Operating Rooms Optimization in a Cardiology Public School Hospital: The Joint and Sequential Use of the Models of Min and Beliën

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Abstract--**This study uses joint and sequential models of Min and Beliën to allocate elective cardiac patients in a finite number of operating rooms at any given day of the week, with particular medical staff, in a cardiology public school hospital. Currently, due to the process being empirical, most patients awaiting surgery are at a critical medical condition. The lack of systematic programming also causes a prolonged wait time for scheduling, which further aggravates the patient's condition and extends his or her stay in the hospital. With this, the risk of the patient collapsing and having to undergo an emergency surgery increases, leading to imbalance of the surgical center's routine and hindering the surgical program. The joint use of the two models provides a weekly schedule of surgeries, prioritizing patients by level of criticality and increasing the level of use of post-operative beds. Therefore, a reduction of 29% was obtained in quantities of beds needed to meet the demand of the surgical hospital. The daily and weekly occupancy of these beds was maintained, thus avoiding the oscillations between idleness and burden on the medical staff. This work has used mathematical models to focus on optimization of scheduling elective surgeries, with attention to the level of critically of patients present in the current waiting list for their surgeries.**

I. INTRODUCTION

Looking for improvement in scheduling elective surgery is justified in scholarly literature by means of high costs, profits and investments involved in this kind of medical intervention.

The elective surgery grew 11.7% in two years in Brazil, passing from 2,120,580 surgeries performed in 2012 to 2,370,039 in 2014. In the same period, the Ministry of Health investment jumped from R$ 1.04 billion to R$ 1.33 billion, which represents a nominal growth of 27.2% [21] and in real terms a 16.7%.

Surgical centers are responsible for generating high costs for its proper operation [13; 11] and the scheduling of surgeries is one of the critical factors for the optimization of the use of material resources, financial and people [7].

The two types of uncertainties right certain in the literature are the uncertainties of beginning and duration of the surgery [5]. In function of these uncertainties, the appropriate scheduling of surgeries in operating rooms is a combinatorial optimization problem of difficult development [7].

Minor improvements in the efficiency of the scheduling elective surgeries can cause significant cost to the hospital, and for this reason, the development of an optimized model of scheduling is of extreme importance to meet the social and institutional needs [16].

Reference [14] studies the theme scheduling of surgeries since the 1970. At that time, there was already concern in finding a way technique, structured and organized to reduce operational costs involved in the activities.

This work has focused on optimization of scheduling elective surgeries, with attention to the level of severity of patients present in the current waiting list for their surgeries.

II. LITERATURE REVIEW

Elective surgery is that which can await more propitious, i.e. can be programmed. Typically, it is performed after several tests, in order to obtain the best conditions of health of the patient.

The literature differs in relation to the formal types of existing surgery due to the fact that part of the health professionals do not differentiate the urgency and emergency categories, considering them of same class [12].

The postponement of surgical procedures is a practice that should be avoided as much as possible, in addition to bringing tangible damage to the hospital, brings intangible damage to the patient, and could even compromise the clinical picture.

The doctor is responsible for classification of the patient as to the complexity of the procedure necessary for their treatment. According to the severity of the clinical picture of the patient, the doctor will define a date expectancy for the surgical procedure to be performed.

To set the date for the patient's surgical procedure, it is not known whether it will be possible to perform the procedure on the day set. The Manager queries the patient waiting list and if there post-surgical beds available patient's surgery is scheduled. Otherwise, the patient will be registered on the waiting list.

The severity of the clinical condition of the patient is considered when it integrates the waiting list. This causes more serious paintings have priority over less serious frames.

There is a possibility of surgical procedures being delayed, if it does, the doctor should set a new date for the procedure should be rescheduled. If the procedure is considered a priority, it will be scheduled on another date, if it is not considered as a priority, it will once again join the waiting list.

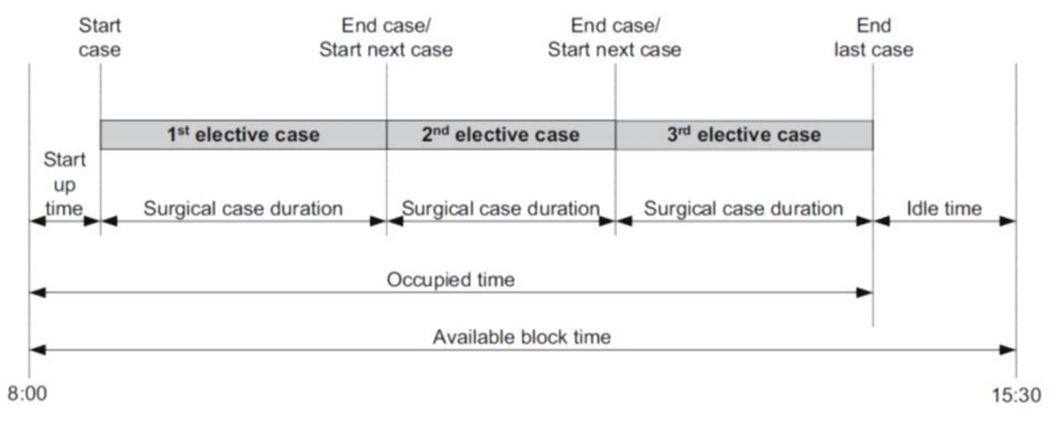

Figure 1 – Representation of the time measured
Adapted from: [9]

The daily occupancy rate of beds for the treatment of post-surgical patients is a variable that deserves to be considered, because the use of input spikes lead to greater need and greater scaling nursing staff to take care of that number of patients while under-utilization of this resource results in unoccupied beds and nursing teams idle , which implies in an attempt to use resource leveling through a cyclic scheduling of surgeries optimized.

In 1997 it was believed that an occupancy rate ideal for surgical beds would be between 80% and 85% [18], because there was a lot of pressure on the administration of hospitals in the occupation reached the limit available. This occupation can be observed and better understood by the fig 1.

This thought encouraged some case studies of Jacksonsville Naval Hospital [8], where it found that the operating rooms were used in just minute 69.25 available on year, whereas the surgical Department of only seven rooms were underutilized. He noted that the system of registration and scheduling of surgeries were done manually which made the process extremely slow and difficult recovery of history for further study.

The main focus was to reduce costs seeking a better relationship between occupation and cost. In an attempt to measure the underutilization and overutilization (for example, overtime and additional costs) it was observed that the costs were high in both situations and the focus should be on the inefficiency of the process [22].

The literature suggests, in a first hypothesis, that an ideal surgical schedule is measured by the maximization of their occupation [24], i.e. the responsible for scheduling should occupy all the available time of the beds and that the factors to improve this efficiency would be the continuous observation of the patients, the repeated evaluations and a team considered to be wise in their decisions.

Some studies about scheduling elective surgeries using linear programming [3; 4; 15], consider the total number of beds available per day and the number of hours that each bed can be used, in order to obtain the maximum occupation available surgical blocks, and can reach up to 99.7.

This maximization of use becomes a problem since there is no availability for emergency surgery or margin to deal with any variation that may occur; that is, the method presents an operational risk in its conception, which refutes the first chance. The distribution of elective surgeries and elective not in the block is shown in Fig 2.

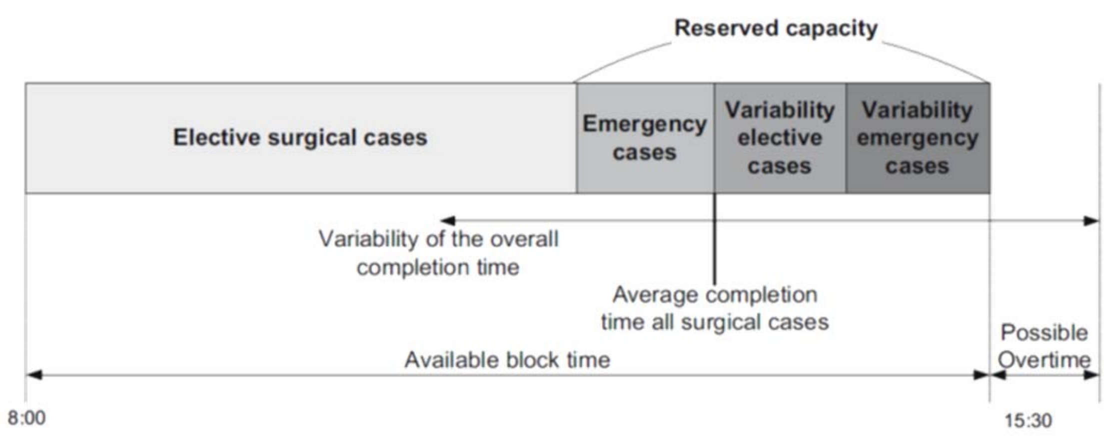

Figure 2- Distribution of elective and not elective surgeries on the block
Source: [9]

According to [17], the costs in a surgical Center can be divided into three categories: cost associated with the scheduling of a patient, cost associated with the unplanned resource utilization and costs associated with unscheduled demand.

Second [11], scheduling elective surgeries directly impacts on resource allocation for emergency surgery. Do not take this factor into consideration can cause an increase in unplanned overtime costs and hospital material.

According to the same authors, proper analysis of scheduling elective surgeries increases the effective distribution of surgeries in a surgical Center. So, avoid spending on the postponement of surgical procedures, because of the accumulation of procedures in one day, and decrease expenses from idle rooms that could be used for the care of a patient.

Only maximize the use of the time available does not guarantee a minimum cost in the process. This is presented in Fig 3.

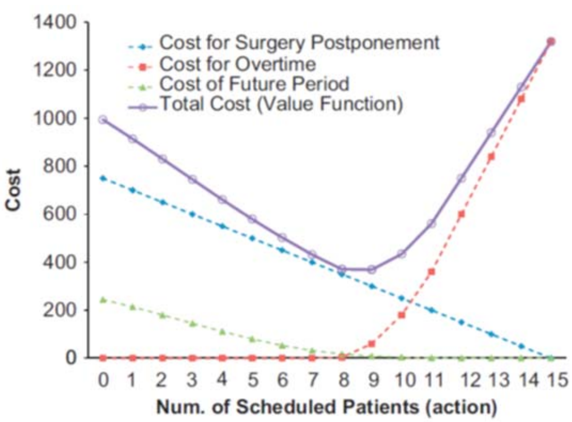

Figure 3 – Function Costs depending on the number of scheduled patients
Source: [16]

The hopes of patients for surgery raises an additional charge that directly impacts on total costs. A margin of overtime is acceptable to achieve the best balance between the costs and the occupation of surgical beds. An example is shown in Fig 4.

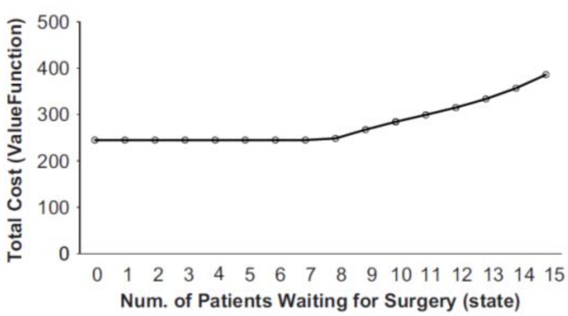

Figure 4 – Function Cost depending on the number of patients in the waiting condition
Source: [16]

Some of the essential information for scheduling of surgeries is the estimated duration of the different types of surgical acts [10]. The policies of reducing waiting time and scheduling need reliable reality-based parameters established to monitor and take actions in order to improve and optimize the process.

Many countries observe the number of patients on the waiting list, but more important than the quantity of patients is the patient waiting time, since this raises the patient's clinical condition worsened.

Some market specific software for scheduling, using the regression method to predict the weather, but are less accurate that prediction of the surgeon [23]. This points to the choice of other methodologies to obtain better accuracy.

Another key factor for the effective management of a surgical Center is the surgical procedure scheduling of patients according to the complexity of their treatments [17].

The classification system of patients is an important tool for providing data from the patients ' conditions. These data help in sizing of resources allocated for the treatments [1].

Through the classification of severity of patients is possible to estimate the resources needed for each particular case and, using an efficient scheduling of surgeries, you can prevent the accumulation of resources in a surgery. The accumulation of resources in a single surgery can affect the treatment of emergency and urgent cases. [1].

The classification of patients regarding the complexity of treatment is an activity that should be established and encouraged in hospitals. Most health professionals do not use a standardized patient classification procedure [19].

There are specific classification systems as for laparoscopic cholecystectomy [20], but on the other hand there is not yet an internationally recognized standard for classifying patients for elective surgeries, which leads the ranking of priority depending on the seriousness or need for surgery be the responsibility of the doctor in charge of the patient.

Despite a critical patient scheduling be a priority, it must be considered that the postponement of a patient considered non-critical may lead to worsening of your condition and consequently to increase costs [16].

Reference [6] conducted an extensive literature review on work related to the scheduling of surgeries. The authors selected and gathered several works to be assessed and divided into the following categories:

a) Characteristics of patients – dividing the research conducted for elective surgeries and emergency;
b) Performance measures – assessing the criteria of analysis employed in the polls, such as waiting time, time to postpone the surgery, financial values or amount of interventions within the studied horizon;
c) Decision-making level – indicating what type of decision to be taken, be it regarding date, time, number of rooms, or capacity of operating rooms. In addition, divided the work whose decisions were located on the technique to be

used, the type of surgeon needed or at the level of attention to the patient;

d) Type of analysis – sorting studies in the optimization problem, in any decision-making needed to solve the problem, a scenario analysis, an analysis of complexity or a statistical treatment of data;
e) Solution technique – grouping studies in accordance with the procedures of employees solution, such as, mathematical programming methods, constructive heuristic model, simulation or analytical approach;
f) Uncertainty – indicating if the researchers have incorporated a stochastic or deterministic approach in its work;
g) Research´s application – dealing with the application and what were the practical implementations of the studies.

The main idea at the junction and adapt the proposed algorithms for both models is to try my best to get a flexible scheduling and optimized to be able to use it in a hospital.

The main scheduling algorithm development, according to the mathematical model proposed by [2], does not take into account the situation of patients on the waiting list for surgery. In this case, the algorithm proposed by [16] can assess the current waiting list and influence the decision of Manager about getting or not in overtime costs, as well as, define which patient should be elected for surgery, in view of its gravity.

In the case study of public teaching hospital specializing in cardiothoracic surgery, it was found that some types of surgical procedures are scheduled cyclically, but randomly about the days of the cyclic period given. For this reason it was proposed and [2] that set, as optimized as possible, the preset surgeries cycle, taking into account the least number of beds needed to meet this demand post-surgical. This is an important tool for the definition of the days of elective surgeries within the cyclic period and also for defining which operating rooms would be released so that the Manager had the freedom of choice of other surgeries during the cyclic period, thus a leveling of the number of beds needed to meet the cyclical considered surgery.

For this purpose was developed in Matlab ® algorithm in order to meet such a proposal based on [2], and [16] and adapted to the needs of the hospital. The developed tool has the flexibility to the hospital Manager can change the surgeries that should be regarded as fixed in the cyclic scheduling, as well as, the cycle time, the rooms available for these surgeries and medical teams of each specialty.

The amount of each type of surgery per cycle, the amount of medical staff by specialty and the amount of operating rooms available are the input parameters of the software to the capping of amount of post-operative beds needed for the care of all demand for surgeries.

A restriction not referred to in the mathematical model proposed by [2], but which is of great importance to the surgical Center Manager, is the restriction which limits the amount of surgical blocks in the same amount of surgical teams by type of surgery; for example, if the hospital has only two medical teams carrying out certain type of surgery it is important that the system does not determine more than two blocks for that surgery within the same day.

Although the software improve performance of cyclic scheduling with respect to scheduling manual, some problems still need the skill of the Manager of the hospital. For example, decide which patients should be assigned to the surgeries defined on that cycle, and if there is need to increase the number of surgeries defined in the cycle, even having to incur extra costs for the hospital, so that a patient does not have its picture worsened.

To solve this latter difficulty was added to the program the model proposed by [16].

III. METHODOLOGY

As mentioned above, this work aims to optimize the scheduling of elective surgery, with attention to the critical level of patients waiting to their cardiothoracic surgery at a public school hospital of cardiothoracic surgery in São Paulo. This required mapping the entire surgical scheduling process this hospital. The hospital released a database containing detailed information about the 41,785 surgical procedures performed between the years 2012 and 2014.

In this hospital, a manager is responsible for the scheduling of surgeries. The selection criteria used to accomplish such a task is mainly the availability of post-surgical beds and concern to perform a number of surgeries in order not to use overtime. When a doctor is faced with the need to schedule an elective surgery of high priority, it will be scheduled at the earliest possible time. Thus, the priority cases are not part of the waiting list.

Because of this scheduling system often, inoperative operating rooms are found by lack of resources, or because the early end of a procedure. However, it is also frequent occurrence of cases that incur overtime, showing two contradictory scenarios in a short period.

Cyclic scheduling is a surgery schedule that is repeated after a certain period (referred to as cyclic time). During this cycle there will be a number of times that the surgery cannot be allocated. These periods are called inactive periods, and others as active periods. Usually cyclical periods are multiple weekly where weekends are inactive periods.

Another concept used is the surgical block; one block is defined as the smallest unit of time for which a surgical room is allocated to a specific surgeon (or surgical group). Because of large lead times and costs of operating room, in practice, one or two blocks are allocated per day and per operating room.

A. Construction of the proposed algorithm

The proposed algorithm should give the manager a surgical center the flexibility to define and get to simulate what the surgery should be considered as cyclical. For this purpose, we developed a program with the user interface in

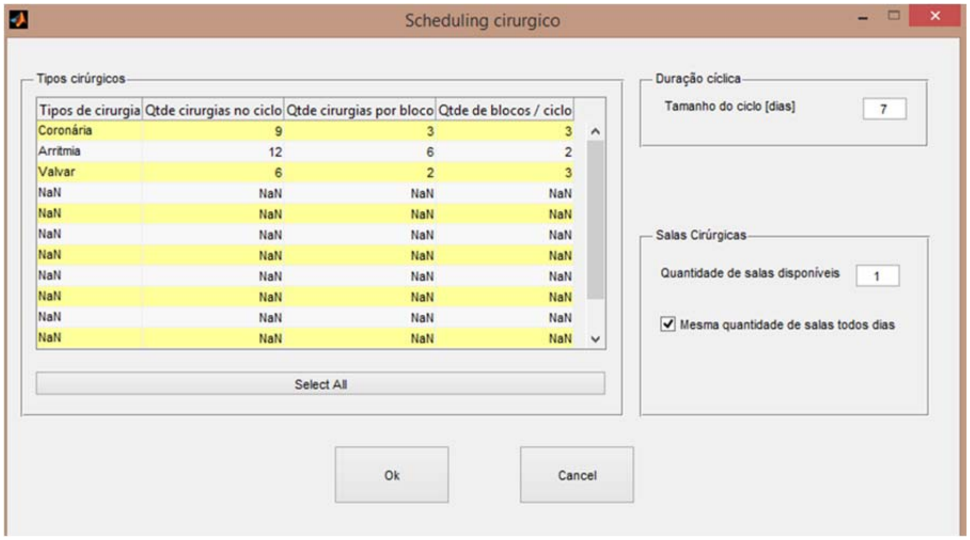

Figure 1 – Main Program Screen
Source: The authors

Matlab, and in the main program screen was inserted a table to define:

- The types of surgery that should be considered as cyclic;
- The amounts of surgeries per cycle;
- The amount of surgical blocks per room;
- The amount of surgical teams available per day for a given type of surgery;

All these variables are editable so that the manager can analyze what the best scenario, that is, what surgeries can be classified as cyclical, restrict or modify the number of rooms available during a cycle, and set the cycle size, as shown in Fig 5.

This environment allows the manager to simulate various conditions defining the ideal cyclic scheduling.

The manager gets, in this phase of the program, a table defining the surgery blocks in the days of week, missing define which patients will be selected and if there will the need to change some of the predefined blocks. Fig 6 shows an example of this table.

	Monday	Tuesday	Wednesday	Thursday	Friday
Coronary	2	1	0	0	0
Arrhythmias	1	1	1	1	1
Valve	2	1	0	0	0

Figure 6 - An example of a schedule of cyclic surgeries
Source: The authors

At this moment is introduced the second algorithm that will have as input parameters the quantity of surgical blocks defined in the first algorithm, as well as the duration of each surgery.

Will be the responsibility of the manager define the unit cost of postponing a surgery, by surgical type and by criticality of the patient. This parameter added to the information on the durations of the various types of surgery and their postoperative times to reestablish the patient were obtained from the database of the hospital. Other information that you enter this second stage is the current situation of the patient list waiting for their surgeries and their criticality. This will allow the algorithm developed to define patients' names to be operated and, if the manager should or should not increase the number of surgeries on some of the blocks in that decision period, even incurring overtime. The scheduling system works as shown in Fig 7.

B. Algorithm steps

The mathematical model proposed by [2] was developed by linear programming method that is one of the techniques of Operations Research used more when it comes to optimization problems. The linear programming problems (LP) seek efficient allocation of limited resources to meet a certain goal, in general, to maximize profits or minimize costs. This objective is expressed by a linear function, entitled "Objective Function"; in this case, the objective function is defined to minimize the use of post-operative beds, by defining a master surgical scheduling which will imply, on average, in the minimal use of post-operative beds. This objective function will be minimized, however, satisfying some pre-established constraints.

Objective Function = min (μ)

You must also define which activities consume resources and in what proportions they will be consumed. This information is presented in the form of equations and linear inequalities, one for each resource. The set of these equations or inequalities is called "Model Constraints".

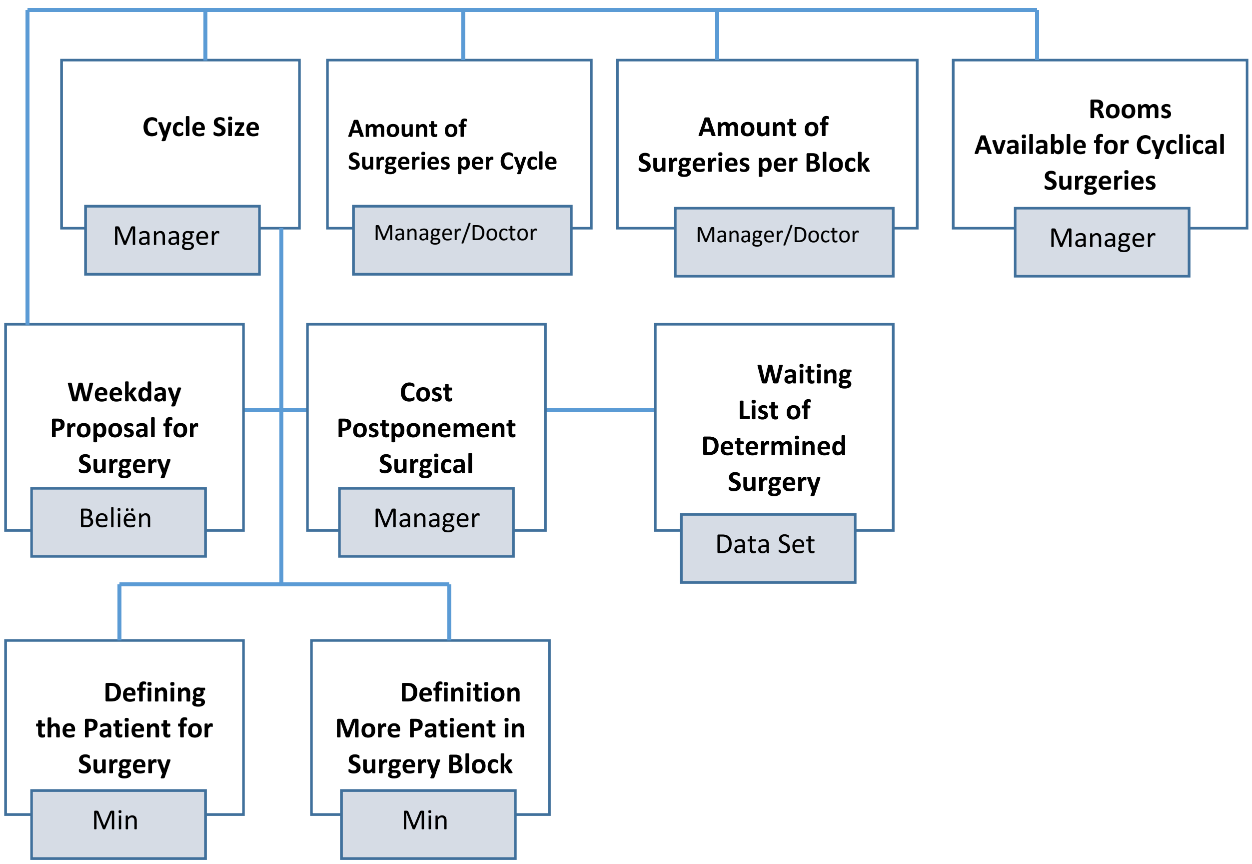

Figure 7 - Organization chart of the software steps
Source: The Authors

C. Model Constraints:

$$\sum_{i \in A} x_{is} = r_s \quad \forall\ s \in S \tag{1}$$

$$\sum_{s \in S} x_{is} \leq b_i \quad \forall\ i \in A, \tag{2}$$

Equation (1) requires that each surgeon receives the requested number of surgeries, while the inequality (2) requires that the related number of blocks not exceed the number of available blocks (rooms) in each day of the cycle.The data set of doctors "S" (1) and the data set of blocks "A" (2) should be flexible so that the manager can simulate many combinations of these sets. These sets were created in Matlab with dynamic features so that they can meet all kinds of simulation conducted by manager.

Follows the model proposed by [2]:

$$\mu_i = \sum_{s \in S} \sum_{j \in A} \left(\sum_{d=\mathrm{dist}\,(i,j)}^{m_s} p_{sd} n_s \left\lceil \frac{d}{l} \right\rceil \right) x_{js} \quad \forall\ i = 1, \dots, l \tag{3}$$

$$\mu i \leq \mu \ \ \forall\, i = 1, \dots, l \tag{4}$$

$$x_{is} \in \Re_0^+, \dots, \min(rs, bi)\} \qquad \forall\, s \in S \text{ e } \forall\, i \in A, \tag{5}$$

$$\mu_i \ \in \ \Re_0^+ \ \ \forall\, i = 1, \dots, l \tag{6}$$

$$\mu \ \in \ \Re_0^+ \tag{7}$$

The mathematical model assumes that the patient average number of particular surgeon "S", stay exactly "d" days in the hospital must be equal to p_{sd}*n_s (average binomial distribution with success probability p_{sd} and attempts n_s).

Dist (i, j) is the distance between day i and day j in the cycle, defined as i-j+l if the day j preceding the day i and i-j+2 otherwise.

When the length of the patient's stay in the hospital is higher than the number of days set for the cycle, it must be added twice (or more), as explained by the factor [d/l].

The [16] model uses the Markov chains in its development. The state representing the waiting list of patients for elective surgery is defined as the vector $\vec{s} = (s_1, s_2, \dots, s_i)$, where s_i is the number of patients with criticity "i" waiting for a surgery in a given period. This list is dynamic and always updated with the patients' movimentation in the hospital.

The decision to be made by the algorithm is the number of patients to be selected for a given state $\vec{s}$. The decision for the next period should be performed at the beginning of each period. An action is defined as the vector $\vec{a} = (a_1, a_2, \dots, a_i)$, where a_i is the number of critical patients scheduled for surgery i.

Checked in that decision period the set of states and a set of actions for these states, with the limits imposed to the actions, it calculates the reward of each action, according to equation (8) of the endless horizon Markov.

$$v_n(\vec{s}) = min_{\vec{a} \epsilon A_s} \{ c(\vec{s}, \vec{a}) + \lambda \sum_{\vec{d} \epsilon D} p(\vec{d}) v_{n-1}(\vec{s} - \vec{a} + \vec{d}) \} \quad (8)$$

Where:

$$c(\vec{s} - \vec{a}) = \sum_{i=1}^{I} c_i(s_i - a_i) + c_o \int_B^{\infty} (x - B)\, dF_a(x) \quad (9)$$

Equation (8) shows that the cost function of simple period $c(\vec{s} - \vec{a})$ is defined by the tradeoff between the cost of surgical delay and the cost of overtime.

D. The cost of surgical delay

The cost of surgical delay is the sum of unit costs defined by the criticality of the patient multiplied by the difference between the state of criticality i and the action taken about this state i.

$$\sum_{i=1}^{I} c_i \; (s_i - a_i), \quad (10)$$

Where c_i is the unit cost of delaying the patient's surgery with criticality i

As the priorities are ordered from most urgent for less urgent, it is known that c_i is descending in i.

E. Cost of overtime

When the total expected duration of surgeries exceed the surgical center capacity (B), costs overtime will occur. The expected total overtime cost can be defined as:

$$OC = c_o \int_B^{\infty} (x - B)\, dF_a\,(x) \quad (11)$$

Where:

c_0 is the unit cost of overtime,

The F_a (x) is the cumulative distribution function of the total duration of surgery

x is the number of scheduled patients.

Therefore, for a type of surgery lasting times normally distributed with μ mean and variance σ^2, the expected extra time (E_{ET}) equals:

$$E_{ET} = \mu(x)\phi\left(\frac{\mu(x)}{\sigma(x)}\right) + \frac{\mu(x)}{\sigma(x)} exp - \left(\frac{\mu^2(x)}{2\sigma^2(x)}\right) \quad (12)$$

$$\mu(x) = \mu x - \mu_{OR} \quad (13)$$

$$\sigma^2(x) = \sigma^2 x \quad (14)$$

Where:

$\mu(x)$ is the average total time overtime

μ_{OR} is the capacity of the operating room

$\sigma^2(x)$ is the total extra time variance

ϕ is the normal cumulative distribution standard

The algorithm solves the conflict between the postponement surgery costs and overtime costs by storing this information in the vector $c(\vec{s} - \vec{a})$, simulating the cost of all the possible actions for the current state of the hospital waiting list.

Also, through the cost of waiting for each patient with their criticality, the algorithm analyzes the current list and defines which patients should be scheduled for their respective surgeries.

The result of the sequential simulation of the two algorithms will be an optimal and flexible cyclic schedule to meet the hospital's needs by selecting which patients according to their criticality, should be scheduled and if will need to add any surgery beyond the proposals in the cyclic scheduling with in order to provide the best value to the patient and the hospital.

III. RESULTS

Through the hospital database were calculated the average durations of the surgeries coronary, arrhythmias and valve as shown in Table 1.

TABLE 1 - AVERAGE TIMES FOR EACH SURGICALLY

Type	Time [min]
Coronary	296
Arrhythmias	96
Valve	43

Source: Authors

And it calculated the number of surgeries per block within the normal working hours, as shown in Table 2.

TABLE 2 - NUMBER OF SURGERIES PER BLOCK FOR EACH SURGICALLY

Type	Amount of surgery per block
Coronary	2
Arrhythmias	5
Valve	3

Source: Authors

The weekly goal of the surgery of coronary, arrhythmias and valvular were provided by the hospital allowing the calculation of the weekly amounts of blocks for surgery, as shown in Table 3.

TABLE 3 - SURGICAL GOALS OF THE STUDIED HOSPITAL

Type	Weekly goal	Amount of surgery per block	Amount of blocks
Coronary	14	2	7
Arrhythmias	40	5	8
Valve	15	3	5

Source: Authors

With setting the weekly target surgical blocks to be executed, next step is to build a schedule so that there is minimal variation in the number of beds used by patients after surgery. For this is necessary to execute the algorithm proposed by [2], which has as input data blocks by surgical targets within a period of a week, and the probability of days that the patient uses the hospital bed after surgery. Data probability of time to post-surgical patients remain in the hospital were extracted from the database and are provided in Table 4.

TABLE 4 - STAY PROBABILITY OF PATIENTS IN POST-OPERATIVE BEDS AS SURGICALLY

Patient's length of stay	Coronary		Arrhythmias		Valve	
	Amount	Prob. (%)	Amount	Prob. (%)	Amount	Prob. (%)
1	0	0	1264	68	0	0
2	0	0	333	18	0	0
3	0	0	120	6	0	0
4	0	0	71	4	0	0
5	0	0	59	3	0	0
6	233	19	0	0	47	11
7	384	32	0	0	79	19
8	273	23	0	0	105	25
9	160	13	0	0	98	23
10	152	13	0	0	90	21
Total	1202	100%	1847	100%	419	100%

Source: Authors

After all the data (number of surgical units, targets, postoperative stay period) enter to the algorithm, the result was obtained for the proposed weekly schedule surgery. This result is shown in Table 5.

TABLE 5 - SCHEDULING SURGICAL WEEKLY CONSIDERING THE TYPE OF SURGERY

Surgeries	Coronary	Arrhythmias	Valve
Monday	7	8	0
Tuesday	7	7	0
Wednesday	0	9	10
Thursday	0	8	5
Friday	0	8	0
Surgical goal	14	40	15

Source: Authors

The need of beds per day calculated by the algorithm according to the defined schedule is presented in Table 6.

TABLE 6 - OCCUPATION OF POSTOPERATIVE BEDS AT OPTIMAL SCHEDULE

Monday	Tuesday	Wednesday	Thrusday	Friday
32	32	32	32	32

Source: Authors

As the algorithm makes a simulation of various situations to reach the point of minimal objective function, a possible schedule and the worst result to the need for beds it has been compiled in Table 7.

TABLE 7 - OCCUPATION OF POSTOPERATIVE BEDS AT RANDOM SCHEDULE

Monday	Tuesday	Wednesday	Thrusday	Friday
29	28	27	45	30

Source: Authors

It was found by applying the algorithm need for beds only with the weekly schedule modification of these three operations rose from a need to 45 beds, in the case of a random cyclic schedule to 32 beds, thereby obtaining a 29% reduction of the number of surgical beds, meeting the goals and constraints of surgical capacity.

Now that the surgical cyclical schedule that determines the day and the amount of surgeries is defined, the next step is to schedule patients by type of surgery. This definition of elective patient is performed through simulation of Markov algorithm that takes different actions according to the waiting list at the time of scheduling elective [16].

IV. CONCLUSION

The goal of developing an algorithm for scheduling elective surgery, with attention to the level of criticality of the present patients on the waiting list for the respective surgeries, reducing the number of beds needed for the post-surgical phase was successfully met.

As demonstrated in the results, there was a decrease of 29% in required amounts of postoperative beds to meet the demand of the hospital. Furthermore, the algorithm gave the leveling daily and weekly occupancy postoperative beds. This reduction has generated as an immediate consequence of a decrease in the need for medical personnel required to attend hospitalized patients after surgical interventions. With the reduction of fluctuations in the amounts required postoperative beds for the execution of surgeries, was reduced to idleness or overload of the medical staff.

Additionally was incorporated the patient criticality as an input parameter of the surgical scheduling process resulting in a chain of decision making to optimize the scheduling process of surgical procedures. It is therefore possible to reduce the total cost of an operating room and reduce the time that patients remain on the waiting list and their risk of dead.

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