Modeling a Public Hospital Outpatient Clinic in Peru Using Discrete Simulation

Valeria Quevedo
Universidad de Piura, Piura, Peru, valeria.quevedo@udep.pe

Javier Chapilliquén
Universidad de Piura, Piura, Peru, javier.chapilliquen@gmail.com

ABSTRACT

The main objective of this study is to assess the quality of care at a public hospital's outpatient clinic in Piura, Peru, which is one of the most visited in the region. Studies show a high dissatisfaction towards the service offered by public hospitals, mainly due to long waiting times. This hospital is not exempt from that situation. The initiatives implemented by the government to solve these problems were not supplemented with a rigorous analysis to help quantify their impact;therefore, discrete simulation was used. After being validated through historical data and hospital personnel, the model was capable of measuring the outpatient clinic's service level and facilitated the identification of bottlenecks. The most critical medical specialties are Obstetrics, Internal medicine, and Gynecology, which are the most utilized and have the longest queues. The results also help identify the services with a low utilization rate: Admission, Pharmacy, Laboratory, and X-ray. High idle time at the insurance verification process was also found. It seems adequate to integrate the tasks of insurance verification with admission and other services. The model used in this study can be applied to any public hospital in Peru given the fact that their outpatients process is similar.

Keywords: Discrete simulation, simulation modeling, public hospital, outpatient clinic

1. INTRODUCTION

More than a third of the Peruvian population does not have medical insurance. This population uses a government subsidized public medical system. Patients are charged a small amount which covers the hospital's variable costs (Alcalde-Rabanal et al., 2011).

Satisfaction surveys administered by the Peruvian Health Ministry show a very high dissatisfaction towards the service offered by the hospitals, mainly due to the long waiting times (MINSA, www.minsa.gob.pe).

There are many initiatives that have been implemented in order to solve these problems. However, all these initiatives use quality tools based on satisfaction surveys, brainstorming, etc. without using a quantitative tool to quantify the impact of a number of different possible solutions by carrying out "what-if" scenario analysis.

Discrete event simulation has been used for a variety of health care applications (Jahn et.al. 2010). For example, it has been used to improve patient care in emergency departments (Abo-hamad, and Arisha, 2013; Brenner et.al., 2010; Cabrera et. al., 2012; Hoot et.al., 2008; Jamon and Lin, 2012; and Zeng et. al., 2012), to improve bed utilization in hospitals (Holm et.al., 2012), to model outpatient clinics (Al-Araidah et. al., 2012; Villamizar et.al., 2012), to analyze the capacity of the Intensive Care Unit at a hospital (Troy and Rosenberg, 2009), or to improve radiation theraphy planning process (Werker et.al. 2009).

For all the above, discrete simulation with ARENA was used for modeling the outpatient clinic of a public hospital in Piura, at the north of Peru; this hospital is one of the most visited in the region. The simulation tool can help hospital management assess the service level through measuring queue length, waiting times, and utilization

rates at the different health services. Additionally, it will allow trying many operational changes to determine the optimal system configuration.

2. SYSTEM DESCRIPTION

The hospital offers 25 medical specialties. In 2004, 67 957 patients were attended, while in 2010 this number increased to 107 202 outpatients. In six years, the number of attended patients duplicated; 30% of those patients had medical insurance, 60% did not, and the rest were exonerated of the payment due to their economic situation (INEI, 2012).

The outpatient clinic has 4 stages. First is admission. Second is the insurance module just for the patients with insurance, where they will receive the payment waiver. The third stage is the medical assessment itself. Finally, the last stage includes pharmacy, x-ray and laboratory tests. All areas work from 7:00 am to 1.00 pm, except x-ray which works until 4:00 pm.

The process at the outpatient clinic is described as follows:

(1) Patients arrive at the clinic's admission area, where they can schedule a medical appointment for that day. If the patients have insurance, then they need to approach the insurance module; here, the insurance staff verifies if the insurance will cover the medical expenses, otherwise they need to pay for them.

(2) Patients go to the waiting room to be called by the specialist for their assessment. The hospital offers 25 specialties, where the most visited are: obstetrics, gynecology, pediatrics, ophthalmology, gastroenterology, cardiology, echography, internal medicine, neurology, odontology, otorhinolaryngology, rheumatology, orthopedics, and urology.

(3) After the assessment, patients will go to pharmacy, x-ray diagnostics, and laboratory, according to doctor's instructions. Laboratory is the only one that has two subsystems: reception and lab test. Before these services, patients with insurance need to go to the insurance module once again to get a payment waiver for those services.

Throughout the process, patients' experience long waiting times and queues.

3. SIMULATION MODEL

An extended survey was carried out in order to collect data on the arrival process, and the service times at the different stages. To represent the real process, process observation, database retrieval, interviews to doctors, nurses, and hospital employees, and time studies were conducted.

The service process was modeled by a discrete event simulation system, using Arena software (Kelton et. al., 2009, and Law & Kelton, 2007)

3.1 INPUT ANALYSIS

Probability distribution was used to describe the time between arrivals and the services time, Input Analyzer from Arena was used:

Time between patients' arrivals was described by an exponential distribution. The receptionist's service time, at the admission area, varies according to the type of patient (with insurance or without insurance). An Erlang distribution describes the service time of the receptionist for patients with insurance; while a lognormal distribution for patients without insurance service time is observed.

For the 15 medical specialties chosen to be modeled, a triangular distribution was used for the service time. One doctor per specialty is available.

For the pharmacy, x-ray, and lab tests time services, triangular distribution was used. The lab receptionist service time follows a normal distribution. An external arrival to these services coming from hospitalization and

emergency room was also considered in the model. The time between external arrivals in the pharmacy was described as a weibull distribution, while x-ray and laboratory external arrivals were described as uniform distributions.

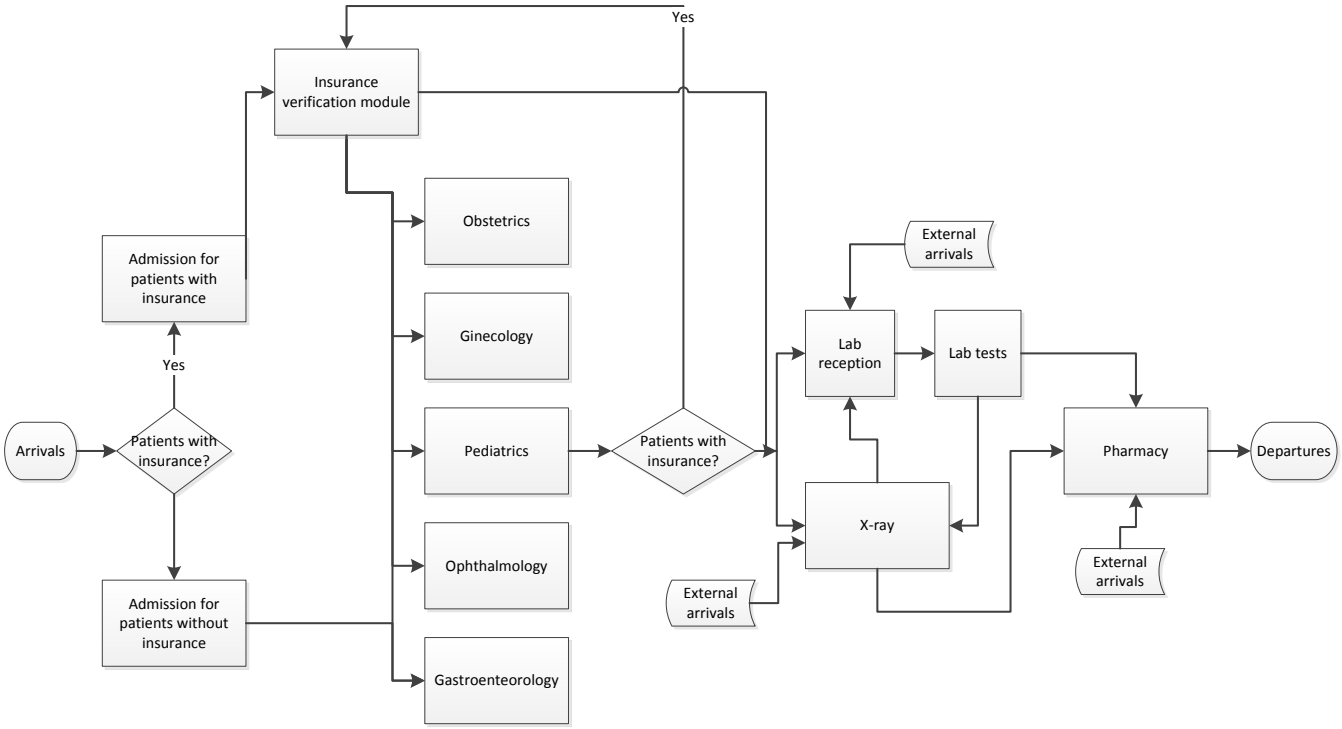

Figure 1: Process Flow of the outpatients clinic

3.2 Model

The conceptual model is represented in figure 1. Based on those processes, resource availability, and the results from the input analysis, a simulation model was developed using ARENA 10.

First, a small portion of the model was built, and after its functionality was established, more areas and complexity were added. Once the model was complete, its functionality was verified. After checking if the model does what is intended to, the model was also validated. At this stage, the amount of daily average patients treated was compared to the historical data. Meanwhile, other service indicators such as average time spent at the different queues and total average waiting time in the hospital were validated by the hospital personnel working in those services. Subsequently, it was concluded that the model is a credible representation of the real system.

4. RESULTS

One of the objectives of this study was to measure the service level of the different medical services offered to the outpatients. To do that, some indicators, approved by the hospital management, needed to be defined. One of them is the total average waiting time in the system, which was 83.27 minutes for patients with insurance and 77.84 minutes for the patients without insurance. Even though this seems like a short waiting period, it is only an average. The maximum total waiting time for a patient reached 326.67 minutes or 5.4 hours. Other indicators were: average waiting time, queue length, and utilization rate at every stage of the process.

In admission, the average waiting time was not as high as expected, and there is almost no difference between the waiting time for patients with insurance and patients without insurance (28.8 and 28.75 minutes respectively); nonetheless, there is a slight difference when it comes to the average maximum waiting time reached (135, and 148 minutes respectively). However, there is a big difference between the number of patients with insurance in queue (3.85) and the ones without insurance (9.03), getting an average maximum queue length of 27 and 55 patients respectively. Even though the average is not that high, admission gets very congested during the first two hours, reaching 40 patients in queue on average (for patients without insurance). This is because the receptionist starts attending patients at point 120 in time (7 am), and then it dramatically dropped to less than five (in less than an hour). See figure 2. The utilization rate was also analyzed. On average, the receptionist is busy 57.11% of the time.

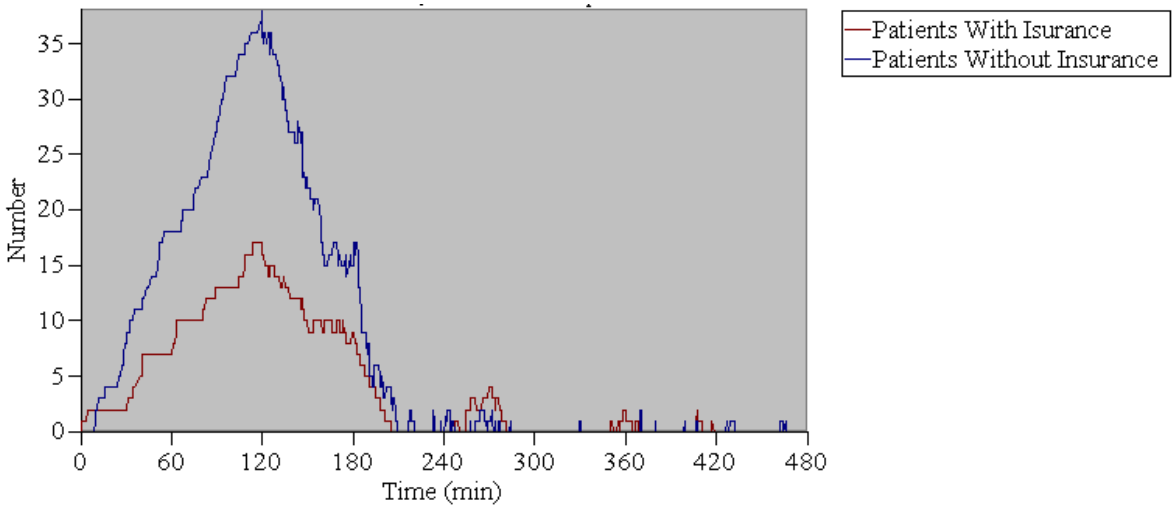

Figure 2. Number of Patients in queue at the admission for patients without insurance (at the top) and with insurance (at the bottom)

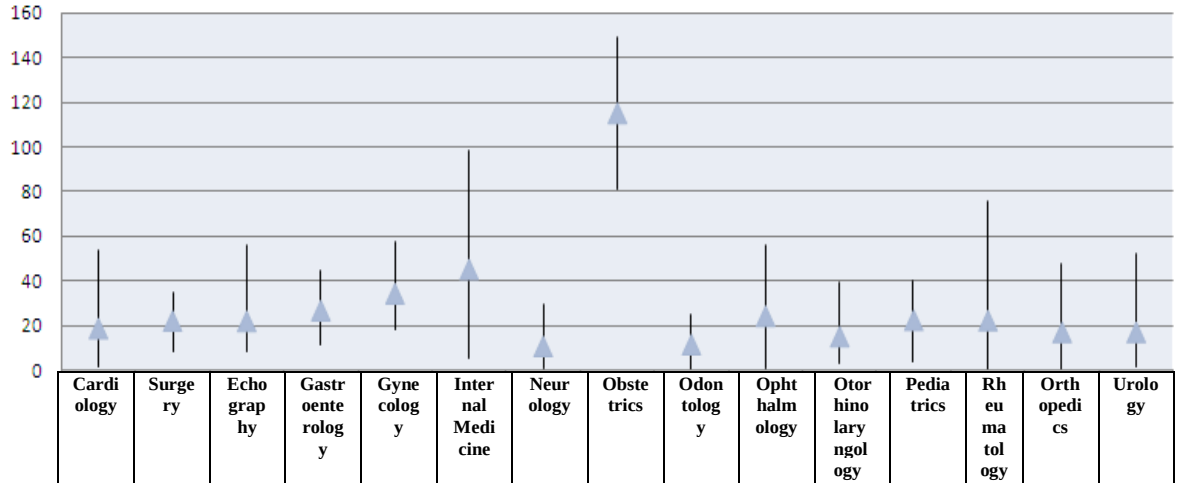

Figure 3: Waiting time in queue for each specialty at the outpatient clinic

Each of the 15 specialties was analyzed. As figure 3 shows, Obstetrics was the specialty with the highest average waiting time, more than 2 hours, reaching a minimum average time of 1hour 20 minutes, and a maximum of 2 hours 28 minutes. See figure 3.

The average patient waiting time at the Internal Medicine specialty is not that high, about 40 minutes, but it has the highest range (maximum value – minimum value) which is approximately 100 minutes. For the rest of the specialties, the average waiting time is between 20 and 40 minutes.

Another indicator analyzed was the average number of patients in queue. The results show that on average, on a standard day, Gynecology gets up to 10 patients in queue and after approximately three hours this number plummets to 0. Obstetrics quickly reaches up to 13 patients in queue, then it drops to 6 patients, then this number starts steady. See figure 4.

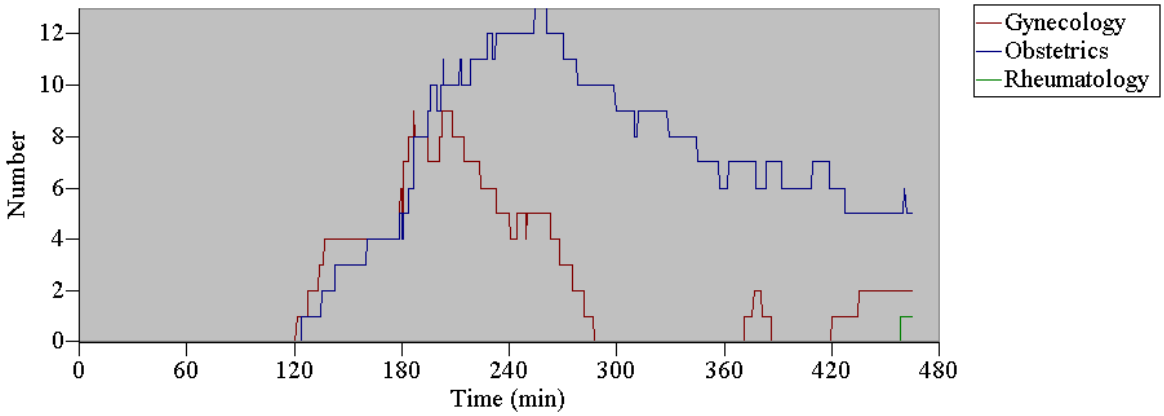

Figure 4: Number of patients in queue for Obstetrics (the one at the top), Gynecology (at the bottom)

Analysis of the utilization percentage indicates that Obstetrics has a high utilization rate (on average it is 100%). Gynecology and Internal medicine have the second highest utilization rate, 72.9 and 73.68 on average respectively. Results show that the insurance module is fully occupied for just 30 minutes during the day, when the average queue is 10 patients.

When it comes to pharmacy, the average utilization rate is 65.05%, with an average queue length of maximum 6 patients during the first 60 minutes, and an average length of between 1 and 2 patients after that.

In the laboratory, the average utilization rate for its receptionist is 47.6%, while for the lab test is 32.82%. Length queue of the receptionist is very high during the first 2 hours, and then peaks at 6 patients for short times. Apparently, there is no problem in the lab test, given that the queue reaches a maximum of 1 patient.

Finally, x-ray service shows an average utilization rate of 54.85%, getting up to 5 patients during the first 2 hours of service, and then it dropped to 0, 1 or 3.

5. WHAT-IF SCENARIOS

Given the results, one obstetrician was added as a resource in the model. The average patient length gets up to 6, instead to 13, and after an hour it drops to 3 patients, and then keeps decreasing. The rest of the indicators are shown in the following table:

Table 1: Comparison between current and proposed scenario

Number of obstetricians	Average waiting time in queue (minutes)	Average length queue	Utilization rate
1	148.93	6.48	100%
2	41.66	1.09	69.35%

Another possible scenario analyzed is adding another receptionist for patients without insurance. Here are the results:

Table 2: Comparison between current and proposed scenario for 2 receptionists at admission for patients without insurance

Number of receptionist for patients without insurance at the admission area	Average waiting time in queue (minutes)	Average length queue	Utilization rate
1	28.75	9.03	57.11%
2	20.17	3.14	29.03%

Results of the current situation show that the lab receptionist is a bottleneck; long queues are formed. As it was expected, by adding another lab receptionist, the bottleneck now is the subsequent process: lab test. By adding this second receptionist, the average waiting time does not reduced much.

6. CONCLUSIONS AND DISCUSSION

Discrete simulation is a tool for analyzing complex systems where there is a number of random variables involved. It can provide more understanding of the system, and hence take better decisions. This tool is perfectly applicable to the health sector. This study shows the use of this tool to a public hospital in Peru, showing good results.

In this study, a simulation model of a public hospital´s outpatient clinic was presented. The simulation results were compared with the observed results at the outpatient clinic with minimal differences, which validates the model used for the present study. The results give a better understanding of the current process at the clinic. The first stage of the study helps the hospital management to identify objectives for the service level indicators (utilization rate, queue length, waiting time). Results show that the most critical medical specialties are Obstetrics, Internal medicine, and Gynecology, which are the most utilized and have the longest patient queues. There is a need for increasing resources in these areas, especially at Obstetrics due to a high utilization rate: 100%.

The model also helped identify a high idle time at the insurance module. Also, a low utilization rate in pharmacy, lab, x-ray and admission area was found. Therefore, it seems adequate to integrate the insurance module tasks with the admission and the other services.

Some what-if scenario analysis was also performed. This analysis permits quantify the impact of possible solutions. By adding a second obstetrician, the service level improves drastically: the average waiting time for a patient can be reduced by 72% (from an average of 148.93 to 41.66 minutes in queue). It also shows that adding more staff level at admission or reception lab does not improve the service level at the outpatient clinic. More analysis to try different resource allocation and system configuration will be done in subsequently studies, which needs to be closely studied with the hospital management.

Finally, it can be said that the model used in this study can keep being used for continuous improvement at the hospital, and also, given the fact that the outpatient process is similar to any public hospital in Peru, the model with slight modifications can be used in all of them.

REFERENCES

Abo-hamad W, and Arisha A. (2013). *"Simulation-based framework to improve patient experience in an emergency department"*. European Journal of Operations Research. Vol. 224. Pp 154-166.

Al-Araidah O, Boran A, and Wahsheh A. (2012). *"Reducing Health Care Delivery at Outpatients Clinics using Discrete Event Simulation" Int J Simul Model 11*, vol.4 pp175-185.

Alcalde-Rabanal JE, Lazo-González O, Nigenda G. (2011). *"Sistema de salud en el Perú", Salud Publica de Mexico*, vol. 53, num. 2, pp. s243-s254.

Brenner S, Zeng Z, Liu Y, Wang J, Li J, and Howard P. (2010). "*Modeling and Analysis of the Emergency Department at University of Kentucky Chandler Hospital Using Simulations"*. Journal of emergency nursing. Vol 36, issue 4, pp 303-310.

Cabrera E, Taboada M, Iglesias M, Epelde F, and Luque E. (2012). "Simulation Optimization for Healthcare Emergency Departements". Proceedings of the International Conference on Computational Science, ICCS 2012. Vol 9, pp 1464-1473.

Holm L, Luras H, and Dahl F. (2012) *"Improving hospital bed utilisation through simulation and optimization with application to a 40% increase in patient volume in a Norwegian general hospital".* International journal of medical informatics. Vol. 82, issue 2, pp 80-89.

Hoot N, LeBlanc L, Jones I, Levin S, Zhou C, and Gadd C. (2008). "*Forecasting Emergnecy Department Crowding: A Discrete Event Simulation".* Annals of Emergency Medicine. Vol. 52, issue 2, pp. 116-125.

Instituto Nacional de Estadística e Informática, INEI. (2012). "*Condiciones de vida en el Perú"*, julio-agosto-setiembre 2012, http://www.inei.gob.pe.

Jahn B, Theurl E, Siebert U, Pfeiffer K. (2010). "T*utorial in Medical Decision Modeling Incorporating Waiting Lines and Queues Using Discrete Event Simulation".* Value in Health. Vol. 13. Num 4. Pp 501-506.

Jamon P, and Lin L. (2012). *"Models for improving patient throughput and waiting at hospital emergency departments"*. Journal of Emergency Medicine. Vol. 43, issue 6, Pp-1119-11268.

Kelton W, Sadowski R, Zupick N. *Simulation with Arena*, 5th edition New York. McGraw-Hill; 2009 Science/Engineering/Math.

Law AM, Kelton D. *Simulation modeling and analysis*. 4th edn New York: McGraw-Hill; 2007.

Ministerio de la Salud, MINSA. Observatorio de calidad en la salud reports, http:// www.minsa.gob.pe/dgsp, 11/8/2013 (date accessed)

Troy P, and Rosenberg L. (2009). "*Using simulation to determine the need for ICU beds for surgery patients".* Surgery. Vol 146, num 4, pp608-620.

Villamizar JR, Coelli FC, Pereira W, Almeida R. (2011) *"Discrete-event computer simulation methods in the optimisation of a physiotherapy clinic"*. Physiotherapy. Vol 97. Pp. 71-77.

Werker G, Sauré A, French J, Shechter S. (2009). "*The use of discrete-event simulation modeling to improve radiation therapy planning process".* Radiotherapy and Oncology vol 92, pp 76-82.

Zeng Z, Ma X, Hu Y, Li J, Bryant D. (2012). *"A simulation study to improve quality of care in the emergency department of a community hospital"*. *The Journal of nursing.* Vol. 38, issue 4, pp 322-328.

Authorization and Disclaimer

Authors authorize LACCEI to publish the paper in the conference proceedings. Neither LACCEI nor the editors are responsible either for the content or for the implications of what is expressed in the paper.