Discrete Event Simulation-Based Approach for Hospital Services Development and Monitoring

Duccio Cocchi[1], Roberto Miniati[1], Francesco Frosini[1], Paolo Avezzano[1], Ernesto Iadanza[1], Matteo Curiardi[3], and Andrea Belardinelli[2]

[1] University of Florence, Department of Information Engineering, Florence, Italy
[2] Careggi Teaching Hospital, Head Department, Florence, Italy
[3] Metis Consortium, Careggi office, Pisa, Italy

Abstract— **Discrete event simulation techniques have been already used for many years and in several areas to improve manufacturing workflows and services provided to customers. Despite being born in the industrial environment, over the years the use of this instrument has brought great advantages in healthcare as well, by improving the efficiency of the organization in a quick and economically sustainable way.**

The goal of this work is to present a simulation model which is able to correctly optimize the operation of the laboratory analysis in hospitals, in order to quickly assess the effects of the changes connected with different scenarios proposed. The new system for on-line reservation will also be assessed as well as the effects of its introduction –by following up the results of previous studies. The main performance indicators analyzed are the 'waiting times of patients for the acceptance', especially as regards patients without a reservation, 'the number of patients in the queue' and the 'utilization rate of resources.'

The simulation model has been proved to be an excellent tool to support organizational decisions that allowed to identify that an earlier opening time of the front desks will be the best way to reduce waiting times for patients. Furthermore the model is able to predict the number of patients in the queue beyond which the waiting time rises above a critical value. The on-line reservation system greatly improved the 'waiting times of patients' with reservation but the 'waiting times' for direct-access (not booked) ordinary and urgent patients still remain high.

Keywords— **Discrete Event Simulation, Arena models healthcare.**

I. INTRODUCTION

A discrete event simulation model is able to characterize processes, even complex, where the factors that govern the process (defined elements or entities) are interdependent with one another and work together to achieve a common goal. The characterization of the system allows, therefore, a detailed analysis of the performance of the overall system in terms of speed, capacity and calculation [1].

The use of simulation in medical processes allowed a correct use of the available resources and optimized the waiting time, in such a way as to reduce, as far as possible, the length of the queues [2-7]. The main performance indicators analyzed by the models are the 'waiting times' for receiving a service, how many patients use the service and how long the patient takes to complete the exam. This allows to simulate reality for long periods, economically and on the process view by identifying bottlenecks in order to allocate resources in the best way. In the market there are different simulation software. This project will be using the product Arena® Rockwell Automation.

The creation of the model has seen the need to identify the main stages of the process studied, and the process flow. The main problem encountered when trying to implement a model of this kind is that it requires an accurate knowledge not only of the various steps of the process but also of the times associated with them. Therefore, if these were not obtained by the hospital DB, they will be calculated on the field.

If each block represents a specific phase of the process, each block can be associated with a time of service and a number of entities in the queue to the service. Using the historical data we can create a set of weighted characteristic.

In a previous study [8] the authors describe the application of a Lean Six Sigma approach to analyze the medical laboratory services at the Florence Teaching Hospital, defining the main Key Performance Indicators (KPIs) and proving that this methodology is a proper tool for process optimization. The authors also suggested solutions for reducing patients waiting times, especially using a booking system. In continuity with that work this paper evaluated the outcomes of those solutions through the measurement of the same KPIs.

In addition to that, the purposes discussed in this paper concern the way to the access of analysis laboratory (e.g. sampling, sample delivery, results performance report or similar). They are as follows:

- On-line booking (recently enabled the ability to book the service and show up at the appointed time without waiting for now lots available for booking are still limited but is expected to gradually increase them)
- On-site booking

The original version of this chapter was inadvertently published with an incorrect chapter pagination 961–964 and DOI 10.1007/978-3-319-32703-7_187. The page range and the DOI has been re-assigned. The correct page range is 967–970 and the DOI is 10.1007/978-3-319-32703-7_188. The erratum to this chapter is available at DOI: 10.1007/978-3-319-32703-7_260

E. Kyriacou et al. (eds.), *XIV Mediterranean Conference on Medical and Biological Engineering and Computing 2016*,
IFMBE Proceedings 57,
DOI: 10.1007/978-3-319-32703-7_188

Considering that the distribution of users varies widely in relation the daytime, the weekday and the number of accesses to the structure, the aim of the work will be to simulate the activities of the center by evaluating the impact of some organizational changes (e.g. reduced booked for certain hours and days, dedicated counters, etc.) with the aim of identifying the organizational solutions for optimizing the quality of the service, patients and workers.

This would support the hospital decision makers by creating different organizational scenarios, evaluating its behavior and comparing its performance in relation to specific needs and context. The main stages in which the project will be divided are:

• Analysis of the specific hospital scenarios;
• Implementation of the simulation model with Arena software;
• Experimental validation of the model;

II. METHODS

A. Paper Goals

The Florence Teaching Hospital is one of the biggest hospital in central Italy with a yearly laboratory workload of over 100,000 tests and the delivery of 80,000 blood test reports. The main purpose of the project was to evaluate the results of a new process organization presented in [8] through the development of a simulation model of the laboratory services.

B. Process Analysis

The functional flow of the process includes a first step of booking (reservation box), a second step of reception (check in - check out), and a third step of pick (Lab. performance) [8]. Important for the evaluation of the waiting times for acceptance ('waiting time') and for picking up the test results ('clinical time' - 'operational time'). The type of services provided include results' pick up (ordinary and urgent) for patients presenting without reservation and for patients booking online (takes precedence over the other), the delivery of biological samples with or without reservation (booking always takes precedence on direct access) and other services, each with its own particular "schedule" of arrival. The doors open at 6:30 and patients can get the ticket in 1 of the 8 front desks since 7:15 am. Patients are called according to the ticket priority (for those without reservations) or to the time of booking. Upon completion of the check-in patients pay the amount to a different station (still within the same room) and the receipts are presented before and in order to access to available boxes for clinical activity.

C. Model Building

The model was built by accurately studying the booking, check-in, paying and results pick up adopted by the medical laboratory services of the Careggi Teaching Hospital. According to the scientific literature [9], to properly simulate the operation of the process is necessary to know the number of patients arriving to the front desks, the average time of service for check-in and test pick up. Also, to validate the correct operation of the model, we need the historical data related to waiting times of patients.

These data were obtained through direct observation, interviews with staff and accessing hospital databases.

D. Measurement of the Indicators

The specific indicators for the analysis of the proposed simulation scenarios are:

• Wait for the acceptance of direct check-in, ordinary and urgent (WTA);
• Total number of patients queuing for acceptance (NQP);
• Number of patients in the queue for acceptance based on the type of service requested and the chosen mode of reservation (NQP);
• Total number of patients accepted (TPA);
• Rate of resource utilization (front desks & results delivery boxes), very useful for those scenarios where the resources' allocation planning is based on the daytimes, weekdays or performance types.

The KPIs are analyzed according to the day of the week because it was observed in the historical data a strong relation with the number of patients at the input.

Figure 1 shows how the model reports the key points in the study, in the box 0 is indicated the time, in order to assess the performance of the indicators during the workday. The wait time for acceptance is indicated by the box number 1, the total number of patients in the queue for acceptance is shown in the box number 2, the number of patients in the queue for acceptance based on the type of application required and the booking arrangements are outlined in Box 3 and finally the total number of patients admitted is located in Box 4. These are the patients waiting the clinical performance in the calling box.

E. Simulation Scenarios

The scenarios assessed by the model involved:

• The optimization of use of the front desks with the purpose to reduce the waiting times for acceptance.
• Selecting the patient's priority according to the waiting time and the number of patients in queue.

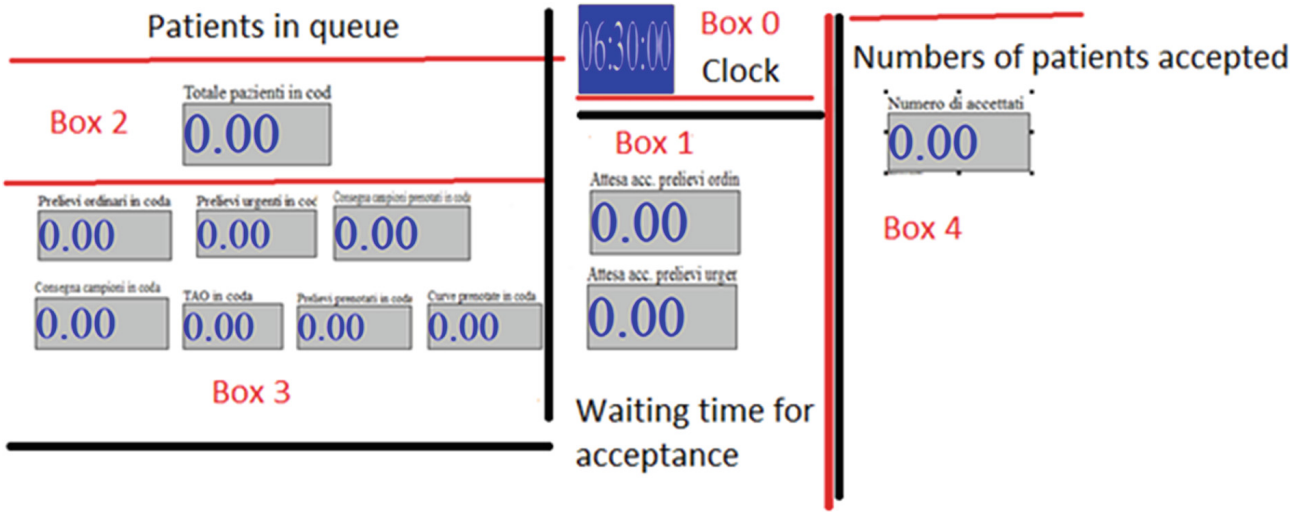

Fig. 1 Section of the model used to monitor the key indicators

• The identification of the number of patients in the queue which stay within a waiting time threshold previously set.

III. Results and Discussion

From January 2016 it was set up a reservation system for the whole blood test system. The number of reservations available was increased steadily to 20% of the total in June. The waiting time for the patients check-ins with reservation is very low (less than 1 minute in average), but the average waiting time for ordinary blood tests exceeds 90 minutes and the urgent ones exceeds 40 minutes. Because the study shows that the highly number of accesses of patients without reservation is detected in the first days of the week and after the holidays (Fig. 2), it was decided a change in the booking system, to reduce the work-load in these days.

Table 1 Model validation

Primary indicators	Model results	Historical data
Patients accepted	512	491
Ordinary blood test check-in	90,9 minutes	91,9 minutes
Urgent blood test check-in	38,3 minutes	38,3 minutes
Delivery samples check-in	18,5 minutes	19,2 minutes

The model used to analyze the scenarios proposed has been validated by comparing the waiting time for acceptance and the number of patients admitted between the model and the historical data. The average time to process the practice of acceptance has been set as the one detected by direct observation at the analysis laboratory and historical data. In Table 1 is reported the comparison of data relating to Monday, traditionally the day of the week with the highest number of accesses. The percentage difference is less than 5% in the worst case.

The first simulated scenario is to test the results of these organizational changes to the process:

• Establish specific pathways for patients urgent, ordinary and booked;
• Increase the resources available from 8 to 9 front desks for acceptance;
• Vary the opening hours of the front desks passing from 7:15 to 7:00;

Table 2 Comparison of wait times for acceptance.

Type of service	Current situation	Anticipated opening
Ordinary blood test check-in	92,6 minutes	76,7 minutes
Urgent blood test check-in	41,5 minutes	26,9 minutes
Delivery samples check-in	18 minutes	10,3 minutes
Payment	7 minutes	5,6 minutes
Blood test	19,6 minutes	19 minutes

As shown in Table 2 the anticipated opening of the front desks can achieve a significant improvement in waiting times of patients without the need to increase the available resources.

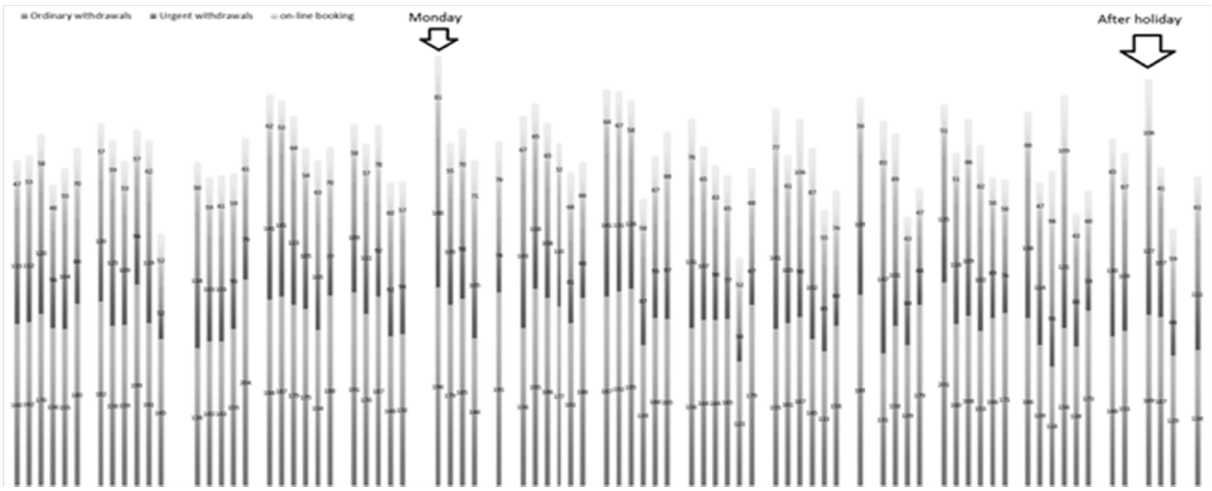

Fig. 2 Number of daily accesses

The second scenario analyzed through the simulation the priorities of patients according to the number of patients in queue or based on the waiting time of the patients in the queue. Despite the various organizational changes tested the results of simulations lead to state that this type of solution is not adequate to lead to an improvement of the sys-tem performances.

The third scenario analyzed serves to find the max number of patients waiting within a time threshold set previously. This in order to better manage the available resources according to demand. The simulation suggests that it is possible to identify this max number of patients in queue beyond which the wait exceeds a value established in advance, and then letting an alert for temporary opening of a further front desk in case of need.

IV. Conclusions

The results showed how the use of simulation models can lead to an improved organization of the process with benefits for patients and for the operators themselves. I was also demonstrated how this technique can be a valuable tool for the management of hospital services. The discrete event simulation was effective for improving service quality (e.g. Waiting times reduction), sizing the service with proper and adequate workload and for avoiding bottlenecks.

Regarding the service monitoring of the new organization further developments will include the development of smart reporting for periodically estimating the performance variance with the target values.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

1. Sharma P. (2015) Discrete-Event Simulation. International journal of scientific & technology research volume 4, issue 04, april 2015 issn 2277-8616.
2. Jun J. et al. (1999) Application of discrete-event simulation in healthcare clinics: A survey. Journal of the Operational Research Society.
3. Günal M. et al. (2010) Discrete-event simulation for performance modelling in health care: a review of the literature. Journal of Simulation.
4. Thorwarth M. et al. (2009) Application of Discrete-Event Simulation in Health Care: a Review. Dublin Institute of Technology.
5. Cayirli T. et al. (2003) Outpatient scheduling in health care: a review of literature. Production and Operations Management, 12, 519–549.
6. Fone D. et al. (2003) Systematic review of the use and value of computer simulation modelling in population health and health care delivery. Journal of Public Health, 25, 325.
7. Eldabi T. et al. (2007) Simulation modelling in healthcare: reviewing legacies and investigating futures. Journal of the Operational Research Society, 58, 262-270.
8. Miniati R. et al. (2015) Experience of Lean Six Sigma Quality Approach to Hospital Laboratory Services. IFMBE Proceedings Vol. 45.
9. Karnon J. et al. (2012) Modeling Using Discrete Event Simulation. A Report of the ISPOR-SMDM Modeling Good Research Practices Task Force–4. Med Decis Making September–October 2012 vol. 32 no. 5 701-711.

Author: Roberto Miniati
Institute: Department of Information Engineering, (University of Florence)
Street: Via di Santa Marta 3, 50139
City: Florence
Country: Italy
Email: roberto.miniati@unifi.it