Discrete simulation applied to the improvement of patient flows in hospital institutions

Simulación discreta aplicada a la mejora de los flujos de pacientes en instituciones hospitalarias

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ABSTRACT

Hospital services need to develop management based on the phenomena that make up their environment and project themselves to the needs of their patients. In this sense, managing patient flows allows for optimizing hospital resources and increasing patient safety during the patient's journey. The objective of this article is to improve the management of patient flows in hospital institutions through the application of discrete simulation. The proposed methodology integrates the processes of planning, execution, verification, and action. Among the tools used are the process descriptions, Diagnosis Related Groups definition, and discrete simulation. Additionally, tools from manufacturing systems are adapted to hospital management in the solutions proposal. Among the main results, patient flow management is improved in the Urology service of the Faustino Pérez Hernández Clinical and Surgical Teaching Hospital in Matanzas province, Cuba. The process is described, and a simulation model is built to identify insufficiencies and check the feasibility of improvements. Discrete simulation is an operations management tool that facilitates managing and improving patient flows in hospital institutions.

Keywords: Discrete simulation, patient flow, hospital institutions.

RESUMEN

Los servicios hospitalarios necesitan desarrollar una gestión basada en los fenómenos que conforman su entorno y proyectarse a las necesidades de sus pacientes. En este sentido la gestión de los flujos de pacientes permite optimizar los recursos hospitalarios y elevar la seguridad del paciente durante su trayectoria. El objetivo del presente artículo es mejorar la gestión de flujos de pacientes en instituciones hospitalarias mediante la aplicación de la simulación discreta. La metodología propuesta integra los procesos de planeación, ejecución, verificación y actuación, entre las herramientas se utiliza la descripción de procesos, definición de Grupos Relacionados con el Diagnóstico y la simulación discreta, además

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en la propuesta de soluciones se adaptan herramientas propias de sistemas de manufactura a la gestión hospitalaria. Entre los principales resultados se mejora la gestión de flujos de pacientes en el servicio de Urología en el Hospital Clínico Quirúrgico Docente Faustino Pérez Hernández de la provincia de Matanzas, Cuba, se describe el proceso y se construye un modelo de simulación que permite identificar insuficiencias y comprobar la factibilidad de las mejoras en el proceso. La simulación discreta constituye una herramienta de la administración de operaciones que facilita la gestión y mejora de los flujos de pacientes en instituciones hospitalarias.

Palabras clave: Simulación discreta, flujo de pacientes, instituciones hospitalarias.

INTRODUCTION

Health, considered a social product, requires an organized response that allows obtaining synergy in the integrality of actions and interventions to achieve the well-being of the population [1]. Ensuring equity in this area requires systems and services to be accessible and allocated according to people's needs, and there must be a sustainable model of care to ensure this [2].

Health services can be classified into Primary Health Care (PHC) services; they possess great relevance as they constitute the first effort to meet the most immediate needs of the population [3]; Secondary Health Care Services (SHCS), services related to care in internal medicine, pediatrics, gynecology-obstetrics, general surgery and psychiatry are provided [4] and Tertiary Health Services (THS): reserved for the care of less relevant problems, it refers to the care of complex pathologies that require specialized and high technology procedures [5].

Within the health services are the hospital institutions that have their particularities; among them, they have specialized services, advanced or state-of-the-art technology, they provide hotel services; in this case, it is taken into account that the patient is the client and the same does not decide what to buy or what service to consume, the doctor is the one who decides this; services are provided 365 days/year 24 hours/day, so they constitute or become costly centers.

Hospital management integrates the processes of planning, execution, verification, and performance [6]. Its objectives are to evaluate the process of nature and the services provided by the health institution, to assess the quality and quantify the resources used, the compliance with standards and regulations, the correct execution of protocols, and to inspect and control the measurable methods that are executed in dependence on the users [7].

In these institutions, patients circulate through different departments, floors, premises, and buildings to be attended by specialists, technicians, nurses, or other health professionals [8]. This patients movement, with a focus on its trajectory, is considered patient flow [9]-[12]. Several tools are aimed at managing and improving patient flows, including Lean methodology or Lean healthcare [13], [14], linear programming [15], queuing theory [16], resource allocation, capacity planning [9], and process simulation [17].

The simulation of discrete events within the simulation of processes contributes to identifying obstacles that are manifested daily in the patient's transit through the institution to reduce waiting time and long days of stay of patients from having a preview of how the process is. The objective of this article is to improve the management of patient flows in hospital institutions through the application of discrete simulation.

LITERATURE REVIEW

Hospital management is the appropriate use of professionals, nurses, technicians, and administrative staff to provide quality care to patients. According to the available scientific information, they express their knowledge to modify the ailment's clinical course (effectiveness) optimistically, and that considers the minimum problems and price for the beneficiary and for humanity itself (efficiency) [18]; it also takes into account being a generous system with the environment because the health industry is the fourth largest generator of carbon emissions worldwide, leading to the need for environmentally friendly practices by a multidisciplinary team [19].

Each nation has designed and structured its health system according to its culture, geographical, and social conditions. The management procedures in hospital institutions are accordingly. An analysis of 28 hospital management procedures is presented; their selection is conditioned by the prevalence of administrative management over clinical management. They contemplate the management of patient flows explicitly or implicitly as an element contributing to the improvement of hospital performance and those procedures that group two or more elements in their conception. The selected models identify the main elements of hospital service management models. For the analysis, a binary matrix showing the tools used in management and the procedures studied is constructed. This matrix is processed with the support of the Ucinet software, Version 6.698, Figure 1.

A total of 15 elements treated in the hospital management models are analyzed, and the results show that the most frequently used (located in the center) are information-gathering techniques (67.86%), process diagnostics (53.57%), operations planning (53.57%), process representation (50%), indicator analysis (50%), patient flow (50%), process classification (46.43%). The most frequently used (located at the bottom left) are team building (35.71%), benchmarking (35.71%) and process definition (28.57%). Little used (bottom right) in hospital management models are brainstorming (14.29%), case mix (14.29%), service level (10.71%), patient satisfaction (10.71%), and process simulation (3.57%).

The authors who group the most elements in their model proposals [20] are apply the diagnosis, characterization, and classification of processes, evaluation of the level of service, risk analysis and identification of hospital case mix, propose an improvement and control program, show a significant contribution to the management of hospital processes. Regardless, it does not develop tools that allow the administration of activities at the operative level, and [21] develops a methodology for continuous improvement of an emergency department, based on the Lean Healthcare methodology to improve the level of service provided efficiently, but does not include a tool to model the proposed improvement tools, nor a method to verify the impact of the proposed solutions.

Marqués León [22] and Marqués León *et al.* [23] developed a procedure for planning drugs and materials for medical use, highlighting the deployment of master and aggregate planning

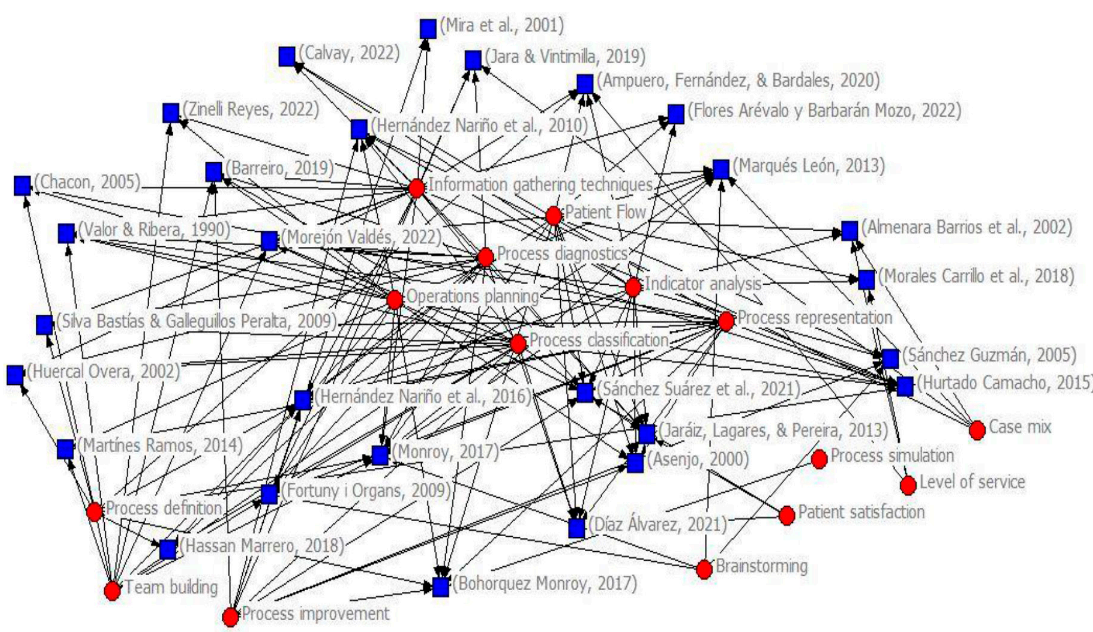

Figure 1. Main elements addressed with in hospital service management models.

adapted to health services. Sánchez Suárez *et al.* [24] proposed a procedure for the structural analysis of processes to identify key variables to be prioritized in management.

Ampuero *et al.* [25], Díaz Álvarez [26], Morejón Valdés [27], and Flores Arévalo and Barbarán Mozo [28] recognize patient flows as a variable that influences the performance of hospital institutions, but none of them focus on their management. [25] conducted a methodological study to demonstrate the need to break down functional barriers in health institutions and concludes with the usefulness and relevance of process improvement in these organizations. Flores Arévalo and Barbarán Mozo [28] present a comprehensive improvement plan to strengthen hospital management. Nonetheless, it recognizes a series of elements (clinical management, administrative management, human resources management, technological resources management, information system management, research and teaching, and financing and payment mechanism), it does not recognize case mix as an element of great importance in the alignment between clinical and administrative management.

Conversely, the authors [25]-[29] recognize the usefulness of indicators to measure the management of processes in hospital institutions from the strategic to the operational levels. Regardless, the analyses carried out show no evidence of specific indicators aimed at measuring the management of patient flows.

The management of a hospital is very complicated due to the characteristics of its products, which are mainly constituted by the discharges of all diagnosed patients. Consequently, there is a need to reduce the infinite number of possible cases into a smaller, more manageable, and valuable quantity in management terms.

In this sense, hospital casuistry is presented as a tool capable of reducing groups of patients with similar clinical behavior, first transforming them into codes based on clinical data (diagnostic categories) from a universe of patients seen in a given period. Of all hospital service measurement systems, the most extensively tested, validated, and known is Diagnosis-related groups (DRGs), a system for grouping patients into clinically consistent classes with equal resource consumption [23].

PATIENT FLOW MANAGEMENT IN HOSPITAL INSTITUTIONS

Organizing patient flows represents a significant challenge for administrators since medical activity alone has great variability intrinsic to it, which makes it very complex. The Hospital has a fixed and rigid capacity versus a variable and random demand [8].

Patient flow is the continuous patient care capacity of a service in which clinical and administrative activities and decisions are involved. When this flow varies, is delayed or interrupted, patients tend to accumulate at various points of service delivery resulting in delays, risks and nonconformity of care [30].

Efficient management of patient flow has become an urgent issue for most Hospitals. Emergency Department saturation, staffing shortages, complication ratios, and even mortality rates are factors linked to cases of hospital bed shortages and staff burn-out when patient volume is maximized [31].

Currently, the challenge faced by medical services is to identify more quickly the patients who require management in the institution according to their level of complexity through an agile diagnosis and prompt assignment and intervention of the required specialist, who should give a timely start to the indicated treatment.

On the one hand, failure in the management of patient flows is the origin of several typical problems in hospitals; among these problems are [32] failure to meet the individual needs of patients, prolongation of patients' length of stay, worsening health outcomes, under- and over-capacity utilization, workload variability and stress for hospital staff, increased medical errors, placement of patients in inappropriate settings, and increased hospital readmissions.

On the other hand, [33] states that there are two simultaneous patient flows: spontaneous demand, which is random entry 24 hours a day, 365 days a year, and Referral, which is patients derived from other healthcare centers. Predicting patient flow is considered an arduous task due to challenges such as increasing patient volume, a widely recognized problem that negatively affects the healthcare system's performance. There are many uncertain situations that could lead to an increase in patient volume [34], these situations of various natures make management complex, in this sense process modeling and simulation is presented as an effective tool for flow analysis and its improvement.

DISCRETE SIMULATION IN THE IMPROVEMENT OF PATIENT FLOWS

Discrete simulation is a technique for mimicking the behavior of a complex physical or theoretical system under certain particular operating conditions. It has proven to be useful as a tool that reduces uncertainty about how changes will affect the existing system. Currently, different software allow simulation: Arena, FlexSim, GPSS, Simio, Delmia Quest, and Witness [35].

It is divided into the modeling and the experimental part. In the first one, the problem is referred to based on two types of relationships (logical and mathematical), and in the second one, the program is run by computer software. Following the previously mentioned concepts, the general objectives of simulation are to represent an existing system and, based on the analysis performed, design an improved one.

It has been frequently used in the service sector, and the health service is not exempt from it, being a complex system composed of numerous variables and random events. There are different studies in hospital services where discrete simulation is applied since it can be used to address patient flow problems [33], identify inefficient processes [36], evaluate the effects of scheduling personnel and resources [17],[37], validate the implementation of solution alternatives [38], among other elements that make it an efficient, powerful tool with great potential in hospital units.

METHODOLOGY

The proposed Methodology for the improvement of patient flows through discrete simulation is composed of four (4) stages and seven (7) steps, which integrate procedures for obtaining the DRGs of the selected service, application of simulation models, and a proposal of actions, which allow evaluating the level of improvements applied in the process.

Stage 1. Familiarization

This stage's objective is to familiarize the researcher with the hospital under study and to form the work team.

Step 1. Formation of the work team

The work team should be composed of seven (7) and 15 people, mostly members of the Board of Directors and the different key result areas, to integrate a multidisciplinary work team that will successfully implement the proposed design to improve patient flow. Training is provided to homogenize language and communication among team members on operations management, management systems, tools, and the primary medical elements related to research.

Step 2. Hospital classification

The classification of hospital systems first highlights the need to divide organizations into four major groups. Hospitals have their particularities in research. This classification will determine the level of complexity in developing the proposed simulation model and the improvements introduced to improve patient flows. Criteria: Hospital profile (General (more than two specialties), clinical-surgical, maternal-child, gynecological-obstetrical, and special hospitals), Territorial location (Rural, local, municipal, provincial or national hospitals) and Number of beds (0 to 300 beds, From 300 to 600 beds and more than 600 beds).

Stage 2. Process selection and description

This step's objective is to analyze all the processes involved in the organization, determine their interrelationships, and select the one that most affects patient flow.

Step 1. Process selection

For this purpose, the General Process Map is proposed to visualize all the strategic, support, and operational processes at each level of the organization; a brainstorming session is held to identify or review the existing one. Finally, the work team selects the process with the most significant impact on the delay or bottleneck. Once the process has been selected, it is determined which service is the most affected and which statistical procedures can be taken into account. Then it is described in the simplest possible way that is easily understood by the work team.

Step 2. Definition of the DRGs

For the definition of the DRGs, the procedure proposed by [22] is used: Form the Minimum Basic Data Set (MBDS), determining the Major diagnostic categories (MDCs) and definition of the DRGs.

Stage 3. Analysis of patient flows

The objective is to identify problems that affect the proper functioning of patient flows.

Step 1. Application of the simulation model

1. Problem formulation

The problems should be precise and concrete to support the detection of symptoms that affect the system's operation. For this purpose, a series of logically sequenced questions were proposed, which helped to form the basis for the formulation of the problem: Is the system's operation fully understood? Is the sequence followed by the system the favorable option that allows the execution of a good service? What constraints hinder the execution of the service with the highest quality? What would be the optimal solution to these constraints?

2. Design of the conceptual model

The purpose of this step is to specify the model based on the characteristics of the system elements to be studied and their interactions, taking into account the objectives of the problem. In formulating the model, it is necessary to define all the variables that are part of it.

3. Data collection and processing

It is necessary to identify, collect, and analyze the data for the development of the simulation model. For this, it is of utmost importance to direct observe each activity carried out in the process and collect all the detailed information according to the variables and the fundamental parameters of the system, from interviews and documents reviews.

4. Construction of the model

The simulation model is built based on the conceptual model and data collection. Different simulation languages exist; in this case, Rockwell Arena 14.0 will be used because it is one of the most updated regarding modeling and because the results in the program output are effective.

5. Model verification and validation

This step is significant because it is necessary to verify an adequate correspondence between the real system and the model. First, the model is checked to see if it is correctly made; that is, it is analyzed to see if the values obtained are similar to or adjusted to those offered by reality.

6. Analysis of the results

The main objective of this step is to analyze the simulation results to detect problems. The model provides insight into the system's behavior as a function of particular actions that affect the interrelationships. This opens the door to the next phase, as the analyzed data will be used to apply improvement methods.

Stage 4. Proposal of improvement actions

This stage aims to solve the main problems affecting the process under study and their root causes.

Step 1. Proposal of actions

A plan of action is proposed to mitigate the effect of these problems in the entity under study, in conjunction with the entity's management, establishing the deadlines for implementing the improvements, which will enable their monitoring.

Step 2. Verification of improvements introduced

A comparison should be made between the level achieved after implementing the improvement actions and the initial state. Implementing the proposed changes may be difficult. The work team may encounter resistance to change and should; therefore, take measures to counteract this possibility. At this stage, it is important to analyze the impact of improving patient flows in the process under study, taking into account the analysis of service efficiency, time and total number of patients in the system, resource utilization, and patient waiting times.

RESULTS AND DISCUSSION

The proposed procedure for improving patient flow in hospital institutions is applied to two services: General surgery and Urology. The results correspond to the interest of the project associated with the national program "Improvement of Science Management and University Innovation as a contribution to the improvement of quality in the health sector Matanzas."

The work team comprised ten (10) people: four members of the board of directors, four specialists, a nurse, and a professor from the University of Matanzas. The team members participated in three workshops. Workshop 1 addresses general topics of operations management, operations programming, key functions and areas, and their contextualization in the health sector. Workshop 2 delves into the main hospital management tools emphasizing improving patient flows. Workshop 3 explains in detail the simulation tool to be used and the role that each team member will play in constructing and validating the model.

The Faustino Pérez Clinical and Surgical Teaching Hospital was opened on February 15, 1995, which occupies an area of 4 000 m^2, on the central highway, km 101, northwest of the city of Matanzas.

In order to improve the disposition of the flow of patients and the service in general, it is necessary to classify the hospital, for this purpose it is worth mentioning that there are several classification criteria: the service is provided by professionals in the sector with the support of equipment, which are operated by specialized labor, it is received by people (patients), tangible and intangible actions occur on people, a service can last a few minutes or several years, the benefits can be ephemeral or last several years or decades, low degree of labor intensity and high degree of interaction and adaptation, this places the hospital as a service workshop, high degree of security or personalization, person to person is provided at the location of the service, there is physical proximity between the patient and the professional in the sector, high degree in which people, facilities and equipment are part of the service experience, the degree of adjustment of the characteristics of the service on demand is high, the organization is classified as a service workshop, according to the complexity of the services provided it is second level (general hospital).

Firstly, it is necessary to consult the entity's General Process Map to define the assistance process to be studied; if it is obsolete, it should be updated to have an overall view of the relationship between the processes. In the institution under study, the processes are updated and grouped as follows: key processes (General Surgery, Emergency and Urgent Care, Outpatient and Ambulatory Care, Diagnostic Means, Admission System and Procedures, Hospitalization); strategic processes (Economic Management, Human Resources Management, Quality Management, Metrology and Accreditation, Knowledge Management) and support processes (Supply, Central Sterilization, General Services, Maintenance, Information Management, Clinical Support and Nursing).

The work team defines within the most significant key processes in the medical hospitalization process because it is the central axis of the hospital and its sub-processes: Internal Medicine, Geriatrics, Nephrology, Hematology, General Surgery, Urology, Cardiology, among others, represent the highest percentage of operation of the entire entity.

Regardless, in agreement with the work team, it was defined to investigate this process in the Urology service, mainly because, according to the statistics of the year 2021, this represents the highest cause of admission after General Surgery, with a figure of 853 patients. It is among the most frequent surgical activities, with 1138 surgical operations. Additionally, the investigation has a strong relationship with the international project evaluating the impact of the strategy, attention, and follow-up on patients with obstructive urinary syndrome.

The Urology service aims to ensure the care of all patients with both congenital and surgical pathologies. It has different providers within the hospital system: Pharmacy, Laboratories, Imaging, Blood Bank, Sterilization Center, Hospital Stores, General Services, Laundry, Kitchen, Maintenance, Operating Room, and ENSUMED. The activities included in it are: Receiving the patient by the physician, examining the patient by interrogation, giving admission order, reviewing the current disease, complying with the guidelines given by the physician to the ward nurse, performing different diagnoses, performing treatment to the disease that the patient has, waiting for the patient's recovery, giving clinical follow-up to the patient by the physician and nurses, discharging the patient.

Among the main risks detected in the process are the following: Error in the preparation of the clinical history, error in supplying medicines, incorrect sterilization of medical materials, deficient diagnosis of the patient, unqualified and unskilled personnel, incorrect use of surgical instruments, deficient organization and preparation of the surgical process, violation of medical protocols, inefficient functioning of surgical equipment biological risks contraction of infectious-contagious diseases, physical and chemical damage, presence of other pathologies in the patient.

The information necessary for the definition of the DRGs was collected based from the discharge book of the Urology service, where the patients discharged in the last year were taken into account. A review was made of the set of key indicators necessary for the preparation of the MBDS: medical history number, date of admission and discharge, age, sex, data of interest on physical examination, main diagnosis, reasons for admission, type of admission, history of current disease and family and personal pathological history.

The MDCs were determined by checking the main diagnoses, which were selected according to the reason for the patient's admission to the Urology service. The review confirmed that the main causes of admission to the process are Urinary Obstructive Syndrome, Infections and inflammations of the urinary system, Oncology and Lithiasis. According to the review of the data, it can be summarized that the main Major Diagnostic Categories of the Urology process are Obstructive Disorders of the Urinary Tract and Oncology, Figure 2.

For the formation of the DRGs, the team considered the data collected from the international project, the frequency of these pathologies in the process, length of stay, resource consumption, and their importance. Thus, 11 DRGs were initially defined as the most important in the service and divided into surgical and medical groups, Table 1.

Based on a consensus with the research team, it was determined that medical treatments would not be taken into account since they are not significant in the admission process service and do not affect the flow of patients from admission to discharge. The Urology department has normed that the MDCs: CIE 10 N35.1, CIE 10 N35.2, CIE 10 N40.2, CIE 10 C61.2, and CIE 10 C61.3, are grouped in ambulatory surgeries. Thus, the 11 DRGs can be reduced to the following: Urethral stricture, Benign prostatic hyperplasia, and Prostatic adenocarcinoma (treatment: open surgery) and Urethral stricture, Benign prostatic hyperplasia (treatment: outpatient surgery).

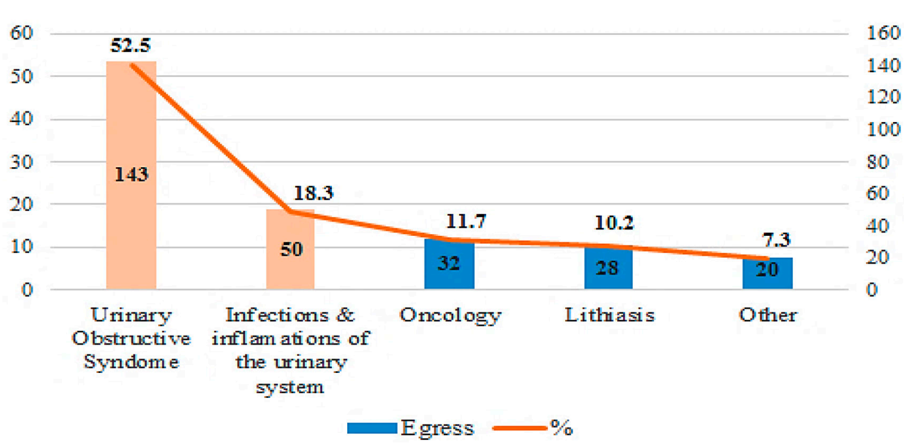

Figure 2. Analysis of the main MDCs.

Table 1. DRGs of the urology Process.

MDCs	Type	DRGs
CIE 10 N35	Medical	Urethral stricture with medical treatment
CIE 10 N35.1	Surgical	Urethral stricture with instrumental treatment
CIE 10 N35.2		Urethral stricture with endoscopic treatment
CIE 10 N40		Urethral stricture with open surgery
CIE 10 N40.1	Medical	Benign Prostatic Hyperplasia with medical treatment
CIE 10 N40.2	Surgical	Benign Prostatic Hyperplasia with endoscopic treatment
CIE 10 C61		Benign Prostatic Hyperplasia with open surgery
CIE 10 C61.1	Medical	Prostatic adenocarcinoma with medical treatment
CIE 10 C61.2	Surgical	Prostatic adenocarcinoma with endoscopic treatment
CIE 10 C61.3		Prostatic adenocarcinoma with laparoscopic treatment
CIE 10 N35		Prostatic adenocarcinoma with open surgery

Develop a simulation model to determine the waiting time to be attended, the time it takes in the system, the percentage of resource utilization, the average length in the queue, and other data that allows the understanding, analysis, and identification of the limitations in the flow of patients in the Urology service according to the clinical characteristics of the patients.

Sufficient information is available for the design of the conceptual model: Length of the working day: eight hours, with a 24 hours on-call team consisting of a specialist, a resident, and two nurses; Workforce: The service has 11 specialists, eight residents, and 14 nurses; Service capacity: 20 actual beds, and the arrival of patients depends on this capacity, while the surgical activity depends on the type of operation to be performed. Two surgical rooms are assigned for surgical operations, one ambulatory and the other central.

For data collection, direct observation of activities, interviews with various specialists, and document review were used, see Table 2. The activities are timed, and the optimistic (TOp), probable (TPr), and pessimistic (TPe) times are determined.

Table 2. Data collected in the Urology Service.

Activities	TOp	TPr	TPe	Resources
Physician orders admission	10	5	3	urologist 1
Preparation of the medical history	20	10	5	urologist 1
The Patient is admitted to the ward	20	10	5	nurse, bed
Nurse complies with medical indications	30	20	10	nurse, cama 1
Visiting pass by doctors, nurses and students	20	10	5	urologist 2, bed, students
Update medical records	10	5	3	urologist 2
Time prior to surgery	360	600	840	–
The Patient prepares for his surgery	90	60	30	nurse 2
The Patient undergoes surgery	–	–	–	urologist 3, urologist 4, anesthesiologist, nurse 3
Outpatient surgery Open surgery	50 120	40 80	30 60	
Patient arrives in the recovery operating room	25	15	10	bed, nurse 1
Visiting pass by doctors, nurses and students	20	10	5	urologist 2, bed, students
Update medical records	10	5	3	urologist 2
Order for payment issued	–	–	–	–
Outpatient surgery Open surgery	1440 11520	720 8640	360 5760	
Medical discharge	20	15	10	urologist 2

Through data simulation the simulation of these data, it is estimated that the arrival of patients to the system follows a constant distribution, with an average of 3 patients/day. Of this total of patients admitted, 2% are confirmed with Prostate Adenocarcinoma, 12% with Urethral Stenosis, and 24% with Benign Prostatic Hyperplasia. Of the total number of patients with Benign Prostatic Hyperplasia, 31% are treated with open surgery, while 69% are treated with ambulatory surgery. The processes' activity times follow a triangular distribution, whose minimum, maximum, and mode values are represented in Table 3 as the optimistic, pessimistic, and probable values.

The simulation model was built using Rockwell Arena 14 software. A duration of 24 days was selected to ensure that the data were within a high probability interval. The model is verified of by reviewing statistical documents, interviewing several system experts, and other analyses carried out in the hospital. Sufficient quantitative and qualitative information was available on the operation of the Hospitalization process. An experimental run, with the actual data from the Revitalization document and the software output data, shows that the model output reasonably reflects the actual behavior of the process.

Analysis of results

The main results to be analyzed are the behavior of the GRDs and the resources involved in the process. The main results are summarized in Table 3, where TTS (Total time in the system), VATIME (Average time in the system using resources), and WAITTIME (Average time in the system waiting to be served) are all expressed in days. Concerning the average queue length, the most relevant durations in minutes (min) are visits by physicians and students (121.622 min), open surgery (88.848 min), Preoperative (60.388 min), outpatient surgery (47.592 min), and Discharge order (40.648 min).

The percentages of resource utilization are shown in Figure 3. The bars in the percentages represent the standard error of the same.

Table 4 summarizes the proposed improvement actions, which were carried out jointly by the working group and the entity's managers who were not part of it. Compliance deadlines are set.

Verification of improvements introduced

With the help of the modeling, it was possible to verify that the application of the dispatching rules

Table 3. Simulation results abstract.

DRGs	TTS	VATIME	WAITTIME
Urethral stricture	6.1248	2.0953	0.74614
Benign Prostatic Hyperplasia	7.3121	3.8092	0.76514
Prostatic adenocarcinoma	6.9261	2.549	0.76135

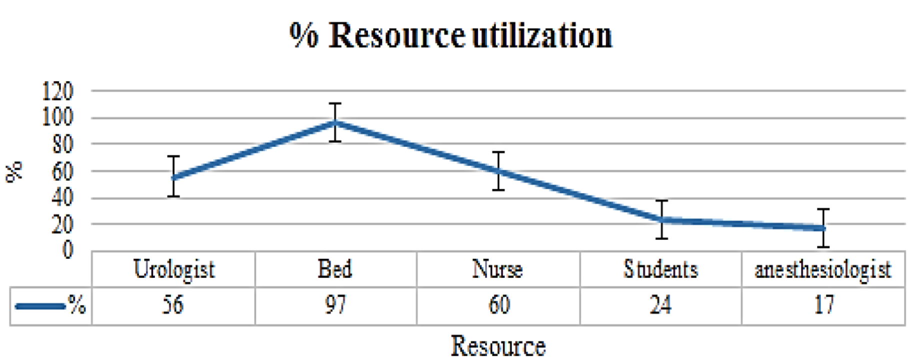

Figure 3. Percentage of resource utilization.

Table 4. Proposed improvement actions.

Proposed actions	Term
Operation scheduling techniques such as the Dispatch Rules should be use to establish the optimal sequence of operations to be performed in the operating rooms. It is determined to apply the SOT rule (shortest operation time) for outpatient surgeries and the EDD rule (the operation with the highest priority according to the physicians' criteria is performed first) for open surgeries.	1 day
Increase eight beds in the Urology service admission room, which does not affect any hygiene protocol.	3 months
Assign personnel to jobs.	3 days
Enabling a workstation that coordinates patient flow from the patient's admission to the discharge process ensures improved uptime.	1 month
Preparation of a public document notifying about the patient's estimated discharge. Digital technologies can be used.	1 month
Implementing an automated system reduces the time required to prepare documentation, update medical records, and perform other information collection activities.	3 months

in the scheduling of surgical operations increases by 25% the number of outpatient operations and 47% the number of open surgeries. Kendall's method is used to determine a first approximation and consider the criteria of all the experts. In agreement with the author is the research developed by [39] that evaluates priority rules for the programming of surgeries and highlights the use of tools such as integer or mixed programming, metaheuristic, and heuristic or decision and dispatch rules.

With the resource allocation using the index method, 77% of the three open surgery work teams and 95% of the six outpatient surgery teams are obtained utilized. The method developed foresees a feasible and straightforward solution for specialists to apply. It allows analyzing different scenarios and percentages of use based on objectives clearly set by the management. Other tools, such as the integration of machine learning models and linear programming [40] and Markovian modeling [41], that allow resource planning in the hospital context are evidenced in the literature.

The design of a workstation coordinating the flows decreased the patient stay time by 31% by optimizing the waiting time for patient discharge. Thus, research such as that of [42] highlights the role of coordination in managing activities that impact increasing timely information flows, optimizing patient routes, and managing discharges. While [43] proposes a method for medium-term capacity planning and proposes as future studies the use of discrete simulation for short-term capacity analysis (operational capacity planning) to integrate the strategic, tactical, and operational levels to reduce waiting times, the use of discrete simulation for short-term capacity analysis (operational capacity planning), to integrate the strategic, tactical and operational levels to reduce waiting times.

CONCLUSIONS

The article proposes a methodology for improving patient flows using discrete simulation, integrating the trajectory approach (grouping of patients in groups related by diagnosis), and a proposal for corrective actions where it contextualizes tools from manufacturing systems to hospital management. The methodology is flexible and can be applied in other hospital services to support managers' decision making.

With the application of the proposed methodology, it was possible to improve the flow of patients in the Urology Service of the "Faustino Pérez" Clinical and Surgical Teaching Hospital by increasing the number of open surgery (25%) and outpatient surgery (47%), increasing the percentage of utilization of open and outpatient surgery equipment by 77% and 95% respectively, and decreasing the waiting time of patients by 31% through the use of flow coordinators.

Among the positive implications in the practice of the service stand out is the increase in process performance, the elimination of activities that do not generate value for the patient, a key element in reducing waiting lists and hospital stays, results that have a significant impact on quality, efficiency and hospital costs; while healthcare managers can identify bottlenecks, propose collaborative improvement solutions (teamwork), organize surgical interventions through the efficient use of resources and outline strategies to achieve specific service goals through an improvement plan that allows them to take advantage of the opportunities identified and proactively reduce deficiencies.

On the one hand, future research should propose hybrid tools to simulate more accurate improvement proposals by integrating uncertainty and how to deal with it, using statistical tools to calculate arrival and service distributions. On the other hand, to align the estimation indicators (hospital stay and waiting times) produced by the simulation model with control panels that allow online operational follow-up in support of effective decision-making.

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