, providing the necessary parameters to consider in the simulation model presented in Table 5.

Table 5. Adjusting parameters

	Geometric	Neg. Binomial	
	p	n	p
Zone 1	.02373	4	.10046
Zone 2	.02509	6	.13608
Zone 3	.03043	4	.12167
Zone 4	.03271	8	.23007
Zone 5	.06195	4	.23935
Zone 6	.02846	3	.08644
Zone 7	.03846	4	.16234
Zone 8	.09091	4	.30435
Zone 9	.05036	3	.16003
Zone 10	.13725	3	.33478
Zone 11	.07955	4	.27207
Zone 12	.09722	4	.030172

According to the tests of fit goodness (Anderson-Darling and Kolmogorov-Smirnov) that offer the same program; the shaded values for each zone were taken into account. Furthermore, it was estimated the percentage of persons requiring such services as shown in Table 6. These values allow the estimation of the service demands.

Table 6. Percentage of type of people served per zone

Zone	%Stundent	%Employee	%Other
1	67%	19%	14%
2	48%	26%	26%
3	54%	27%	19%
4	54%	24%	22%
5	63%	17%	20%
6	64%	28%	8%
7	78%	14%	8%
8	61%	24%	15%
9	63%	23%	14%
10	66%	14%	20%
11	46%	26%	28%
12	63%	25%	12%

2.4 Model Formulation

Once analyzed the data, the simulation model was built in SIMIO; this software allows you to build and run dynamic 3D models of a variety of systems, such as manufacturing, supply chains, emergency departments, airports and service systems. This software uses a modeling approach by objects, where the models are constructed by combining objects representing physical components of the system. Simian model may represent the real system (SIMIOA LLC, 2010), this allows a more simple interaction between the shaper and the system to model, in addition to its visual appeal, as shown in Figure 3.

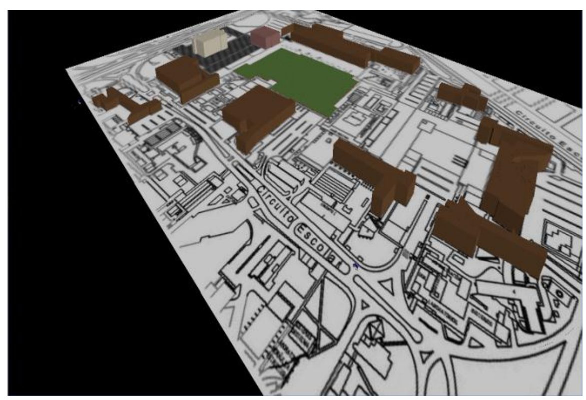

Figure 3. Simulation model in SIMIO

This model was built taking each zone as an entities generator source, which represent the events that require the attention of the ambulances.

2.5 Model Verification

The model was verified by checking the nonexistence of no logical error when running the simulation; at the time the data was also analyzed by reviewing the results obtained were consistent with the real system.

2.6 Simulation Results

In this model each zone events were estimated considering the semester from August 2012 to December of that year, the model was run with ten replicas, figures 4-6.

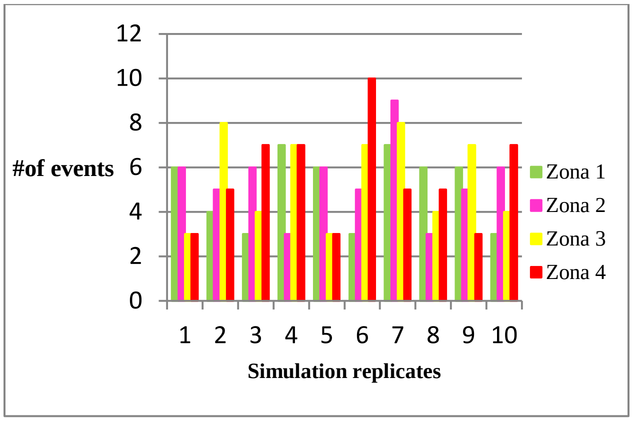

Figure 4. Number of Events per zone (1-4)

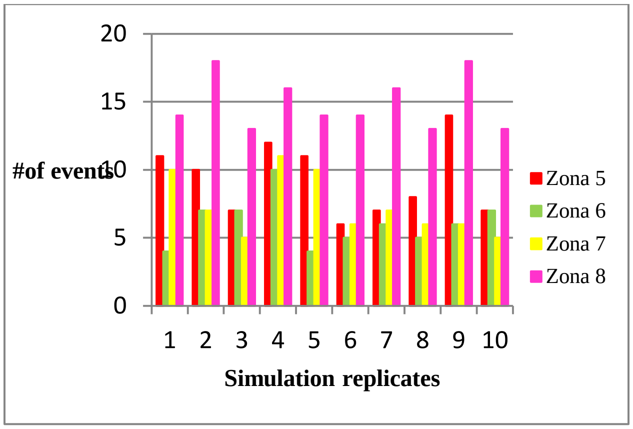

Figure 5. Number of Events per zone (5-8)

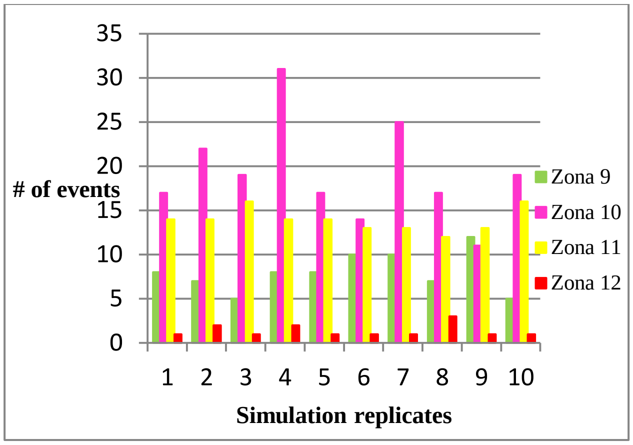

Figure 6. Number of Events per zone (9-12)

The model also provided results which show the time of transport along the simulation, as Figure 7 demonstrates.

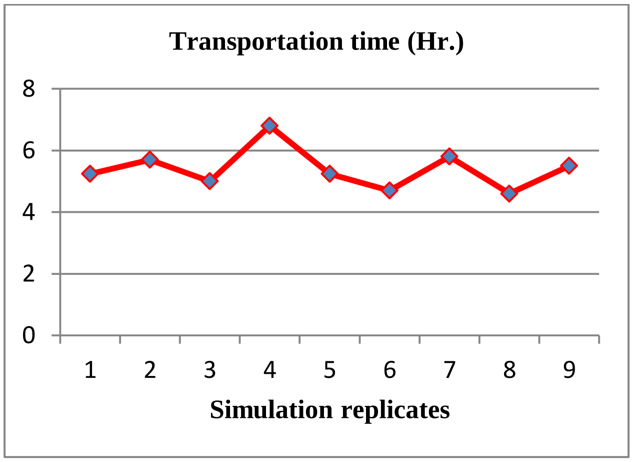

Figure 7. Transportation time

From the same model, the amount of people requiring the ambulance services was obtained, as seen in Figure 8.

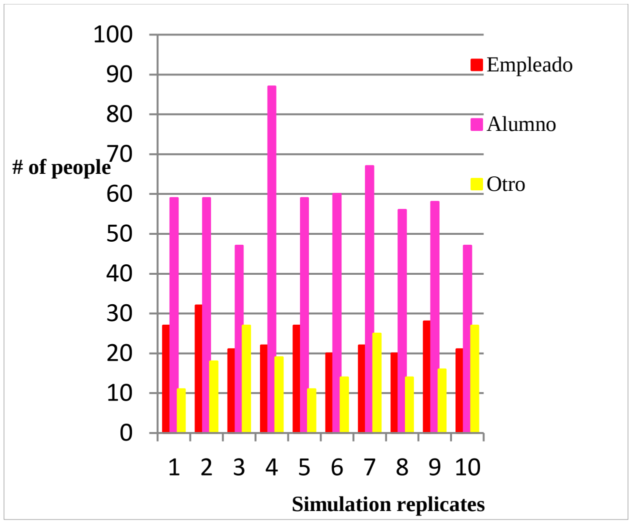

Figure 8. Number of people served

3. LOCATION MODEL

The MCLP model (Maximal Covering Location Problem), proposed by Church and ReVellle (1974), is an alternative to address and consider the deficiencies of the model SCLM (Set Covering Location Model), maximizing the population coverage restricted to the number of ambulances available, making the best use of the available resources.

One of the problems associated with the fixed coverage model is that the number of facilities (resources) needed to meet the demands of each node is likely to exceed the existent amount. The model even treats the nodes identically, which means that it is equally important to cover a demand node requiring 10 visits, to one that generates 100 per year (Daskin, 1995). These two concerns are considered to determine the number of facilities (resources) to be located and maximize the number of covered claims, this is exactly what the maximum coverage model aims; in order to formulate this model the follow definitions are used:

$$max\colon \sum_i h_i Z_i \tag{1}$$

$$Z_i \leq \sum X_j \ \forall i \tag{2}$$

$$\sum_j X_j \leq P \tag{3}$$

From equation (1) h_i denotes the demand of node i, Z_i is a binary variable which equals 1 if the node is covered, 0 otherwise; of equation (2) X_j is also a binary variable which will value 1 if the ambulance is located at the site j, 0 otherwise; of equation (3) P value represents the total number of ambulances to locate.

The result gave the following table showing the ambulance and the zone where it was located, Table 7.

Table 7. Relationship between ambulance and zone covered

Ambulance	Zone
1	8
2	5
3	3
4	12

4. RESULTS

The solution of the location model is implemented in the simulation model to evaluate the results, showing a decrease on the transport time and therefore the response time, as shown in Figure 9.

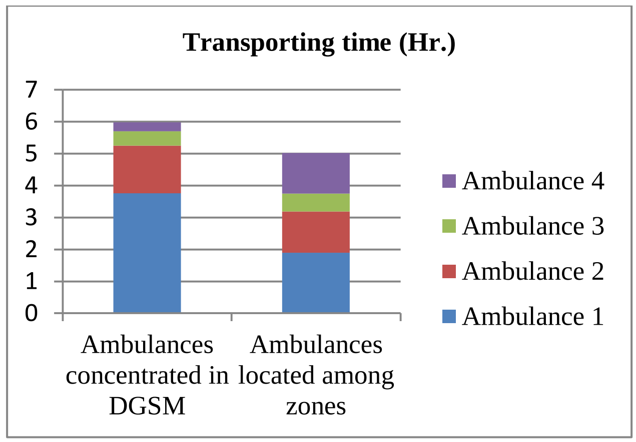

Figure 9. Graphical comparison between the original system and the proposed model

As noted in the chart above (Figure 9), there is a decrease of 16.1%, and a better distribution of labor between ambulances, generating savings in terms of maintenance and fuel, among others. Appreciating an even more efficient service.

5. CONCLUSIONS

The discrete event simulation is a useful tool for analyzing the system in question and it is possible to develop models able to represent satisfactorily all the phenomenon included on the system's activities. These models made possible the diverse scenarios experimentation with a statistically acceptable reliability, evaluating escenarios with an increased demand and others to reduce the response time; therefore, the combined use of optimization techniques, such as zoning and simulation, improves the system's optimal values search; allowing the simulation and analysis of a large number of alternatives.

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Jose Alexander Vindel studied Industrial Engineering at University of the Valley of Mexico (UVM), he's currently studying a Masters in Operations Research, and his lines of interest are logistics and simulation.