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Modeling and Performance Evaluation of the Operating Room in a Hospital

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Abstract*—With the aim of rationalization, resources optimization and service quality improvement, Moroccan hospitals are improving their management strategy, especially in the operating rooms. Budget cuts and the increasing number of patients of the operating rooms services are the major constraints of reasonable hospital management. Those operating rooms responsible are in charge of searching for a way to respond optimally to these needs. Therefore, it is undeniable that the optimization of the allocated expenses and resources of these rooms has become a necessity. In the present work we model operating rooms using the object approach with UML. A study of a real case of the National Institute of Oncology (NIO) is presented to elucidate the functional, static and dynamic aspects. Subsequently, we present the results of performance of operating rooms modeled using the simulation software ARENA, taking in account various configurations of evolution of the structure of the studied system.

***Index Terms*— operating room, performance evaluation, modeling, optimization**

I. INTRODUCTION

In recent decades, hospitals have worked to promote health policies tailored to the needs expressed by the population in terms of availability and access to services, by trying at the same time to overcome the many constraints imposed particularly by the increasing number of patients and chronic financing gaps.

Despite of the efforts and achievements, the insufficiencies remain in some domains, particularly operating blocks. They are currently at the heart of the problematic, given the importance of material and human resources allocated to their functioning.

The present work has been prepared in order to model in one hand, the operating blocks to better understand how it works at first. We were based on the specific case of the NIO operating blocks to manipulate real data, to elucidate the functional, static and dynamic system, and to identify the dysfunctions and insufficiencies with the aim of performing their optimization. In the other hand, evaluate the performance with ARENA, taking in account the system status evolution according to the modeling sets.

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II. HOSPITAL MANAGEMENT, STATE-OF-THE-ART REVIEW

In recent years, several studies have focused on adapting the industrial production methods to the hospital sector, in particular to the operating blocks.

In reference [2], the authors presented a SOMO-based scheduling algorithm to address the operating room scheduling problem, the scheduling objective is to minimize the total withed idling time and the completion time of the last operation and a special objective function has added to address the performance priority problem

In reference [4], the authors studied an operating room scheduling problem with open scheduling strategy, no time slot is reserved for a particular surgeon, they develop a new heuristic algorithm to solve it.

In reference [3], the authors have modeled the decisional and physical, logical subsystems, following the ASCI (Analysis, Specification, Design, Implementation) methodology. Then, they had evaluated both the resource utilization of an operating multidisciplinary block and its design, while basing on frequent interventions and submitting the trajectories of “patients for surgery” to the constraints of dedication, through UML coupled with ARIS Toolset and ARENA tools.

In reference [1], the authors had mathematically formulated the planification issue with the assignment format and the resources constraints. The aim was to maximize patient satisfaction and reduce his stay costs. Then, a comparison of a political operative programming followed: open scheduling, block scheduling and modified block scheduling, by showing that the choice of the schedule heavily depends on the strategic policy conducted in the operating block.

In reference [5], the authors had compared the intervention real durations and those provided by surgeons at the programming activity weekly meetings, to improve the operating activity planification, and show the dependence of the interventions exactitude prescribed periods. After studying 210 interventions, there is a significant difference between the intervention real and expected duration, because the actual time was not taking into account the induction of anesthesia and surgical installation.

In reference [6], the scheduling problem was modeled as a hybrid flow-shop with cycles. Resources which are used in series are: the pairs of porters (go stretcher), operating rooms, recovery positions and pairs stretcher (stretcher back). The objective was to minimize the final completion interventions date.

III. STUDY OBJECTIVE

The operating block is a strategic sector for the hospital activity. Its management is complex because the operating room interacts with several actors and systems, and requires more human and material resources. The major aim of our study is to provide operating blocks managers with all necessary tools to improve their functioning. We restrict our study to the planification and scheduling of surgical procedures in the context of "scheduling block".

We are interested in this article in the operating block modeling and performing evaluation. Indeed, the theoretical model allows us to firstly, understand the operating block working system and determine its failures. On the other hand, it is an asset to choose an organization and size the human and material resources of the studied system. We focus on modeling and performing evaluation the operating block of the National Institute of Oncology for a real case illustration.

IV. MODELING THE NIO'S CASE STUDY

The different diagrams were established in the Rational Rose 2003 tool, for the operating block of the National Institute of Oncology NIO, Rabat.

A. Use Case Diagram

The identification of requirements and user needs is the first step in the analysis and design using UML. The use case diagram is the best way to illustrate it.

The use case diagram then describes the major functions of a system from the perspective of the actors.

The Fig. 1 shows the use case diagram of the operating block. In our system, we develop the following processes:

- The preoperative management;
- The programming;
- The intraoperative management;
- The postoperative management.

The patient is the actor who launches the process in the system by requiring a surgical consultation and ends it up when paying the bill.

At the meeting of the services technical staff, the patients surgeons share information on intervention proposed patients and validate a pre-program operation. The service technical staff must provid the service operating pre-program to the block programming cell.

The programming cell is composed of doctors (block coordinator, anesthesiologist and hospital services chief or their representatives), block care supervisor, head nurse and anesthetist nurse block. Operations programming are carried out one week in advance and is validated by this cell.

The supervision cell in turn contains: the block head nurse, the blocks rooms supervisor who is responsible for the programming implementation, and the anesthetist of the on call block. The supervision is done daily. The supervision cell prepares its final program on the day scheduled by the programs, it adjusts the operating program and integrates emergency.

A bio cleaning team makes the bio cleaning on the patient direct care in the intervention rooms: a prior bio cleaning before the patient direct care early in the day, inter-patient during the day and the terminal in the end of day.

?A logistics team comprising of officers, provides logistics of transferring patients of surgery in the operating block. The surgery can only be achieved if the patient is transferred to the operating room.

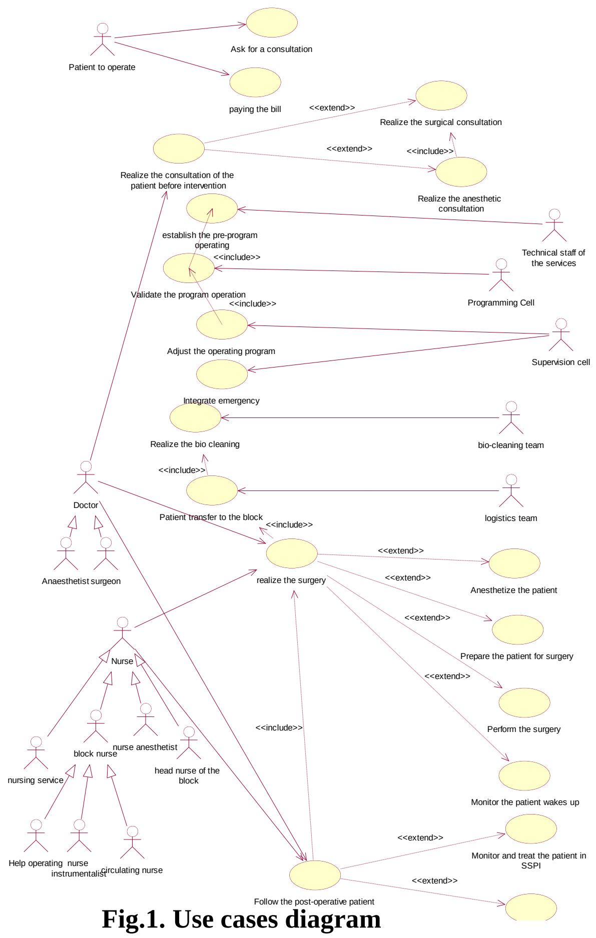

Fig.1. Use cases diagram

B. Class diagram

The class diagram is the most important object-oriented modeling diagram, it is the only mandatory one during a such modeling. While the use case diagram shows a system in terms of actors, the class diagram shows the internal structure. It can provide an abstract representation of the system objects which will interact together to realize the use cases.

The class diagram shows the operating block structure with abstraction of the temporal and dynamic aspects.

Fig. 2 presents a class diagram view of the operating block. The process begins with a consultation that may be surgical or anesthetic made by a doctor who is related by inheritance to the surgeon and AIM (Anesthesiologist intensivist medical)

Several resources interact in the system: human resources such as nurses who are linked by inheritance to the service nurse, the head nurse of the block, the anesthetist nurse and the block nurse that is in kinship with the operative help, registered state nurse (SCD) and instrumentalist and certified circulating nurse (SCD). The stretcher bearers can be either individuals or property transferring stretcher. The patient to operate is the key element of the system. The services technical staff, the programming cell and the supervision cell is the actors in the programming. All these resources are related to the human resources department class to determine their availability.

The class "operating block" consists of the "operating room" class which is in need of equipment and operating materials associated with sterilization service, the "PCR" (postoperative care room) class and the "Schedules logistics" class.

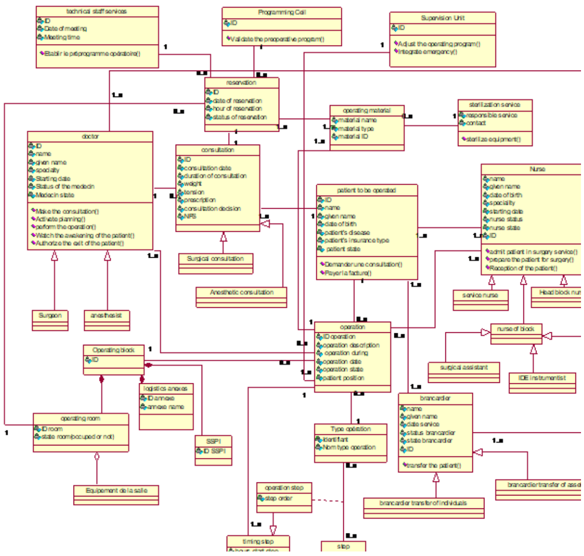

Fig. 2. Example of a class diagram view

C. State-transitions diagram:

The UML state-transition diagrams describe the internal behavior of an object using a finite status automaton. They present the possible sequences of status and actions that a class instance can handle during its life cycle in response to discrete events.

They usually specify the behavior of an instance of workbook (class or component), but sometimes the internal behavior of other elements such as a use cases, subsystems and methods. The status diagram is the only one of the UML standard, offering a complete and unambiguous of all behaviors of the element to which it is attached

An example of status diagram of an operation is illustrated in Fig. 3.

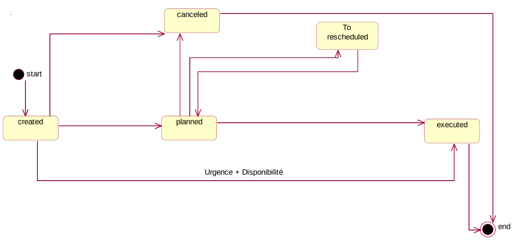

Fig.3. Example of an operation state diagram

D. Activity diagram

Activity diagrams can focus on treatments. They are therefore particularly suitable for modeling the flow control path and data flow. They allow plotting the behavior of a method or the progressing of a use case. Activity diagrams are relatively close to state-transition diagrams in their presentation, but their interpretation is quite different.

The status machines are dedicated to reactive systems, but they do not give a satisfactory vision of a process involving multiple workbooks and must be completed, for example, by sequence diagrams. In contrast, activity diagrams are not specifically related to a particular workbook. We can associate an activity diagram to any modeling element to visualize, specify, construct or document the behavior of this element.

The construction of the activity diagram represents the sequence of steps constituting a process or tasks performed by a system, subsystem or a user.

Five activity diagrams have been modeled to understand the system dynamics: consulting, anesthesia, intervention preparation, programming and intervention implementation. Fig. 4 shows an example of activity diagram on the operation implementation.

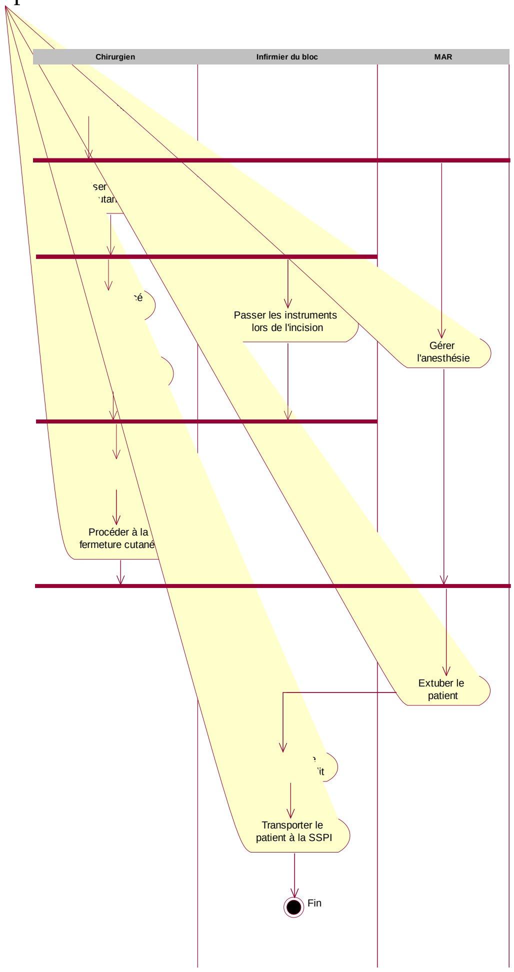

Fig. 4. Example of an operation implementation activity diagram

E. Sequence diagram

The sequence diagram focuses on temporal aspects. The main information in a sequence diagram is the messages exchanged between the life lines, presented in chronological order. These diagrams are constructed in order to model the dynamics of the system by focusing on the sequence of messages.

As it represents the system dynamics, the sequence diagram brings into action the classes instances involved in the making of the sub-function related to it. Each instance is associated with a lifeline that shows its actions and reactions, and the periods during which it operates.

Two types of sequence diagrams were developed during the modeling: consulting and programming. Fig. 5 shows an example of a programming sequence diagram.

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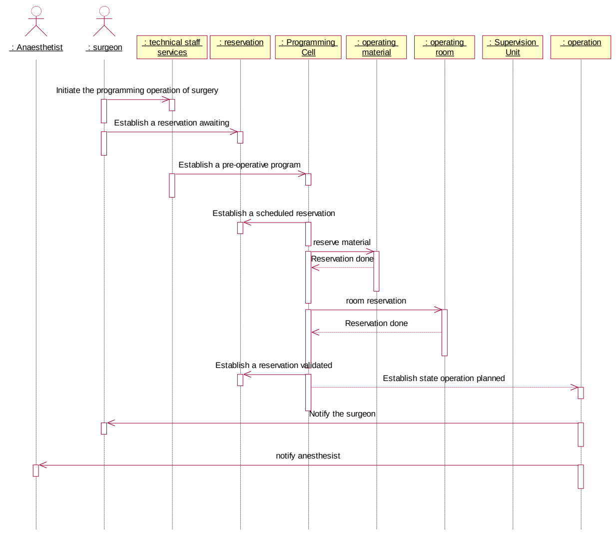

Fig. 5. Example of a programming sequence diagram

V. PERFORMANCE EVALUATION

The simulation for a period of 10 hours functioning of the operating room of the NIO operating room, using ARENA software 09, allows us to reproduce a behavior close to the reality, there for, we can evaluate the performance of the system in a different configuration. The simulation can also allow us to study the system in different of evolution of the structure of the studied system.

In a first scenario, for the data validation, the ARENA simulation (Fig. 6) using constant durations has validated the model with a treatment rate of 100%.

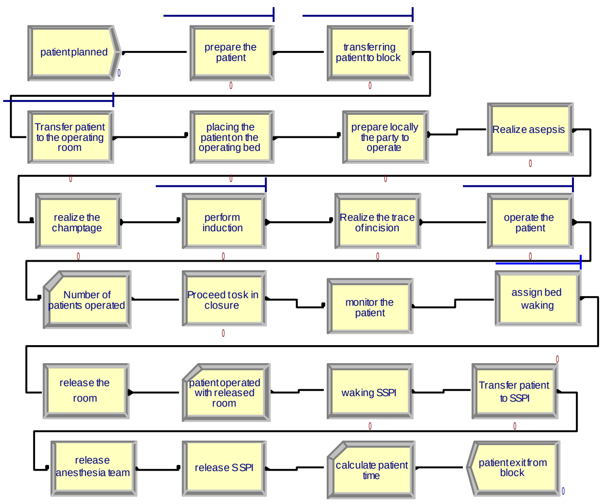

Fig. 6: Simulation with ARENA

The second scenario consists in the use of random durations conform to the current system modeled by the distribution laws (triangular, uniform) whose parameters (TABLE 1) were determined in cooperation with the hospital staff.

TABLE 1: THE ACTIVITIES DISTRIBUTION LAW OF THE OPERATING PROCESS

Activity	Distribution
prepare the patient	Triangular (5,12,20)
transfer the patient to the operating block	Triangular (5,12,15)
Transfer the patient to the operating room	uniform (2,5)
placing the patient on the surgical bed	uniform (2,5
Prepare locally the part to operate	Triangular (2,5,10)
make the drapes	Triangular (3,5,10)
Realize the induction	Triangular (3,8,15)
Operate the patient	Triangular (30,120,300)
Monitor the patient	Triangular (5,20,30)
Awakening PSR	Triangular (30,60,120)

The existing human resources sizing in the operating room is shown in TABLE 1:

TABLE 2: THE HUMAN RESOURCES SIZING

Category	Staff
Surgeon	6
Polyvalent nurse	7
Anesthetist nurse	5
Anesthetist doctor	4
Member of logistics team	2

TABLE 3: THE OPERATING ROOM SIZING

Category	Number
Operating room	3
PSR	3 beds

The current rooms sizing is shown in TABLE 2 and TABLE 3:

We notice that we can operate 8 patients per a day, We see also that The room and the anesthetist are the operating process bottlenecks resources.

In the third scenario, we increase resource bottlenecks: operating room and anesthesist doctor

In the fouth scenarion, we decrease resource bottlenecks. The different results are shown in the table 4 below:

TABLE 4: COMPARISON OF DIFFERENT SCENARIO

Ressource	Curent system	Increasing system	Decreasing system
Anesthetist doctor	78,62%	90,22%	73,09%
Member of logistics team	18,20%	18,68%	18,73%
Surgeon	25,67%	28,04%	17,86%
nursing service	8,29%	7,66%	8,12%
Block nurse	53,98%	81,09%	36,00%
Anesthetist nurse	62,90%	72,18%	43,85%
Operating room	94,99%	92,39%	95,95%
Bed of awakening	30,97%	35,23%	20,04%
Number of patients operated per a day	8	11	6

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We can conclude that we one can simulate and evaluate the performance of the system modeled in different states of improvement or regression of the system in a simple, easy and fluid way.

VI. CONCLUSION & PERSPECTIVES

Modeling of the operating room using UML, has allowed us to understand the functioning of the system according to the three functional aspects, static and dynamic. Simulation, with the advantages it offers, is presented as an ideal tool for analyzing systems with to stochastic events. Therefore, Performance evaluation with ARENA has allowed us to see the influence of different configuration on the current system in a simple way. Our perspective is to optimize the operating room management, on both planning and scheduling. Our approach is to study the hazards that arise on the operating room, especially the operative time that creates overflow situations, cancellations and patient's queues.

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