Emergency system simulation: the case study of E.S.E. San Rafael Hospital

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Abstract: this paper presents the results of a research about the emergency services in the public hospital San Rafael in Tunja (Boyacá), focused on minor procedures, which usually are required by the patients and exceed the assistance capacity and generate delays in the access to the services. For this purpose, a simulation of the real space was made with the software FlexSim in order to find a better option for an improvement of the service. Initially, a diagnostic of the system was made realized in order to measure work and create possible scenarios of operation of the human and physical resources in the services. In order to find out the feasible configuration to obtain the minimum time to attend the patients that required minor procedures, the improvement alternatives were evaluated. With the proposed model, an improvement of 18.7% was obtained in the waiting time of the patients. These results support the decisions by the managers in the hospital and would be a benefit for the patients.

Keywords: simulation, discrete events simulation, health systems, FlexSim *software.*

1. Introduction

According to Jun, Jacobson and Swisher (1999), the simulation of hospital processes has been a novel and effective tool in the analysis of factors related to emergency care. The main problems in the health sector lie in the increasing saturation present in service networks (Arcila, 2010) and the ascending number of traffic accidents (Road Prevention Fund Corporation, 2012). Sanchez (2012) also states that the increase in rates of violence and low outpatient capacity, in contrast to excessive demand, this can be seen as a serious problem in the health sector.

Similarly, due to the complexity and uncertainty that arise specifically in the emergency services, different problems arise, such as prolonged waiting times, inefficient use of emergency courses and unbalanced staff scheduling (Brailsford, Harper and Sykes, 2012; Gul and Guneri, 2015).

Similarly, waiting times consist of long waits for triage, delays in testing or results, waiting for the doctor and shortages of nurses (Paul and Lin, 2012). Therefore, this document aims to present the results of the design of a model simulation of discrete events of the emergency system of the E.S.E. Hospital San Rafael (Tunja, Colombia), in order to reduce the waiting times of patients that require minimum o minor procedures. The E.S.E. Hospital San Rafael is a third and fourth level of complexity hospital, located in the department of Boyacá (Colombia). It is a center of reference for medical care in your department and neighboring departments. The emergency system under study has a rapid process flow during the preliminary stage of user care, so, as stated by Sánchez (2012), the volume of care has grown by 45% in recent years. However, subsequent prosecutions result in high wait times. For the realization of this model, the following specific objectives were structured: (a) to establish a diagnosis of the operation of the system, in accordance with the workstations that make up the study route; (b) determine which workstations limit the system, through a time study; c) identify the probability function to which each workstation's service time is adjusted, through goodness-of-fit tests; d) indicate the possible changes of improvement

resulting from experimentation with the three-dimensional model built with FlexSim *software.*

Discrete Event Simulation (SED) is an instrument of general acceptance in the taking of management decisions. Chemweno *et al.* (2014) and Mielczarek (2014) discuss different reasons why SED is used when making decisions in health entity systems. Some of the reasons expressed by the above-mentioned authors include a) the SED offers an appropriate design methodology for the development of the service by analyzing and b) provides a means of linking industrial processes, focused on improving the methods used in health. However, according to Aebersold and Titler (2014) and Lin, Kao and Huang (2012), there are many obstacles that significantly hinder the process of supply and demand analysis of health care. Due to previous exposed, when conducting studies of the demand of the emergency service of a health entity, there are problems, since there is no information about emergency events that occur and, therefore, it is only possible to study the events that are reported to the health system. According to the above, discrete event simulation is proposed as an appropriate means of finding possible solutions to the research problem, since it conforms to the requirements of the study and offers great methodological advantages by revealing the actual behavior of the system with all the complexity of its relationships and the number of events that occur in all processes. Additionally, according to Blanco and Fajardo (2006) and Lim *et al.* (2012), testing different solutions that improve current conditions before implementing them in the emergency system eliminates time, risk, and cost variables. Through the simulation applied to the health services branch, success stories such as those observed in Shi, Peng and Erdem (2014), Holm and Dahl (2009), Ramis *et* al have been achieved. (2008) and Ruohonen, Neittaanmaki and Teittinen (2006). These researchers have shown improvements in care and administrative procedures, reduction of waiting times by up to a third party, reduction of unnecessary costs, prediction of demand, efficient allocation of resources, among many others. Therefore, it is understood why there are currently specialized software exclusively for hospital use such as Flexsim Health Care and MedModel (Azcárate, Eraso and Gáfaro, 2006)

According to Cheang *et al.* (2003), the results obtained from the evaluation of optimization options highlight nursing personnel as the resource that must be potentialized to establish the appropriate capacity that generates permissible waiting times.

2. Materials and methods

The research developed is a contemporary case study of a holistic nature, since reality is observed in order to have a total view of the phenomenon under study (emergency system for minimum or minor procedures). The study therefore manages three levels of research: exploratory, descriptive and explanatory. As stated by Law and Kelton (1991), these levels are consistent with the objectives and methodological stages described below:

• *System diagnostics.* This stage begins with the description of the current state of the emergency system. To do this, variables such as demand, administrative and assistance procedures are analyzed, as well as the capabilities of physical and human resources. The collection of information was carried out through interviews with officials, direct observation and data provided by the Coordination of Emergencies and the Internal Information System of the Institution (Servinte). Then, from the analysis and processing of data using descriptive and inferential statistics, a study path was established, composed of workstations characterized according to the operating properties and interrelationships.

• *Work measurement.* This stage is performed through a study of times with a total duration of 168 hours, corresponding to 24 hours/7 days, divided into 4 shifts of 6 hours c/u. The criterion in the time-taking *was next event,* where the stopwatch begins to run at the beginning of the event (arrival of a patient). Thus, 30 previously identified user care data were taken for the care path in minimum or minor procedures in the emergency unit; therefore, no measurements of care times were made to several patients simultaneously.

• *Probabilistic characterization.* It consists of determining the probability function to which the service time of each workstation is adjusted. This is done based on information validated by independence tests and goodness-of-fit tests (Kolmogorov-Smirnov, Anderson Darling and Chi squared).

• *Implementation of the computer model.* At this stage the model designed in FlexSim software is *run,* for which the original plant distribution is replicated, and the input data obtained in the previous stage is entered.

On this basis different scenarios were raised for the model, which involved changing the allocation of physical and human resources. In this way, the alternatives that generated the best results in their processing times were chosen, with high deployment possibilities and higher wait time reduction indexes.

3. Results and discussion

Diagnosis allowed the study of the Emergency System to be limited to a study route composed of care and administrative processes. This route starts with the patient's admissions which, after a short wait, is directed to the office, where his condition is diagnosed. Then after doctor write an order in the nursing room, and this record contains the arrangement of application of treatments according to the pathology of the user, who is referred to the procedure rooms. The audit carried out at the train station verifies the services provided, and during the documentation the supports such as medical records, medical orders and evidence notes are organized. Finally, billing checks users' rights and defines the payer for the service. Leaving certificate is the document indicating the patient's final egress. The above is shown in Figure 1.

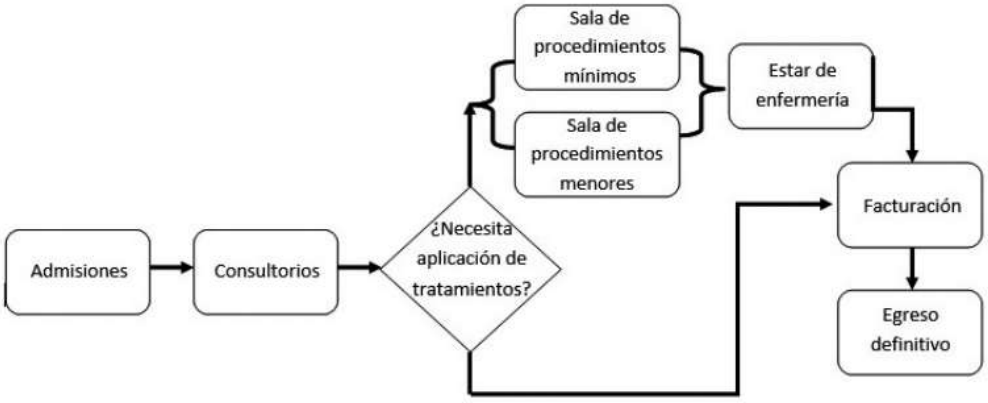


Figure 1. Route of study of patients who require care in minimum or minor's procedure rooms in the emergency system

Source: Authors.

Table 1. Distribution of arrival frequencies of the study route

Pacientes por día	*FO*	*% FA*	*Error relativo*
15.83	11	36.67%	0.49502852
27.66	7	60.00%	0.18287608
39.5	5	76.60%	0.38348613
51.33	5	86.67%	0.14093077
63.16	2	93.33%	0.13800574
75	2	100.00%	1.06059293
			2.40092016
Como 9,48 > 2,4 se aprueba Ho			9.487729037
Error relativo= $\sum \frac{(FT-FO)^2}{FT}$			4

FO: observed frequencies; %FA: percentage of probability accumulated; FT: theoretical frequency according to frequency distribution.

Source: Authors

On the other hand, through the Chi square goodness and adjustment test (Table 1), the demand behavior of services related to minimum and minor procedures was found to be adjusted to an exponential probability distribution, with a reliability level of 95%. According to the above, it can be said that on average the income of 26 patients is recorded daily who require such procedures. These patients account for approximately 25.71% of all patients daily who require any procedure or care in the hospital emergency unit. When comparing workstation capabilities, it follows that even though patients are diagnosed quickly and have the order of workers, a queue is formed, because the rooms do not have the same level of care as the offices.

This same problem occurs in later stages, where there is a deficit that can cause bottlenecks during documentation. The results of the time study were grouped into four shifts, according to the data collection (Figure 2). The shift in which there is the greatest delay in the provision of the service is 7:00 a.m. to 1:00 p.m., due to reasons such as the change of shift of emergency personnel, congestion at the departure of patients who entered in the early morning or the high demand of users towards the middle of the morning. Also, the average standard time of the care process is 4.18 hours.

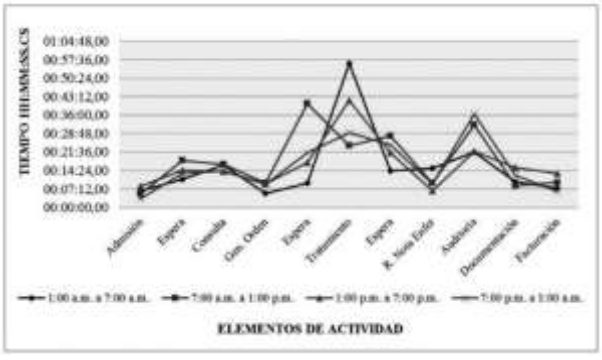


Figure 2. Comparison of standard times by activity elements and shifts

Source: Authors

On the other hand, the application of treatments was identified as a bottleneck in the healthcare part, with an average time of 31 minutes, while the audit is the stage that limits administrative capacity, with a time close to 23 minutes.

In accordance with the information obtained, it is stated that the system data are variables based on observation, the element under study being time; in this case, service times of which are timeouts. Similarly, the descriptive statistic of the data collected during the measurement of the work indicates the stoic or probabilistic nature of the times.

It is concluded, then, that the mean of the data is not a characteristic measure of the process, since there is variability in its behavior, which is possible to represent by means of probability distributions. To verify the usefulness of the time data for each jobstation, independence and uniformity tests were applied using the Promodel StatFit tool.

Goodness-of-readjustment tests were then performed to determine the probability function that best matched the operational intersections service trend (table 2).

During experimentation with the model (Figure 3 and 4), three scenarios were raised in which *Layouts were configured differentiated* by the number of units of human and physical resources of critical work stations (treatment and audit rooms) and by the distribution of plant, according to the institutional design planned for the expansion of emergencies. In this way, the criteria for total time process and capacity utilization of the system were evaluated. They give an overview of the performance that would seal by applying the improvements proposed by the assulation, without losing sight of the real possibilities of implementation of the hospital (table 3).

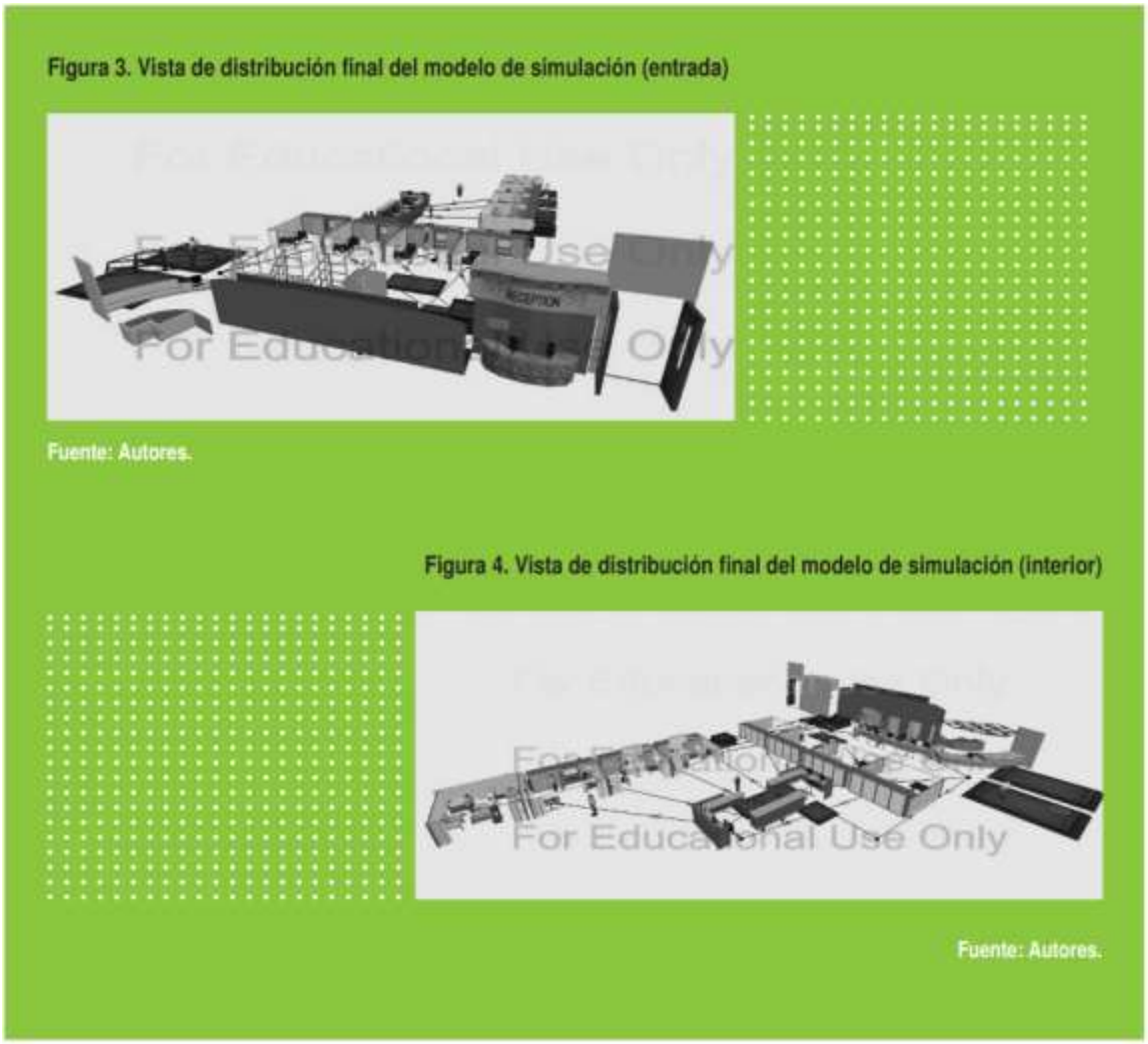
Table 2. Probability distributions of each workstation

ESTACIÓN DE TRABAJO	*DISTRIBUCIÓN DE PROBABILIDAD*	*% AJUSTE*	*PARÁMETROS*		
			MEDIA (μ)	*DESVIACIÓN ESTÁNDAR (σ)*	*TASA DE SERVICIO (λ)*
Admisiones	Lognormal	92.15	5.34	3.33	-
Consulta Médica	Normal	95.11	13.72	5.98	-
Generación de orden Médica	Normal	86.22	7.22	3.27	-
Salas de procedimientos	Exponencial	93.89	35.81	32.22	0.03
Registro nota enfermería	Exponencial	85.50	9.22	7.29	0.11
Auditoría	Lognormal	95.84	24.73	12.25	-
Documentación	Normal	95.29	10.44	3.97	-
Facturación	Lognormal	95.59	8.33	6.57	-

Table 3. Properties of the modeling scenarios

ESTACIONES DE TRABAJO	*RECURSOS (Unid)*						*PORCENTAJE DE UTILIZACIÓN DE LA CAPACIDAD INSTALADA (%)*		
	ESCENARIO 1		*ESCENARIO 2*		*ESCENARIO 3*		*ESCENARIO 1*	*ESCENARIO 2*	*ESCENARIO 3*
	HUMANOS	*FÍSICOS*	*HUMANOS*	*FÍSICOS*	*HUMANOS*	*FÍSICOS*			
Admisiones	2	1	2	1	2	1	16.14%	16.06%	15.01%
Consultorio	4	4	4	4	4	4	34.02%	34.15%	31.13%
Salas de tratamientos	4	3	4	4	4	4	83.13%	82.50%	74.90%
Auditoria	1	1	1	1	2	2	48.34%	47.24%	45.92%
Documentación	1	1	1	1	1	1	20.36%	19.85%	18.83%
Facturación	1	1	1	1	1	1	15.97%	15.82%	14.91%
Tiempo total del proceso (horas)	4.05		3.70		3.40	Disminución de tiempo (min)	7.81	28.75	46.54

Figure 3 and 4. View of final model (Figure 3: Entrance, figure 4 interior)



The percentage of installed capacity utilization does not vary greatly by increasing the number of treatment and auditing results, because user demand is constant, so it is distributed with the new units. The most representative improvement can be seen in the decrease in processing time in each scenario. Specifically, scenario 3 is the most favorable, with 46.54 min from the current system model (table 4).

Table 4. Comparing the properties of the current system model with the proposed model

ESTACIONES DE TRABAJO	RECURSOS (Unid)				% DE UTILIZACIÓN DE	
	ESCENARIO ACTUAL		ESCENARIO PROPUESTO		ESCENARIO 1	ESCENARIO 3
	HUMANOS	FÍSICOS	HUMANOS	FÍSICOS		
Admisiones	2	1	2	1	16.54%	15.01%
Consultorio	4	4	4	4	35.04%	31.13%
Salas de tratamientos	2	2	4	4	86.00%	74.90%
Auditoria	1	1	2	2	49.85%	45.92%
Documentación	1	1	1	1	21.63%	18.83%
Facturación	1	1	1	1	16.30%	14.91%
Tiempo total del proceso (horas)	4.18		3.40	Disminución de tiempo (min)		46.54

The proposed scenario is characterized by having two additional treatment rooms: IRA (treatments) EDA (gastric treatments). Also, an additional audit station is recommended with 3 hours and 24 minutes of processing time. This model represents the shortest waiting time of the patients, under viable implementation conditions to the real system.

4. Conclusions

The main cause of high waiting times by users in the emergency service of the E.S.E. Hospital San Rafael de Tunja is due to the reprocessing of the documentation, that is, the time when the media is organized as stories. Also, definitive exit of the user is only possible when the payer of the service is defined during the verification of insurance. This is usually a long process when the patient has insurance problems. Therefore, the reconfiguration of administrative processes is considered as a possible solution to reduce service time. Through experimentation with the model of simulation of the current emergency system of the E.S.E. Hospital San Rafael de Tunja it was possible to evaluate a configuration corresponding to the investment in physical and human resources that this institution plans to implement in the coming months. The model, as the final product of the study, allowed to know that there is improvement in the functioning of the service with the insertion of the rooms IRA (respiratory treatments) and EDA (gastric treatments), in terms of specialized care of the most common needs.

This, while streamlining care reducing it by 29 minutes of waiting, allows the bottleneck to be traveled to the patient's administrative egress stations. Scenario 3, selected to improve the emergency system, features two additional IRA and EDA treatment rooms, as well as an additional auditing. Scenario 3 combines the increased capacity of scenario 2 treatment application stations with a 50% improvement in audit capacity. As a result, you get a reduction in wait times that require minimum or minor procedures from 1 hour and 47 minutes to 1 hour and 1 minute. This achieves a representative improvement of 18.7% compared to the total time of the process: it goes from 4.18 to 3.40 hours. In the construction of the model, technical restrictions were found to represent the documentation specifications typical of emergency service procedures using the tools of the available *software.* As a result, the results will be subject to validation with actual information that will ensure the reliability of the study. This research can be continued, by adding the other routes present in the emergency room to completely analyze the system using simulation *software* specialized in the area of health that allows to obtain a model closer *t*o reality.

References

Aebersold, M. and Titler, M. G. (2014). A Simulation Model for Improving Learner and Health Outcomes. Nursing Clinics of North America, (3), 431-439.

Arcila, A. M. (2010,). Low hospital capacity. The Colombian. Recovered from http://www.elcolombiano.com/BancoConocimiento/B/baja_capacidad_hospitalaria/baja_capacidad_hospitalaria

Azcárate, C., Eraso, M. L. and Gáfaro, A. (2006). Operational research in Health Sciences: do we recognize these techniques in today's literature? Annals of the Health System of Navarra, 29(3), 387-397.

White, L.E. and Fajardo, I. (2006). Simulation with Promodel production and logistics cases. Bogota: Colombian School of Engineers.

Brailsford, S.C., Harper, P. R. and Sykes, J. (2012). Incorporating human behaviour in simulation models of screening for breast cancer. European Journal of Operational Research, 219(3), 491-507.

Cheang, B., Li, H., Lim, A. y Rodrigues, B. (2003). Nurse rostering problems: a bibliographic survey. *European Journal of Operational Research*, *151*(3), 447-460.

Chemweno, P., Thijs, V., Pintelon, L. y Van Horenbeek, A. (2014). Discrete event simulation case study: diagnostic path for stroke patients in a stroke unit. *Simulation Modelling Practice and Theory*, *48*, 45-57.

Road Prevention Fund Corporation (2012). Accidentality statistics. Recovered dewww.fpv.org.co/investigacion/estadisticas

Gul, M. and Guneri, A.F. (2015). A comprehensive review of emergency department simulation applications for normal and disaster conditions. Computers & Industrial Engineering, 83, 327-344.

Holm, L. B. and Dahl, F.A. (2009). Simulating the effect of physician triage in the emergency department of Akershus University Hospital. In Winter Simulation Conference (pp. 1896-1905).

Winter Simulation Conference. Jun, J. B., Jacobson, S. H. and Swisher, J. R. (1999). Application of discrete-event simulation in health care clinics: a survey. Journal of the Operational Research Society, 50(2), 109-123.

Law, A. M., Kelton, W. D. and Kelton, W. D. (1991). Simulation modeling and analysis (vol. 2). New York:McGraw-Hill.

Lin, C. H., Kao, C. Y. and Huang, C. Y. (2012). Managing emergency department overcrowding via ambulance diversion: A discrete event simulation model. Journal of the Formosan Medical Association, 114,64-71

Lim, M. E., Worster, A., Goeree, R. and Tarride, J. E.(2012). PRM28 physicians as pseudo-agents in a hospital emergency department discrete event simulation. Value in Health, 15(4), A163.

Mielczarek, B. (2014). Simulation modelling for contracting hospital emergency services at the regional level. European Journal of Operational Research, 235(1), 287-299.

Paul, J.A. and Lin, L. (2012). Models for improving patient throughput and waiting at hospital emergency departments. The Journal of Emergency Medicine, 43(6), 1119-1126.

Ramis, F. J., Baesler, F., Berho, E., Neriz, L. and Sepúlveda, J. A. (2008). A simulator to improve waiting times at a medical imaging center. Simulation Conference, 2008. WSC 2008. Winter (pp. 1572-1577).IEEE.

Ruohonen, T., Neittaanmaki, P. and Teittinen, J. (2006). Simulation model for improving the operation of the emergency department of special health care. Simulation Conference, 2006. WSC 06. Proceedings of the Winter (pp. 453-458). IEEE.

Sánchez, C. A. (2012). Executive Management Report 2008-2011 (unpublished report). Tunja: E.S.E. Hospital San Rafael de Tunja.

Shi, J., Peng, Y. and Erdem, E. (2014). Simulation analysis on patient visit efficiency of a typical VA primary care clinic with complex characteristics. Simulation Modelling Practice and Theory, 47, 165-181.