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THE USE OF SIMULATION FOR PROCESS IMPROVEMENT AT AN AMBULATORY SURGERY CENTER

Francisco J. Ramis
Jorge L. Palma
Felipe F. Baesler

Departamento de Ingeniería Industrial
Universidad del Bio-Bio
Casilla 35-C
Concepción, CHILE

ABSTRACT

This work has for objective building a simulation model to evaluate different alternatives of operation of a projected center for ambulatory surgery. For the construction of the model a group of pathologies was selected and real data was taken from statistics of surgeries from a clinical hospital. The information was supplemented by the opinion of medical surgeons and expert anesthesiologists. Similarly, the model was validated by means of the opinion of experts and implemented with the Arena simulation software. Different configurations of operating conditions were studied. It is concluded that the maximum throughput of daily surgeries is achieved, 10 in total, dedicating two beds to preparation of patient, five beds to the transitory hospitalization and using an LPT scheduling rule in the operating rooms, i.e., the heaviest surgeries first.

1 INTRODUCTION

The J. J. Aguirre Hospital of Universidad de Chile it is a major research hospital in Chile, which is projecting a new ambulatory surgery center in its facilities, where patients will enter and leave the center within the same day. The reach and complexity of the ambulatory procedures have increased drastically in the last two decades, thanks to the many technological advances and the economic advantages that it reports. Also, the favorable experience on the part of surgeons and patients plays an important paper in the development of this evolutionary process.

The importance of investigating the topic of the ambulatory surgery comes from the necessity of optimizing the operational conditions of the system, in particular the use of the operating rooms, to reduce costs and to improve the quality of the attention.

The complexity found in these clinical systems, such different patterns of arrival, support staffing, complex patients routing and scheduling, makes simulation an attractive tool to be used as reported by Kalton et al. (1997), Allen et al. (1997) and Isken et. Al (1999),

The main objective of this research was to model the projected facilities in order to study different operating conditions that will maximize the daily throughput of patient. A secondary objective was to learn about the use of the different resources involved in the operation of the ambulatory center.

2 SYSTEM DESCRIPTION

The flow chart of a typical patient's process is represented in Figure 1. A scheduled patient for surgery arrives to the center with a companion and goes to the infirmary for an admission exam. If the nurse detects any problem, the patient is delivered to a doctor for additional exams. Otherwise, the patient goes into the preparation area, where he waits to be called for surgery and his companion goes to the waiting room. While the patient is undertaking surgery, if a major difficulty arises, he may be delivered to traditional surgery facilities. Otherwise, once the surgery it is finished, he goes into the recovery area, and later, to the post operating area. When the patient is ready to leave the center, he meets his companion and exits the clinic. The entire process, from admission to exit is managed by protocols or medical guidelines. Also, it includes postoperative instructions to monitor the patient once he is at home.

From a schematic point of view, the center consists on an infirmary unit, 7 beds for preparation/pot operative, 2 operating rooms, 3 beds for recovery and the corresponding annexed units.

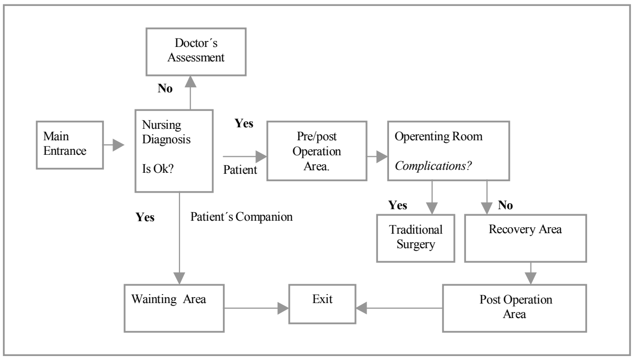

Figure 1: Schematic Patient Process

3 DATA COLLECTION

The data collected over a period of five month by the field engineer were provided to estimate the different distributions used in the computer model. These data mainly consisted of patient arrival times, patients process times in the different areas of the center and the time used by the personnel to prepare the facilities. These data were complemented and validated with surgeons, anesthesiologist and nurses.

A total of 15 different pathologies were selected to be studied, which were considered representatives by the physicians. Examples of the estimated times are given in Table 1. As an example, from this table we can see that a breast operation will have: total operating time Normal with mean 97.7 minutes and standard deviation of 36.5 minutes, admission time uniform with a minimum of 4.5 and maximum of 16.5 minutes, and that the preparation time before the operation, the cleaning time between operation and the recovery time after the operation are distributed according to triangular distributions with the indicated parameters.

Table 1. Estimated Distributions

Variable or Attribute	Phatology	Distribution
TotalTimeOpRoom	Adenoid	TRIA(24.5, 55, 106)
	Tonsil	TRIA(24.5, 55, 106)
	Vesicle	40+ERLA(30.7, 3)
	Varicose	NORM(72.3, 31.9)
	Breast	NORM(97.7, 36.5)
	Meniscus	49+WEIB (51.5, 1.56)
AddmissionTime	All	UNIF(a=4.5, b=16.5)
CleaningTime	All	TRIA(20, 25, 30)
RecoveryTime	All	TRIA(30, 40, 60)
PreparationTime	Adenoid, Tonsil, Vesicle, Varicose	TRIA(20, 25, 30)
	Breast, Meniscus	TRIA(15, 20, 25)

4 MODELLING ASSUMPTIONS

In order to build a model, it was necessary to define entities, attributes of the entities, variables, expressions, static values, resources, groups of resources, drawings, nodes of data and stations. The only entities considered in the model are the patient with their respective companions. Similarly, since the objective of the study is patient throughput, the physicians, nurses and staff are modeled as generic resources without differentiation of their specific role.

Beginning at 7:00 in the morning, patients arrive every 30 minutes to the center, and each arrival consists of batches of two patients with their companion. Human resources used by the model include: 2 medical surgeons, 1 medical anesthesiologist, 1 nurse and 5 assistant nurses.

The times that the nurse uses in the admission exam and the preparation for surgery in the preparation room is the same for all the pathologies are distributed normal with a mean 10 minutes and standard deviation of 5 minutes, and triangular with a minimum of 15 a mode of 20 and a maximum of 25, respectively. The times at the operating rooms, at the recovery and post-operative area depend on the pathology of the patient. The doctors cannot operate any patient after two o'clock in the afternoon.

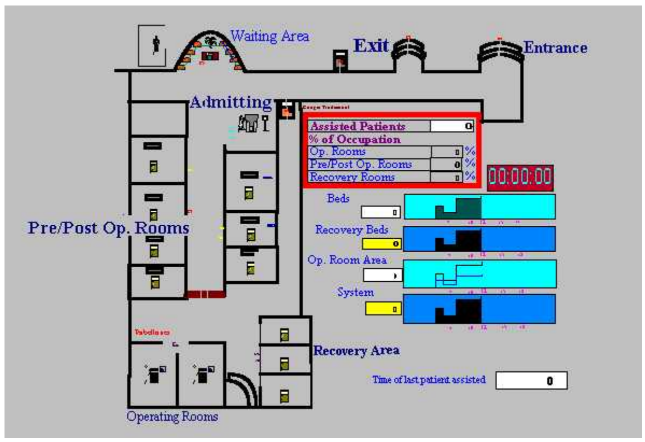

Figure 2: Animation Screen

5 SAMPLE SCREEN

In Figure 2 it is presented a sample of the animation screen of the model which was implemented in Arena. Patient and their companion enter to the system on the upper right and the walk to the admitting area for the admission exam. From this point, if accepted they go to the pre/pos operation room, where they are prepared for surgery and wait until called to the operating room. After surgery, the patient goes into the recovery area on the lower right, and then, to the pre/post operation area, where they wait with their companion until they are discharged from the system.

From the same figure it can be seen that dynamics statistics are reported about: the number of patient assisted, patient in the system, the percentage of occupation of the different rooms, and information about system behavior.

6 MODEL VALIDATION

To validate the system aspects of the model, production runs were made and the results validated with physicians and nurses, and compared to actual data capture at the hospital. Similarly, the animation was of help as a communications and verification device, since it allowed to track patients as they moved through the system. Since nothing unusual was detected, the model was accepted as valid.

7 SCENARIOS

Several improvement alternatives were analyzed in this study. However, just one of them is presented in this paper. This scenario offers the most significant impact in the system's performance. The description of the "as is" situation and the alternative scenario is presented next.

7.1 As Is Scenario

The As Is Scenario considers seven pre/post operation rooms. These rooms are assigned to an arriving patient and used by this patient for preparation before the operation. Then, the patient is sent to the operating room and after the operation is sent back for recovery to the same room he used before for preparation. During the time the patient is in the operating room, no other patient can use the room, neither as preparation or recovery room. This resource has been seized until the patient leaves the facility. Using this criterion the average number of patients that are seen per day is approximately seven. Figure 3 shows the 95% confidence interval for the number of patient seen per day. These results were obtained running 10 replications. The number of replications was defined in terms of a precision level at least of +/- 10% half-width with respect to the mean value. Also, Figure 3 shows an average number o patient seen per day equal to 6.7. The average closing time using this working scheme is presented in the next figure.

Figure 4 shows that the average closing time is around 6:30 pm. The same experiment was conducted increasing the number of patients to eight instead of seven. The results show that the closing time increases in an important percentage.

The next step in the study was to generate an alternative that could offer better results in terms of number of patients seen per day without increasing the closing time. This alternative is presented in the next section.

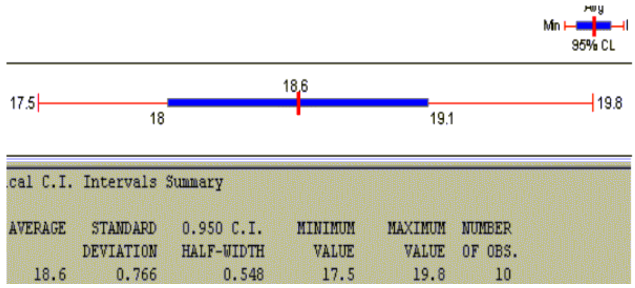

Figure 3: Confidence Interval for Number of Patients As Is Situation

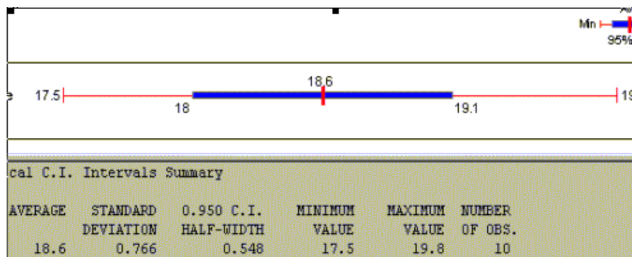

Figure 4: Confidence Interval for Closing Time As Is Situation

7.2 Alternative Scenario

The proposed solution to the problem was to dedicate a number of rooms just for patients' preparation. It was decided that two rooms will be assigned to this activity and the other five will be used as recovery rooms. Using this criterion, the simulation model logic was changed and the new scenario was run. The results show that up to ten patients could be seen per day, with and average of 8.7 patients, using this new method without increasing the closing time. The experiments went even further with eleven patients, but the simulation showed that the closing time could in average increase in forty minutes. For that reason it was recommended that up to ten patients could be scheduled per day. The confidence interval showing these results is presented next.

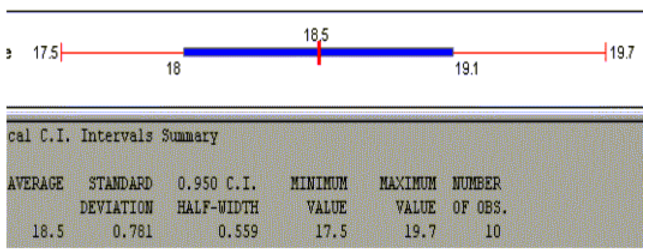

Figure 5: Closing Time Alternative Scenario

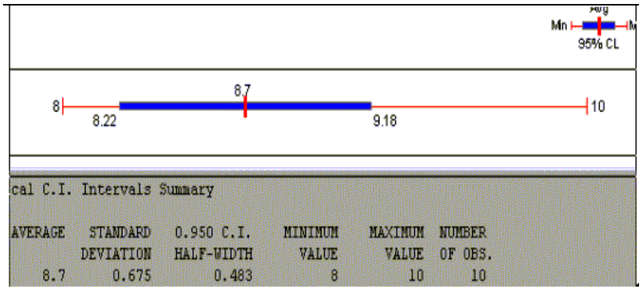

Figure 6: Number of Patients Alternative Scenario

In order to confirm these results from a statistical point of view, a *pair-t test for comparison of means* was conducted. The results obtained from the test show that there is significant difference between the two scenarios in terms of number of patients seen per day. This test shows that the hypothesis that the *number of patients seen per day in both scenarios is not different*, was rejected with a 95% confidence. The difference observed was two patients per day. Figure 7 presents the plot showing the hypothesis rejection.

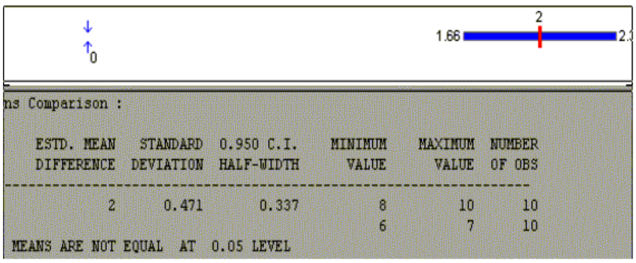

Figure 7: Pair-t test for Comparison of Mean Number of Patients

8 CONCLUSION

With the simulation model implemented in ARENA it was possible to simulate different scenarios for a future ambulatory surgery center.

It is concluded that a maximum throughput of ten daily surgeries is achieved using the alternative scenario, which is dedicating two beds to preparation of patients and five beds for the post operation recovery. It was verified that using a queue discipline of processing the longest surgeries first (LPT scheduling), the utilization of the system is optimized. Although this is done because of medical reasons, that is the longest surgeries probably are more dangerous and the patients require a longer recovery time, it agrees with the theory when we have two parallel servers.

REFERENCES

Allen, P.O., Ballet, D.W. and G. Kimball. 1997. Simulation Provides Surprising Staffing and Operation Improvement at Family Practice Clinics. *HIMSS Proceedings*, 212-227.

Kalton, A.G. Singh, M., R. August, D. A., Parin, C. M. And E.J. Othman. 1997. Using Simulation to Improve the Operational Efficiency of a Multi-Disciplinary Clinic. *Journal of the Society for Health Systems*, 5(3): 43-62.

Isken M.W., T.J. Ward, and T.C. McKee. 1999. Simulating Outpatient Obstetrical Clinics, *Proceedings of the 1999 Winter Simulation Conference*. 1557-1563.

AUTHOR BIOGRAPHIES

FRANCISCO J. RAMIS is an Associate Professor of Industrial Engineering at Universidad del Bio-Bio in Concepción Chile. He received his Ph.D. from Georgia Tech in 1985. His research interests are in Process Innovation, Economic Decision Analysis and Simulation. His e-mail is <framis@ubiobio.cl>.

JORGE L. PALMA is a Field Engineer at Universidad del Bío-Bio. He received his I.E. degree from Universidad del Bio-Bio in 2000. His e-mail is <jorpalma@gohip.com>.

FELIPE F. BAESLER is an Assistant Professor of Industrial Engineering at Universidad del Bio-Bio in Concepcion Chile. He received his Ph.D. from University of Central Florida in 2000. His research interest is in Simulation, Health Systems and Manufacturing Systems. His email is <fbaesler@ubiobio.cl>.