# Improving Surgical Outpatient Flow and Throughput in a Hospital

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December 2021

**Abstract**

The continuous hospital's improvement is fundamental to reduce costs associated with inefficiencies. In *Hospital da Luz Lisboa*, the surgical outpatients (SO) perform the admission through the Day Surgery Hospital (DSH) and the surgical inpatients (SI) through the inpatient ward bedroom (IWB). However, a few SI with admission on the surgery's day enter through the DSH. The entrance of these patients through the IWB presents an inefficiency since the bedroom will not be available during the patient's surgery and recovery. The alteration of the SI with admission on the surgery's day entrance to the DSH was studied, considering the resources needed to improve the SO flow. First, the mapping of all the activities was performed to understand possible causes for the outpatient flow delay. The data involving the hospital activities was collected and analysed, and a simulation was built. Three hypothesis were studied focusing on: the current scenario; the alteration of the SI with admission on the surgery's day entrance; a scenario similar to the previous one but with a specific number of daily patient arrivals. Results showed that no resource alterations are needed in the circuit for the first two hypothesis. However, it was observed that in the third hypothesis an increase of five boxes, one chair and of the staff of the DSH had to be added, alongside with the extension of this department's schedule. These measures will improve the SO flow and allow the alteration of the SI with admission on the surgery's day entrance (increasing the efficiency).

**Keywords:** Surgical Outpatient, Surgical Inpatient, Resource Allocation, Circuit Time, Computer Simulation

## 1. Introduction

Over the years, several improvements have been developed for surgical procedures. By focusing in improving the patient's quality of care, hospitals and clinics have developed innovative ways of providing this services, keeping a close attention on how to also develop cost-efficient improvements. Being the Operation Room (OR) one of the major costs to the hospitals, the need for constant analysis on ways to improve the circuits that pass through this department has been given great attention over the years [1, 2]. Several causes for OR delay have been detected, such as the patient delays, the staff delay and the unavailability of hospital resources [3]. Furthermore, over the years the demand for outpatient surgery as been increasing [4]. This type of surgery enables for patients that undergo less complex procedures (or that do not present a complex condition), to not need to stay overnight in the hospital, without compromising the quality of care. Studies have tried to understand the factors that influence the time that the surgical patient takes in the circuit, also referred as patient's episode. Major attention has been given to indicators such as the patient waiting time in the hospital reception (after performing the admission) due to its influence on the patient's satisfaction in regards to the hospital. Although, some results have shown that the waiting time in the waiting room should be, on maximum, between 15-20 minutes [5, 6], no specific studies for waiting times in the surgical outpatients departments were found. The most reasonable maximum waiting time in the reception for this department is the one presented by the National Academy of Medicine (United States of America), of 30 minutes [7]. To understand the factors that can be related to an increase on the patient's waiting time, Root-Cause Analysis methods and auxiliary tools are used to map and understand the processes involved in the patient's hospital episode. They can be Flowcharts to map the outpatients processes [8]; Ishikawa Diagrams to detect the causes related with hospital inefficiencies [9]; or Pareto Charts to understand the weight that the causes have in the problem (such as causes for surgery delays) [10]. Furthermore, in order to provide a more accurate simulation of the hospital performance, a careful analysis of the data must be performed, thus the need for the realization of distribution fitting tests, such as the Akaike Information Criterion [11] or the Anderson-Darling test [12]. In the health sector several distributions are used to describe the patients arrival rate (Poisson distribution [13]), the patient interarrival rate (Exponential [14] and Gamma distributions [15]), and the service times (Gamma [16], Log-Normal [14], Pearson V [14] and Triangular distributions [17]).

Founded in 2000, *Grupo Luz Saúde* is one of the largest private healthcare delivery groups in Portugal. One of the groups' hospital, *Hospital da Luz Lisboa*, is a national healthcare reference. From the excellence specialization in areas such as oncology and robotic surgery, to the patient focus architecture, the hospital is committed on providing the best quality and comfort to the patients [18].

This Dissertation is integrated in the Project Berlin. Within this project, two initiatives are focus on the optimization of the circuit of the surgical patients of the *Hospital da Luz Lisboa*. Currently in this hospital, outpatients do the admission through the Day Surgical Hospital (DSH). Most of the inpatients go to their Inpatient Ward Bedroom (IWB) after entering the hospital. However, a few of the inpatients, that perform the admission on the same day as the procedure, enter the hospital through this department. When these type of surgical inpatients enter through the IWB, it can be "occupied" for almost an average of five hours without the patient, thus not providing a value to the hospital. Furthermore, an expansion of the *Hospital da Luz Lisboa* is being performed, leading to an expected number of 120 daily surgeries.

The problem in study is to understand the resources required in the DSH to improve the surgical outpatient flow, considering the admission of all the inpatients that perform the admission on the surgery's day through the DSH, and the increase on the number of daily surgeries.

The outpatient circuit begins in the day of the procedure (the inpatient circuit can begin on the previous days to the procedure or in the procedure's day). The outpatient performs the hospital admission on the DSH reception (begins the episode). The inpatients can enter through the IWB or through the DSH. In DSH, the patients will be prepared and will wait there for the procedure. When the Operation Room (OR) is prepared, it will call the DSH in order for them to transfer the patients (or the IWB for some inpatients). In the OR, the patients will receive the anesthesia and the procedure will start. When the procedure is over, they will be taken to the Post-anesthesia Care Unit (PACU) for the primary recover. On the PACU, the patients will be monitored until presenting the conditions required to be discharged from this department. When such conditions are fulfilled, the nursing team from the PACU will contact the DSH to go pick up the outpatients (for the secondary recovery). The inpatients will be transported to their IWB. In the DSH secondary recovery, the outpatients will also be monitored until presenting the conditions to be discharged. When such conditions are presented, and if the physician already gave the medical discharge, the outpatients will be discharged and will go to the DSH reception to finalize the episode.

The remainder of this paper is organized as follows. In section 2, the methodology applied is explained, from the Ishikawa Diagram to the construction of the simulation model. Section 3 describes the results obtained for each hypothesis. Section 4 concludes the paper with some final remarks and ideas for future work.

## 2. Simulation Model Development

### 2.1. Root-Cause Analysis

To understand the processes performed by the surgical outpatient, a Flowchart was constructed taking into account not only the information given by the health professionals from *Hospital da Luz Lisboa*, but also by considering the observed on site. This Flowchart was fundamental for the accurate design of the outpatient circuit on the simulation software. From the mapping performed for the Flowchart, four possible bottleneck moments were observed, between: the moment that the outpatient enters in the hospital and the moment the patient is admitted in a DSH box; the moment between the finalization of the patient preparation in the DSH and the moment the patient is transported to the Transfer; the moment between the end of the procedure and the transport of the patient to the primary recovery (in PACU); the moment between the discharge of PACU and the transport of the patient to the secondary recovery (in DSH).

After the construction of the Flowchart, an Ishikawa Diagram (or Cause and Effect Diagram) was constructed in order to understand the causes that can lead to the delay of the surgical outpatient circuit time (Figure 1). The delays identified were majorly collected from feedback of the health professionals that work in the departments, along with the possible causes identified on site. As it can be observed, in the preoperative phase, the observed

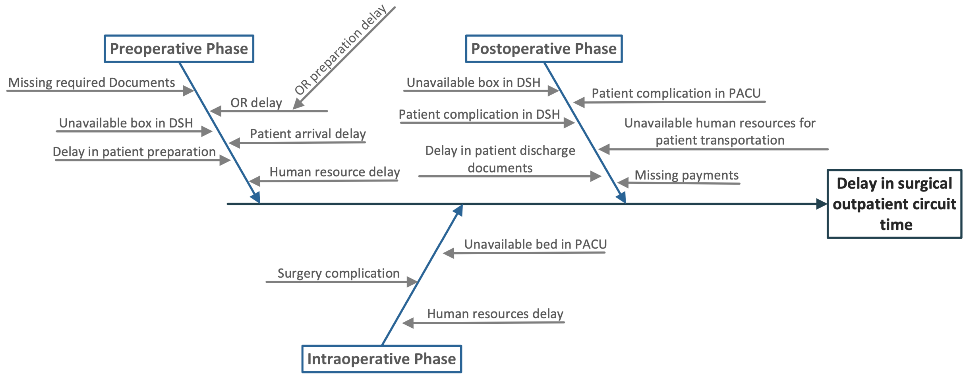



Figure 1: Ishikawa Diagram on the causes of delay in surgical outpatient circuit time.

causes for delay are related to: the missing of required documents (such as the informed consent document); the delay of the patient arrive at the DSH; the unavailability of the DSH to receive new patients; the OR facing a delay in any of the procedures, thus not being able to receive new patients in the Transfer; a complication in the patient preparation; a human resource delay in the patient admission, preparation or transport. For the intraoperative phase, the observed causes for delay were related to: one of the physicians not being available in the scheduled time (e.g. surgeon or anesthetists); a complication on the patient procedure; a lack of available beds in PACU; a delay in the preparation of the OR. For the last phase, the postoperative phase, the observed causes were related to: a complication on the patient' primary recovery on the PACU; a lack of available boxes in the DSH; a complication on the patient's secondary recovery on the DSH; lack of available staff to transport the patient from the PACU; the unavailability of the physician to provide the discharge to the patient; to an anomaly with the patient's payment process.

## 2.2. Patient Arrivals Hypothesis

For the developed simulation, three hypothesis were considered in order to understand the effect of the simulation before and after the modification on the entrance of inpatients with admission on the surgery's day. The first one (H1) focuses on the current patient flow (only a few inpatients enter through the DSH). On the second (H2), all the inpatients that perform the admission on the surgery's day will enter through the DSH. The third hypothesis (H3) is a study requested by the *Hospital da Luz Lisboa*, and although it is very similar to H2, it considers a specific number of patient arrivals: 60 outpatients (being 15 ophthalmology patients) and 48 inpatients enter through the DSH, and 12 inpatients enter directly through their IWB). Furthermore, this last hypothesis considers an expansion that the Hospital is going to have, where the number of ORs is going to be increased to 16 (from the current 12 ORs).

## 2.3. Simulation

The simulation was constructed using the Software *Simul8* (www.simul8.com/). This software allows one to create a simulation of a process or system, thus enabling to manipulate resources and activities using specific distributions of time. Furthermore, this simulation software enables the user to obtain the results of specific indicators for several trials, thus allowing a more accurate analysis. In this study, the simulation indicators are the following:

- Outpatients: Average circuit time for both outpatients; Average number of outpatients that complete the circuit before 8pm, and after 8pm; Average number of outpatients that receive the hospital discharge through the PACU.
- Inpatients: Average circuit time for both inpatients; Average number of inpatients that completed the circuit.
- Average Waiting Times: for the hospital admission (DSH reception); for the patient admission into a Box; for the patient to go to the PACU recovery; for the patient to go to the DSH recovery; and for the DSH administrative discharge (DSH reception).
- Average resource utilization rate: for DSH administrative assistants; for DSH medical assistant; for DSH nurse; DSH cleaning assistant; for DSH Box; for DSH chair; for OR assistant; for Operation Rooms; for PACU nurse; for PACU medical assistant; for PACU beds.

The average time values will be given in minutes and the utilization rate will be given in percentage (which afterwards will be converted in minutes, considering the duration of the simulation). These values will allow to analyse the effects in the allocation of resources (both human and material), and to understand the necessity of resources in the DSH after the entrance modification of the surgical inpatient that perform the admission on the procedure's day.

### 2.4. Data Collection

For the activities' times in the simulation, three sources of data were considered: the data obtained through the computer records (source 1), the data manually collected by the Nursing team of the DSH (source 2) and the data collected on site (source 3). The first two sources were analysed through the same interval of time of 45 days (between December 2020 and January 2021). The third source was collected during the visits to the DSH and the PACU of the *Hospital da Luz Lisboa* (between March 2021 and September 2021). Since the DSH is only open from Monday to Saturday, Sunday was not considered in the studies. Furthermore, the number of surgeries that occur on Saturday decrease drastically when compared with the remaining weekdays. For this reason, the records of the surgeries performed on Saturdays were not considered in the research as it would influence the simulation and underestimate the number of arrivals. It was observed that the source 1 had more complete and accurate information regarding the preoperative phase and the intraoperative phase of the patients than source 2, thus being considered for the estimation of the patient interarrival times distribution, for the duration of the surgeries and for the duration of the recovery in the PACU. From these sources, the source 3 contains far less records than the other sources. Nevertheless, this source provided the data regarding the duration of the patient in the DSH reception (before and after the surgery), the time duration of the activities performed by the Nurse and the Medical assistant in the DSH (before and after the surgery), and of the activities performed by the Nurse in the PACU recovery.

### 2.5. Data Analysis

In order to estimate which input time values should be given to the simulation, a data analysis was performed to understand which distribution best fitted the data sample. The Akaike Information Criterion was considered to be the best choice for the distribution fitting test due to its ability to provide a careful analysis of the model performance as well as taking into account the complexity of it. Using the Software *@RISK* from the company *Palisade* ((www.palisade.com/risk/)), it was possible to estimate the best distribution for the available data. Since the *Simul8* Software has only a few range of distributions that the users can use, from the top best goodness of fit distributions (computed by the *@RISK* Software), the one with the best score, and that is also available to use in the simulations software, was considered. The sample size of the activities time collected on site (source 3) is very small, however it was always considered the minimum size required for the *@RISK* Software to compute the distribution.

### 2.6. Simulation Construction

The passing of the patient through the DSH, the OR, the PACU and again through the DSH were analysed. The shifts of the human resources were provided by the head nurse of each department. Furthermore, although the DSH is only operating from 7am to 9pm, the simulation is defined to begin at 7am and end at 12am (in order to make sure that all the patients are able to finish the circuit and to analyse the possibility of extending the functioning time of the DSH). In the simulation, the DSH was divided in preoperative and postoperative phase, to enable the simulation software to differentiate between both the circuit phases. In the Preoperative phase, three patient entrances were defined, being each one associated to a numerical Label "Patients" value, following the following order: only outpatients of ophthalmology (1); outpatients from other specialities (2); and inpatients who performed the admission through the DSH (3). Furthermore, a constrain for the number and period of the patient arrivals was also given to the simulation, since, according to the obtained data, after a certain hours, there are no records of arrivals.

After the patients enter the simulation through the respective entrance point, in the DSH reception, they will be directed to a queue, then to an activity with a DSH administrative assistant (for the admission) and afterwards to another queue to be admitted in a Box. When both a Box and a DSH medical assistant are available, the patients will be guided to one of the 10 groups of activities, representing the DSH boxes. These simulation groups are formed by three activities - the admission in the box by the DSH medical assistant, the preparation by the DSH nurse and the occupation of the box until the patient can be transported to the Transfer -, and are computed to only receive a patient at a time.

When an OR is available, an activity was defined to represent the patient transport moment from the DSH to the Transfer (the transport is performed by the DSH medical assistants or by the OR assistants, depending of the type of patient). When in the Transfer, the patients will join a queue that symbolizes the patients stay in the Transfer until the transport to the OR. Moreover in this department, another entrance spot was defined for inpatients that enter through the IWB, which will receive the "Patients" label value of 4. These patients are transported by an OR assistant into the queue of the Transfer. When one of the 12 OR is available, the patients will be transferred into it for the procedure. Since in the *Hospital da Luz Lisboa* the OR has a standard beginning time at 8am, the resources "Operation Room" are defined to not receive any patients before this hour. When the procedure is finished, the patients will be directed to another queue (which will provide the waiting time between the OR and the PACU).

Afterwards, the patients will be transported to the PACU, where they will be directed to one of the 24 available activities groups. Each group is formed by the patient monitor activity by the PACU nurse and by an activity that represents the patient bed recovery (without needing the PACU nurse). When the patients finish their recovery and receive the PACU discharge, they will be guided into a crossroad. If the "Patients" label indicates that the patients are outpatients (label value 1 or 2), they will be directed back to the DSH. However, if the label indicates that they are inpatients (label value 3 or 4), they will be directed to a simulation exit points that correspond to the type of inpatient. Moreover, in case the outpatients receive the PACU discharge after 9pm (which is the closing hour of the DSH), the simulation is computed to not transport the outpatients back to the DSH, but instead to an exit point. If the outpatient receives the PACU discharge before 9pm, they will be will be conducted to a queue that will enable the user to monitor the waiting time between the PACU and the DSH.

An activity is defined to represent the transport of the patients to the DSH by the DSH medical assistant and nurse. Furthermore, depending on whether the "Patients" label indicates that the outpatients are from the ophthalmology speciality (1) or not (2), they will be directed into a DSH chair or box, respectively. In the DSH, similar to the preoperative phase, there are 10 groups of activities representing the DSH boxes, each box is using the same resource than the box in the preoperative phase, in order to avoid two patients using the same resource at the same time. Moreover, there are three groups representing DSH chairs, that are only used for the ophthalmology outpatients recovery. Each group is computed to only accept a patient at a time, and has an activity associated to the DSH medical assistant tasks, an activity related to the DSH nurse monitoring the patients and an activity that represents the patient recovery in the box/chair (without the need of the DSH medical assistant and DSH nurse resources). Afterwards the patient will receive the medical discharge, and will be directed to the DSH reception. If the discharge is after 8pm (closing time of the DSH reception), the patients will be directed to an exit where, depending of whether the outpatient receives the medical discharge before or after 9pm and depending on the type of outpatient, they will be guided to specific exit points. However, if the discharge is before 8pm, the patients will be directed to a queue where they will wait for a DSH administrative to be available, to receive the administrative discharge, and afterwards, they will be directed to a specific exit point (depending on the type of outpatient).

## 3. Results

### 3.1. Hypothesis 1

The H1 consists on the current functioning of the DSH. It was possible to compute the current average circuit time for outpatients (from the ophthalmology speciality and other specialities) that finish the circuit before 8pm (still being able to receive the administrative discharge by the DSH administrative assistants). In Figure 2 these average circuit times are presented for 50 simulation tests. It was possible to observe that the average circuit time for ophthalmology outpatients varies between 150 minutes and 350 minutes, and for other speciality outpatients varies between 300 minutes and 500 minutes. From the computer records, the real circuit time of the outpatients was computed (data not shown), and although there are a few underlinings in the circuit time values, it was possible to observe that the range time is very similar to the ones obtained in the simulation, contributing to its validation.

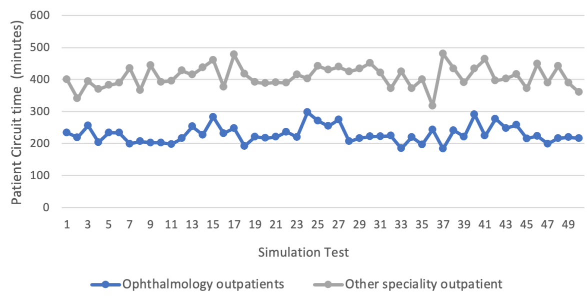



Figure 2: Average circuit times of outpatients that finished the circuit before 8pm, for the current scenario (H1).

Furthermore, the expected pattern of arrivals of patients to the DSH was computed taking into account the computer records of the admission time of 1069 patients, during the 38 days (Figure 3). As it can be observed, there is a large demand of patient arrivals in the first periods of the morning, followed by a quick reduction. In the beginning of the afternoon, a small increase in the patient arrivals is observed again, followed by a reduction until the middle of the afternoon. After 6pm there are not records of patient arrivals.

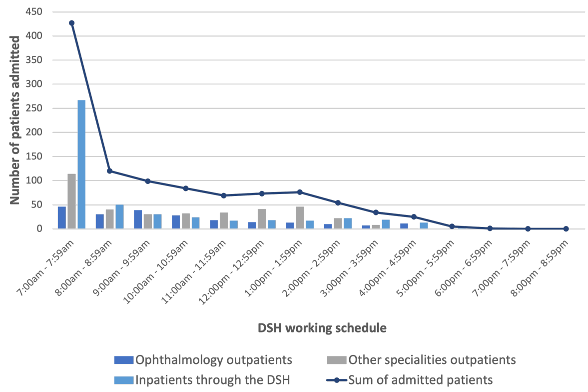
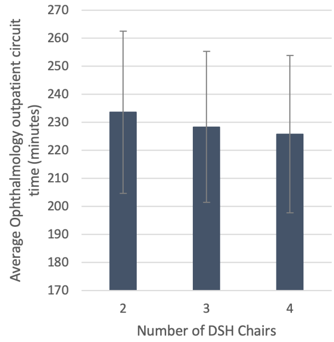


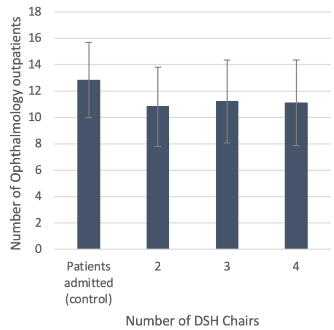

Figure 3: Patient arrival through the DSH working schedule (H1).

Considering the Ishikawa Diagram (Figure 1), the most identified causes for the delay of the surgical outpatient circuit is the lack of available boxes in the DSH, ORs or PACU beds. For these reasons, several scenarios were considered in order to understand the effects in the reduction of the average circuit time, and also to detect possible unnecessary resources that can be removed without compromising the circuit time. It was observed that, since the DSH has the necessary resources to respond to the current patient demand, the variation on the number of DSH boxes did not provide a significant influence on the circuit time and on the number of the outpatients that finish the circuit before 8pm. Furthermore, in all simulations, the waiting time, after hospital admission, to be admitted in a DSH box was always inferior to one min. In the real scenario, it was observed that for a sample of 31 patients, the average waiting time to be admitted in a box was $8 \pm 7.01$ minutes (this differentiation is explained because it is not possible to insert, in the simulation, certain side tasks performed by the DSH staff).

After the variation of DSH boxes, the variation of DSH chairs was also studied. As expected, the decrease in the number of chairs leads to an increase in the average circuit time of ophthalmology outpatients and to a decrease in the number of ophthalmology outpatients that finish the circuit before 8pm (due to creating a bottleneck in the system for this type of patients). Furthermore, an increase in the number of chairs lead to a decrease in the average circuit time and to a increase in the number of outpatients finishing before 8pm (due to having more available chairs for the recovery of these patients) (Figure 4). Since the DSH chairs are only used in the recovery of ophthalmology patients, an alteration of these resources does not present a significant variation in the average circuit time of outpatients that finish the circuit before 8pm.



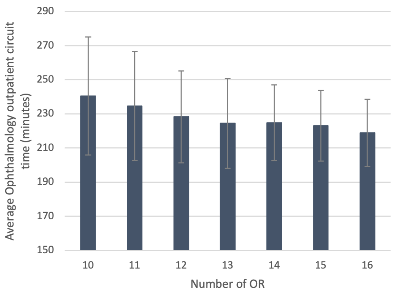

(a) Average circuit time of ophthalmology outpatients that finished the circuit before 8pm, for the several DSH chair scenarios.



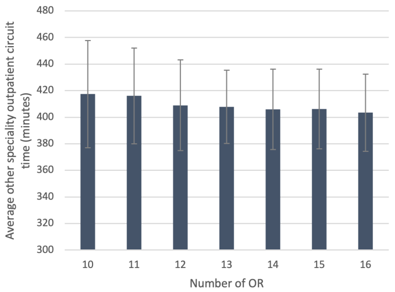

(b) Average number of ophthalmology outpatients that finished the circuit before 8pm, for the DSH chair scenarios.

Figure 4: Effects of the variation of DSH chairs in the average number and circuit time of outpatients that finished the circuit before 8pm (H1).

Initially, the OR had 10 rooms (plus one emergency room), however with the new expansion plan, 6 more rooms were approved to be constructed (resulting in a final value of 16 OR, plus one emergency room). When the computer records were collected, there were already 12 OR functioning. In order to understand the effects that the OR expansion has in the average circuit time of the outpatients, with the current patient demand, several simulations were performed, varying the number of OR between 10 (initial value) and 16 (final value) (Figure 5). Results shown that the average circuit times for outpatients that finish the circuit before 8pm decreases with the increase in the number of OR. However, it is also possible to observe that an increase in the OR would not present a variation in the scenarios with more than 12 OR (current number). Furthermore, it was observed that the average utilization rate of the OR resource is bigger than 50% for 13 ORs or less. This being said, and due to the elevated costs that take to keep an OR functioning, the current number of 12 OR would be the most cost-efficient option to respond to the current patient demand.




(a) Average circuit time for ophthalmology outpatients that finished the circuit before 8pm, for the several OR scenarios.




(b) Average circuit time for other speciality outpatients that finished the circuit before 8pm, for the OR scenarios.

Figure 5: Effects of the variation of the number of Operation Rooms in the average circuit time of outpatients that finished the circuit before 8pm (H1).

Similar to the OR, before the expansion plan, the PACU had a smaller number of beds (nine), which was expanded and currently has already 24 beds available for the patients' recovery. When compared the effects of the PACU beds variation for the 9 to the 26 PACU beds, it was observed that there is a critical reduction of the average circuit time for the ophthalmology outpatients, from the scenario with 9 beds to the scenario with 20 beds. However, it can be observed that after 20 beds the average circuit time tends to be constant. Moreover, from 9 to 24 beds, the average utilization rate was above 50%. This way, for the current demand and taking into account the resources variations performed, it is estimated that 20 Beds would be enough to satisfy the current demand. However, since it is expected an increase in the daily patient demand (hypothesis 3), 24 PACU beds would be essential.

Another cause detected in the delay of the surgical outpatient circuit time is the lack of staff to give response to the patient demand. The effects on the variation of human resources in the DSH and in the PACU were analysed, and it was observed that the variation of the DSH medical assistant resource has the most significant effect on the average number and circuit time of outpatients that finish the circuit before 8pm (Figure 6).

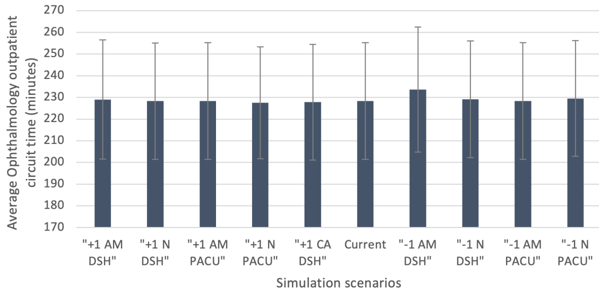



Figure 6: Average circuit time of the ophthalmology outpatients that finished the circuit before 8pm, for different DSH medical assistants (AM DSH), DSH nurse (N DSH), DSH cleaning assistant (CA DSH), PACU medical assistants (AM PACU) and PACU nurse (N PACU) (H1).

### 3.2. Hypothesis 2

The second hypothesis focus on redesigning the inpatient entrance, in order for all the inpatients that perform the admission on the surgery's day to enter through the DSH, thus avoiding unnecessary use of the IWB. The expected pattern of patients arrivals was computed again taking into account this alteration (Figure 7).

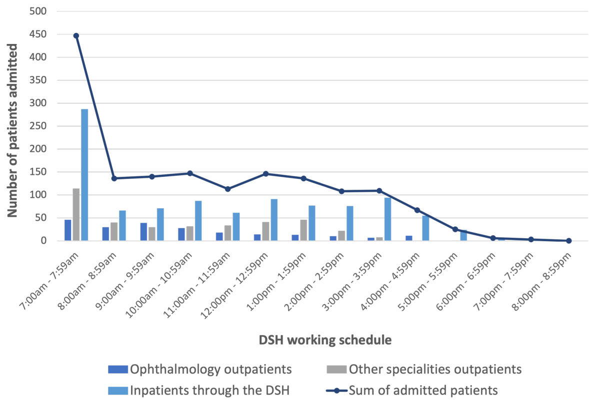



Figure 7: Patient arrival through the DSH working schedule (H2).

As it can be seen, now a higher inpatient arrival throughout the day is expected, possibly requiring more DSH resources. Moreover, since this modification majorly affects the DSH, the analysis performed for this H2 is focused in this department. It was observed that the number and the average circuit time for both types of outpatients that finish the circuit before 8pm is very similar to the values obtained from H1. Although it was expected an increase in the circuit time, the distributions used could not completely mimic the demand of patients that arrive in the first hour of the DSH (possibly allowing for the simulation to not detect a bottleneck in these times of biggest demand). For this reason, similar to H1, there is no need for alterations on the number of DSH boxes and DSH chairs. Furthermore, the DSH human resources were compared, and although the variations of these resources did not show a significant alteration in the average circuit time of the outpatients, the utilization rate presented differences. The comparison between the current resources utilization rate with the one of the resources variations, is represented in Figure 8. As expected, the decrease and increase of the resources will increase and decrease their utilization rate, respectively. One section that is important to note is the one from the increase of the cleaning assistant resource, since the utilization rate of this resource decreases to almost half, when compared to the current one. Although its increase leads to a slight decrease in the average circuit time of the ophthalmology outpatient, the decrease on the utilization rate is much bigger, not being an efficient solution. For these reasons, an alteration on the DSH human resources is not recommended, since it does not provide a cost-efficient solution.

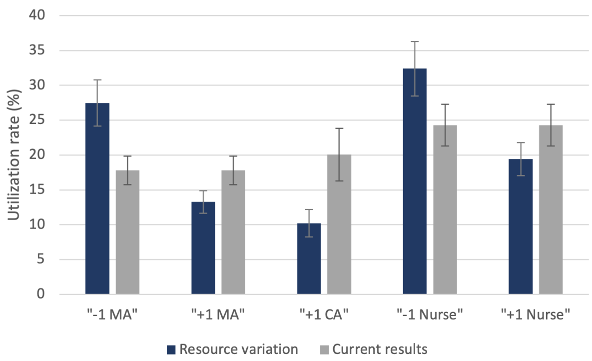



Figure 8: Comparison of the current DSH human resources utilization rate with different DSH medical assistants (MA), nurse, and cleaning assistant (CA) (H2).

### 3.3. Hypothesis 3

The H3 considers that all the inpatients that perform the admission on the surgery's day enter through the DSH, and that a specific number of patients is expected. Furthermore, in this hypothesis, the expansion plans are already concluded, resulting in 16 functional ORs and 24 PACU beds. This hypothesis was specially relevant for the Project Berlin, since it enables to analyse the required DSH expansion, for the elevated patient demand that is expected. In order to obtain the most accurate arrival pattern, specially in the first hours, the percentage of arrivals per hour was computed. First, for each type of patient that arrived in the 38 days, the sum of arrivals per hour was computed, and the percentage of arrivals for each hour was determined in order to understand the weight that the number of arrivals in that specific hour has in the overall number of arrivals. Moreover, depending on the type of patient, the value of expected arrivals for that patient is going to be multiplied by each percentage in order to understand the expected number of patients that will arrive in each hour. Due to the increased demand, it is expected a higher outpatient circuit time (due to the lack of available resources for the increased patient demand). The simulations revealed that the average circuit times of the outpatients, for this hypothesis, are bigger than the ones from the other two hypothesis. Furthermore, it was observed that the increase on the DSH boxes does not decrease the outpatient's average circuit time. For this, a new schedule for patient arrival to the DSH was presented considering that all the surgical outpatients perform the admission on the first surgical slot (8am-2pm) and all inpatients with admission on the surgeries day perform the admission on the second surgical slot (2pm-10pm). This new proposal enabled to avoid bottlenecks in the first hours of the day, and decreased the average circuit time of the outpatients. Furthermore, the influence of the DSH box variation in the patient's waiting time in the hospital reception was studied, and it was observed that the patient's waiting time in the hospital reception tends to decrease with the increase of DSH boxes (Figure 9).

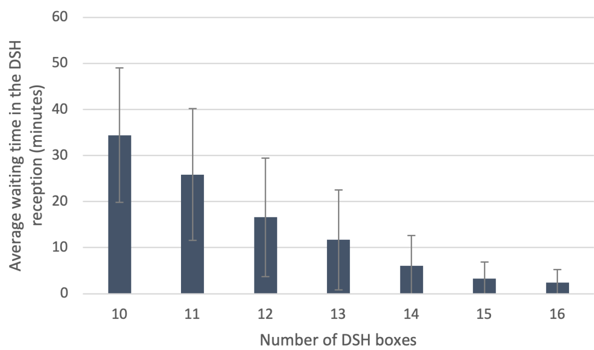



Figure 9: Average patient waiting time in the DSH reception for the several number of DSH boxes (H3).

Moreover, according to the simulation, the patient's waiting time in the hospital reception (after admission) is lower than 30 minutes, for 11 DSH boxes or more, which according to the literature, is the maximum time for the patients to wait in a hospital reception [7]. Furthermore, for 15 and 16 DSH boxes, the average waiting time in the reception is lower than five minutes, which is similar to the values obtained in H1 and H2.

The DSH chair variation was also analysed, considering 15 DSH boxes, being observed that the difference between the scenario with the current number of DHS chairs (three) and the with extra DSH chairs is notable, as expected (Figure 10). Furthermore, the variation of chairs does not provide a significant effect in the other speciality outpatient average circuit time, as expected.

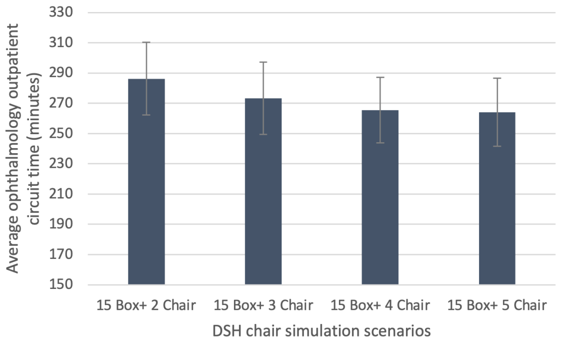



Figure 10: Average circuit time of ophthalmology outpatients that finished the circuit before 8pm, for the several DSH chair scenarios (H3).

The chair utilization rate was also analysed and it was possible to observe that by increasing the number of DSH chairs to four or five, the average circuit time of the outpatients varies in a very similar way. However, the resource utilization rate is smaller for five DSH chairs. For this reason, the most cost-efficient solution would be four chairs.

Due to the increase in the expected patient demand, there is a need for more available human resources in the DSH to admit, prepare, transport and monitor the patients. For this, eight human resource alterations were analysed for 15 DSH box and four DSH chairs (Figure 11). These scenarios represent the addition of one or two DSH human resources in the first shift of each resource (most propitious hours for bottlenecks, in the H1 and H2). As shown, the increase of the DSH resources, in these hours, does not lead to a bigger decrease in the average outpatients circuit time.

Another simulation was performed for four human resource alterations, representing the addition of one or two DSH medical assistants, administrative assistants, nurses, and cleaning assistants in the period from 4pm to 12am, as well as the expansion of the DSH working schedule to 12am. As it can be observed in Figure 12, this expansion would allow for almost all of the 45 other speciality outpatients to finish the circuit, receiving the administrative discharge on time. Furthermore, this alteration would also increase the number of ophthalmology outpatients that concluded the circuit to 15 (which is the total number of this patients that were admitted). Moreover, the increase of one or two DSH resources does not present a variation between these two scenarios. For this reason, the most cost-efficient solution would be to only allocate one more of each DSH human resource in the period from 4pm to 12am.

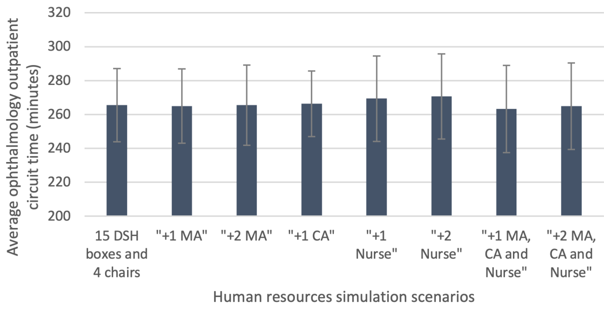



Figure 11: Average circuit time of ophthalmology outpatients that finished the circuit before 8pm, for different DSH medical assistants (MA), nurses, and cleaning assistants (CA) (H3).

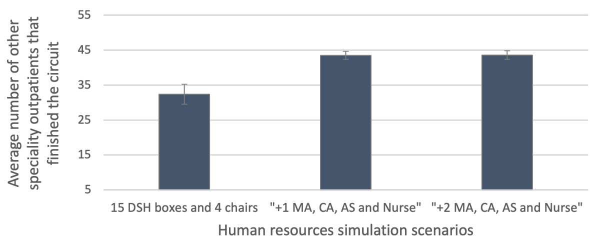



Figure 12: Average number of other speciality outpatients that finished the circuit, for different DSH medical assistants (MA), administrative assistants (AS), nurses, and cleaning assistant (CA) (H3)

## 4. Conclusions

The utilization of a simulation model for this Dissertation came as an innovative decision tool for the surgical patient circuit improvement. Although it was not possible to mimic very well the patient's arrivals on the first hour of the day, the developed simulation can almost successfully mimic all of the other activities of the patient circuit. Furthermore, for both H1 and H2, it was observed that no resource alteration is required (the current resources are able to respond to the current demand). For the H3, due to the expected 120 patient's arrivals, it is recommended 15 DSH boxes, four DSH chairs, the addition of one of each DSH human resources in a shift from 4pm to 12am, as well as the extension of the DSH working schedule to 12am.

The results showed the importance of modelling the demand, and of resource allocation, to improve a system's efficiency. In future works, the addition of the surgical inpatient circuit (with the IWB), in the simulation, will enable the detection of more improvement opportunities in the system.


### Acknowledgements

This document was written and made publically available as an institutional academic requirement and as a part of the evaluation of the MSc thesis in Biomedical Engineering of the author at *Instituto Supeior Técnico*. The work described herein was performed at the company *Grupo Luz Saúde* (Lisbon, Portugal), during the period March-Jun 2021, under the supervision of Dr. Cristina Mesquita. The thesis was supervised at Instituto Superior Técnico by Prof. João Lourenço.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