MESG

Mestrado em Engenharia de Serviços e Gestão

Healthcare Services: Improving conventional surgical rooms through the adoption of a new service design.

Eduarda Pinto Pereira

Master Thesis

Supervisor at FEUP: Professor Abílio Pereira Pacheco

Supervisor at CHUPorto: Engenheiro Bruno Magalhães

U. PORTO

FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

2022-10-17

To my everyday support, the ones that made me who I truly am.

Abstract

The demand for faster but still high-quality service responses has been steadily increasing with regard to the health sector, especially with regard to specialized surgical activities, from which, providing the most suitable, quick and outstanding healthcare treatment has been one of the rising requirements of any surgical department (Fong, Smith, and Langerman 2016). To mitigate the today's challenges, institutions have to constantly search for best practices and update their working methods, alongside innovation, to correctly manage their available and scarce resources and improve the quality of care and the reponsiveness of the service.

This project aimed at developing an improvement proposal to the existing surgical services of a public institutional Portuguese hospital, that would contribute to the optimization of responses by fully understanding the AS-IS of conventional surgical services of the hospital, and how these could be improved in terms of KPIs and processes so that production levels could be maximized and the responsiveness to the population enhanced. To carry this through, a quantitative analysis over retrospective and literature data, as well as an application of service design tools combined with literature existing evidences was perfomed to finally design the service blueprint of an improved solution. Parallel to everything, exploratory and validatory meethings were also performed to verify data, to acknoledge the current functioning processes of the service, to confirm possible solutions of improvement, etc.

Results suggest that, despite the constant efforsts made by top managers, there is still a great margin of improvement when it comes to the surgical services and surgical departments. Although determining the existance of challenges regarding stakeholders and consequences of the public system in the adoption of the proposed solution, it was possible to, alongside OR managers, acknowledge the efficiency improvement that can proveen from a workflow redesign by introducing parallel processing, in terms of the reduction of *Total Patient OR Flowtime* and the consequent improvement of *Throughput* by 1 extra surgical case per OR per day, representing an improvement between 20% and 25% per day.

Resumo

A procura de respostas mais rápidas por parte de serviços mas ainda assim de extrema qualidade, têm vindo a aumentar constantemente no que diz respeito ao setor da saúde, em especial foco naquilo que diz respeito aos serviços cirúrgicos especializados, pelo que, fornecer o tratamento adequado, de forma rápida e excecional têm se tornado numa exigência crescente para qualquer departamento cirúrgico (Fong, Smith, and Langerman 2016). Para mitigar os desafios atuais, as instituições de saúde têm de procurar, de forma contante, as melhores práticas como forma de melhorar significativamente os seus métodos de trabalho, a par da inovação, para gerir de forma eficiente os recursos disponíveis e melhorar desta forma a sua qualidade dos cuidados de saúde e a capacidade de resposta do serviço.

Este projeto visou desenvolver uma proposta de melhoria dos serviços cirúrgicos existentes num hospital publico e institucional português, de forma a contribuir para a otimização das respostas dadas à população portuguesa, compreendendo o atual funcionamento dos serviços cirúrgicas convencionais do hospital e de que forma estes poderiam ser melhorados em termos de funcionamento dos processos com o objetivo de maximizar os níveis de produção e a capacidade de resposta. Como forma de cumprir os objetivos pretendidos, foi realizada uma análise quantitativa sobre dados retrospetivos e encontrados na literatura e uma aplicação de ferramentas de desenho de serviços combinado com as evidenciais de melhores práticas existentes na literatura para, finalmente, conceber um desenho do serviço mais eficiente. Durante todo este processo foi importante combinar métodos exploratórios e de validação para se verificar dados, processos de funcionamento atuais do serviço, validação de possíveis soluções de melhoria, etc.

Os resultados sugerem que, apesar dos constantes esforços feitos por parte dos gestores hospitalares, existe ainda uma enorme margem para melhoria quando se trata dos serviços e departamentos cirúrgicos. Embora determinada a existência de desafios à implementação e adoção da solução proposta, nomeadamente naquilo que dirá respeito aos stakeholders envolvidos e a consequências do próprio sistema de saúde, foi possível, juntamente com gestores do Bloco Operatório, reconhecer a melhoria de eficiência que pode existir através do redesenho do fluxo de trabalho e da introdução de processamento em paralelo, em termos de redução do tempo consumido por doente dentro da sala operatória e consequentemente um aumento no rendimento em 1 caso cirúrgico por sala operatória / por dia, representando assim uma melhora entre os 20% e 25% nos casos cirúrgicos por dia.

Acknowledgments

"There is a purpose for everyone you meet. Some people come into your life to test you, some to teach you and some to use you. Some will bring out the very best of you, keep them close."

Life is full of people, coming and go.

I always try to look at them from the perspective that the ones that go were never meant to stay.

But the ones that stay … the ones that grew with me, cried, laughed … those are the ones I intend on always keep close and thank for all the support they have given me through every stage of my life.

And yes, I could never thank them enough.

This project could certainly not be done without both my brilliant supervisors and without the Santo Antonio's Hospital.

I would like to say a special thank you to them, for always motivating me, helping me grow while always allowing me to be my own self.

But specially, I would like to thank them for passing me the knowledge and wisdom that comes from long and successful years of strong careers.

Last, thank you FEUP.

Thank you for having me,

Thank you for giving me two of the best years of my life,

Thank you for showing me how strong of an institution you are,

And thank you for showing me how strong of a person and professional I can be.

I will certainly never forget you.

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

ACSS – Central Administration of the Health System ("Administração Central do Sistema de Saúde, IP").

AICIB – Agency for Clinical Research and Biomedical Innovation.

CHUPorto – University Hospital Center of Porto ("Centro Hospitalar Universitário do Porto").

CICA – Integrated Center of Ambulatory Surgery ("Centro Integrado de Cirurgia de Ambulatório").

CJMJM – Center of Medical Genetics ("Centro de Genética Médica Doutor Jacinto Magalhães").

CMIN – Maternal and Child Medical Center ("Centro Materno-Infantil do Norte Dr. Albino Aroso").

DOR – Digital Operating Suite.

EU – Europeon Union.

E.P.E. – Public Corporate Entity.

HOR – Hybrid Operating Room.

HSA – Santo Antonio's Hospital ("Hospital de Santo António").

IOR – Integrated Operating Suite.

IS – Information Systems.

LIC – Surgery Enrollment List ("Lista de Incritos para Cirurgia").

NOT – Non-Operative Time.

NUT – Nomenclature of Territorial Units for Statistical Purposes.

OEE – Overall Equipment Effectiveness.

OORE – Overall Operating Room Effectiveness.

OR – Operating Room. Also mentioned as traditional or conventional OR.

ORF – Operating Room of the Future.

OS – Operating Suite.

PACU – Post anaesthesia care unit.

SNS – National Health Service ("Serviço Nacional de Saúde").

SPMS – Shared Services of the Ministry of Health.

TMRG – Guaranteed maximum response time ("Tempo Máximo de Resposta Garantida"). Established of 180 days – 6 months.

TMRG +12 – Referering to the guaranteed maximum response time when exceeding a period of 12 months.

1 Introduction

As stated by the World Health Organization, WHO and DGS (2010), the challenge for the Portuguese health system is to "consolidate and further improve the recent gains in health status and to be more responsive to the expectations of the Portuguese population.".

With the populational growth, aging, and advancement of science and technology, the basic necessities of the population have changed towards more effective and up-to-date responses. The demand for faster but still high-quality service responses has been steadily increasing with regard to the health sector, especially with regard to specialized surgical activities, and so providing the most suitable, quick, and outstanding healthcare treatment has been one of the rising requirements of any surgical department (Fong, Smith, and Langerman 2016).

Any surgical department is not only highly specialized in the treatment it offers, but it also represents one of the most complex and costly fields, with a significant influence on the global overall hospital performance and competitive advantage. In light of the constant evolution of science and being healthcare a constantly evolving field, more complex interventional and surgical procedures have been created, requesting and shifting from traditional methods into less invasive ones while adopting new technologies and surgical techniques.

Because of this, healthcare provision has come to rely on even more sophisticated supports (Kerr 2020), pressuring hospitals to modernize healthcare and continuously search for best practices, optimizing and maximizing the OR usage, and acquiring the latest innovations to ensure a fast and adequate response to their patients, in addition to greater outcomes. Besides this, healthcare facilities also have the obligation and challenge to correctly plan and manage these highly intensive resources to improve the cost-effectiveness of healthcare production in a sustainable manner.

Following the thought of how surgical workforces, surgical techniques, and patient expectations and lifestyles have changed (Kerr 2020), this dissertation intends to contribute to the optimization of responses by fully understanding how the current and conventional surgical services of a public institutional Portuguese hospital have been functioning, and how these could be improved in terms of operating so that production levels could be maximized and the responsiveness to the population enhanced. All with relevant KPIs and processes of the OR as a foundation, as well as the hospital's necessities and the literature's best practices, to design a new service that increases the surgical activities and consequently the responsiveness to the Portuguese population.

1.1 Problem description

The health sector comprises “productive factors, implicit and explicit costs, different functions and internal organizations of hospitals” (Barros 2019). Increasing value for money in health systems is a common theme among countries of the EU, implying with it the improvement of outcomes, quality of care, and the responsiveness of the service, while constantly containing costs (WHO and DGS 2010).

As the government administers healthcare in Portugal through the SNS, it provides universal coverage to all Portuguese citizens through taxation (Barros 2019). This means that it is the state’s responsibility to provide free healthcare in the moment of need and in time of need to any Portuguese citizen (Barros 2019). Nonetheless, when it comes to specialized healthcare treatments such as the ones provided by a surgical department, and with the rising demand faster than the ability to supply them, the need to integrate waitlists becomes inevitable to access that healthcare provision.

Management of healthcare institutions becomes a challenge to ensure that productivity results get maximized while efficiently allocating resource consumption. This is because healthcare institutions are “required to run at maximum utilization” since, as mentioned above, with the rising demand for surgical services, faster than the institutions’ ability to supply them, and the combination of this volume increase with an increasingly resource-constrained environment, hospitals have now the need to evolve in an effort to maintain the quality of care and avoid bottlenecks (Stahl et al. 2006). This means that, as the demand increases and patients consequently integrate waitlists, healthcare facilities need to efficiently improve OR usage and effectively respond to these patients in need (Fong, Smith, and Langerman 2016). In addition, the change in patient expectations and lifestyle has contributed to patients’ demand for more complex treatment plans, making it essential for hospitals to integrate technology innovation projects and improve the overall treatment, patient outcomes, and, consequently, patient satisfaction.

Understanding how to provide these services in the most efficient, high-quality, and cost-effective manner becomes critical in any healthcare system (Stahl et al. 2006).

1.2 Research questions

Keeping in mind how healthcare has been requesting a shift when it comes to surgical workforces and techniques, as well as patient expectations, lifestyle, and the need for faster responses have been increasing (Kerr 2020), and how this dissertation intends to improve the surgical services by enhancing the surgical activities of the hospital and consequently contribute to the reduction of waiting lists by designing an improvement proposal to the current service design, our research questions are as follows:

1. Which indicators need to be taken into account when analyzing the efficiency of performance levels of an OR from a qualitative and quantitative perspective?
2. How can surgical services be redesigned to expect an improvement in the efficiency of performance levels?

1.3 Study and project development at CHUPorto.

This dissertation took place at one of the largest Portuguese healthcare institutions, CHUPorto. Inserted in the category of very differentiated units of the NUT[1] III – Metropolitan Area of Porto (Area Metropolitana do Porto, AMP) (Castro 2021), CHUPorto is an E.P.E healthcare institution, i.e., an SNS integrated hospital, which plays an essential role in meeting the Portuguese population's surgical needs. It possesses an area of influence over the entire Northern Area of Portugal, which is the most populated region, around 36,5% of the entire country's population, covering a total of 3.317.773 people[2] (Centro Hospitalar Universitário do Porto Junho 2021).

Being a university hospital center of reference and one of the most prominent institutions provider of differentiated care in the northern area of Portugal, in fact, it comprehends the entire northern area of Portugal, it stands out for being one of the hospitals with the highest surgical production levels and delivery of high-quality medical care.

This institution is also one of the country's most technologically advanced public healthcare facilities, having already adopted innovative measures in several departments. It is characterized for the constant improvement of its services by incorporating internal and technological innovation projects to ensure the inclusion of the best appliances for diagnosis, monitoring, and treatment of patients. Recently awarded with the AICIB 2021 award for the development of interactive information for participants in pediatric clinical trials (Portugal

---

[1] NUT stands for Nomenclature of Territorial Units for Statistical Purposes, which is a hierarchical system of dividing the territorial division into tiered regions, with the purpose to apply statistical normative (PORDATA 2013).

[2] Important to note that, in Portugal, every patient has their right to freedom of choice about which institution they want to be referred to – process of gatekeeping – which can make the number oscillate (Castro 2021).

Clinical Trials 2021), acknowledged pioneer in launching, together with the Shared Services of the Ministry of Health (Serviços Partilhados do Ministério da Saúde, SPMS), a digital health lab to develop digital health solutions (Saudemais 2022), and in acquiring medical technology that allows for unique procedures to be performed – installation of a laser tumor ablation technology to treat cancer and epileptic patients (Jornal Médico 2021).

CHUPorto englobes a total of four differentiated and specialized hospital units, as possible to see in *Figure 1*, the HSA unit (the one seen on top), CICA unit (the one seen in the bottom), CMIN (seen in the middle right), and CJMJM (in the middle left). Each of these has a strong positioning within the health sector and ensures a response to patients in need. However, this dissertation will only focus on the HSA unit's main center.

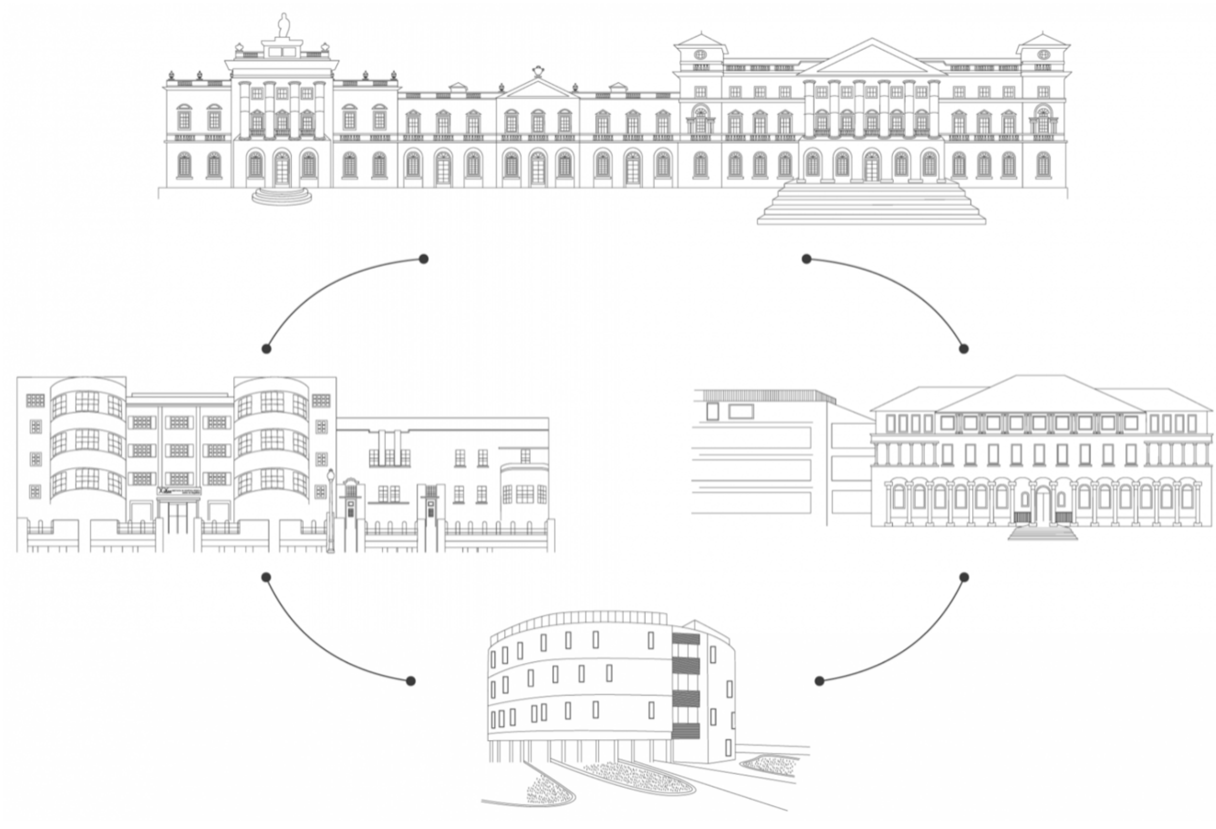


Figure 1. CHUPorto complex. Combination of HSA on top, CICA in the bottom, CJMJM in the middle left and lastly, CMIN in the middle right (CHUPorto's Website 2022).

1.4 Report outline

This dissertation has been structured into six chapters: Introduction, Literature Review, Problem Characterization, Methodology, Results & Discussion, and Conclusion & Future Research.

During *Introduction*, an introduction to the theme, problem, and company where the project took place is made. Besides this, it also presents the objectives, and the research questions to which the study intends to respond.

The second chapter is regarding a *Literature Review* where important topics related to the project are presented, and existing evidence is approached to serve as a foundation for the study. Topics such as Operating Room Management, Operating Room Efficiency, KPIs, Process Reengineering, and Service Design are analysed. Existing literature gaps are also presented in this chapter.

The complete *Problem Characterization* is then presented in the third chapter while being matched with a deeper company presentation.

The *Methodology* comes in chapter four, where the entire research design and tools used during this project are explained.

Chapter five presents the *Results and Discussion* from all three stages of the project – quantitative analysis, application of service design tools and exploratory and validation meetings with the hospital. While results are being exposed, a discussion of them is also made. Two research questions are also answered in this chapter.

Lastly, *Conclusion and Future Research* are presented in the last chapter.

2 Literature Review

The health sector is one of the most indispensable sectors in any country's population, as well as one of the costliest in every economy, being that, in 2021, the current health expenditure grew 12.2%, reaching 11.2% of the Gross Domestic Product (Produto Interno Bruto, PIB) (Instituto Nacional de Estatística 2022). It is, therefore, necessary to define economic and management strategies in order to ensure the National Health System (Serviço Nacional de Saúde, SNS) sustainability while constantly improving health quality (Castro 2021), which can be threatened due to the strain that the increasing demand puts on the healthcare system.

Health quality services involve providing the "right care, at the right time, responding to the service user needs and preferences, while minimizing harm and resource consumption" (World Health Organization 2018). Many actors can be identified to be involved in the quality of healthcare services. Until now, hospitals and medical staff represented the actors having the heaviest weight on the medical care provision. However, nowadays, patients have gained access to such a significant amount of information that even they have become more demanding and less willing to give control over their health to someone other than themselves (Lopes 2020). It then becomes implicit the need to provide a consistent service in its "effectiveness, safety, people-centeredness, timeliness, and efficiency" (World Health Organization 2018).

According to Jerico Mde, Perroca, and da Penha (2011) it is then possible to argue that the concern with quality in healthcare pushes institutions to search for the best practices and to "meet the demands of competitive markets and clients more aware of their rights.".

2.1 Operating room

Within a hospital, the Operating Room (OR) is among the most important areas, giving unique solutions to complex health problems of the population that could not be solved in any other way. In 2021, 654 711 surgeries were performed through the SNS medical institutions (Jornal Médico 2022).

It's not only an important area of any hospital, as it is also a very complex environment comprising multiple actors as well as multiple intersections between various sectors of the hospital (Rothstein and Raval 2018), meaning that, in order to perform, the OR is influenced by several other departments and services requiring an excellent articulation and communication between these. Additionally, its functioning is also dependable, directly, and indirectly, on the physical structure, technology, appropriate materials, and skilled personnel (Costa Ada et al. 2015).

There are different types of operating rooms, performing different surgical styles. The conventional Operating Rooms, the Operating Rooms of the Future (ORF), the Hybrid Operating Rooms (HOR), the Integrated Operating Rooms (IOR), and the Digital Operating Rooms (DOR).

The so called **conventional OR**, also known as traditional operating room, is known between everyone by performing conventional surgeries, meaning open procedures, usually under general anaesthesia. The infrastructural facilities of any OR are highly technical and architecturally demanding (Castro 2021). The OR is an intrinsic part of an Operating Suite[3] (OS), usually composed of several OR's, together with a scrubbing room, support rooms, and sometimes, independent anaesthesia induction and emergence rooms (Lopes 2020).

According to Stahl et al. (2006), the main difference between the conventional and **ORF** design stands in a set of features that allow for a smarter flow of the work. With a different architectural design, ORFs allows for three phases normally performed inside the OR to be made in parallel, saving time in between, thanks to the use of parallel processing through the design of a central operating room with an outside induction and recovery areas, and a control room for surgeons to work between cases.

As for the **HORs**, **IORs**, and **DORs**, the differences lie in the way the technology and data work together, with the common goal of "improving the safety to positively impact patient outcomes and simplifying workflows for surgeons and surgical teams" (Brainlab 2021). This dissertation only incurs on the two first types of surgical operating rooms.

Being such a focal point, any OR is a service with high external and internal flow of patients, personnel, equipment, and materials. Because it is such a highly distinguished environment, with constant technological innovation, very expensive, and highly specialized, waste of time and resources should me minimal (Pereira 2014) (Costa Ada et al. 2015).

2.2 Operating room management

Operating room management represents a vital piece to the high-performance of an OR is, as well as the provision of a fast, unique, and outstanding services. Its fundamentals depend, according to Morris et al. (2018), on "developing policies and procedures that optimize access, efficiency, *throughput*, and staff satisfaction".

[3] Operating Suite refers to the entire set of OR's.

Having the OR the weight it has on the global overall hospital performance and being it's time a highly resource intensive where delays can be a source of lost revenue (Porta et al. 2013) these must be then managed efficiently, not only because of its cost-intensive characteristic, but also because it affects the responses that are given to patients and contribute to patient satisfaction or dissatisfaction with the institution (Marjamaa, Vakkuri, and Kirvela 2008).

The OR performance optimization constitutes a crucial intent and crucial challenge to today's healthcare not only due to the complexity of it, but also because of the wide set of factors that indirectly play an influence. It ranges from managing valuable resources, both materialistic and human, while ensuring their maximum utilization and performance to achieve the common goal of providing distinguished outcomes. However, with **different stakeholders** there are **different perceptions and envisions on how an operating suite should be managed and on what can be considered "efficient"** (Macario 2006).

By far, one of the most important factors influencing the maximization and OR efficiency is to allocate the valuable resource that the OR time is, appropriately to each service and surgery. This because, OR inefficiency is a function of *over-utilized* and *under-utilized* time (Morris et al. 2018). *APPENDIX A: Surgical planning and scheduling*, gives a wider insight into the scheduling and allocation of OR time as an OR management task.

2.2.1 The concept of efficiency in the operating room

An efficient OR management allows for a proper utilization of the available resources to achieve the common goal of a consistent monetization, without waste and lost time, developing a more profitable service (Lopes 2020). It is the "value that gets maximized when OR inefficiencies have been minimized", resulting in the maximum exploitation of the OR's time available on each day and for each surgical service (Dexter and Epstein 2005), ideally without periods of *over-utilization* or *under-utilization* (Morris et al. 2018). It can also be considered as the number of cases that are performed in a day of work – *throughput* – with the minimum amount of lost time and the maximum utilization of the OR time.

2.2.2 Key performance indicators

A rigorous management of the OR follows a line of a continuous analysis over the OR's performance through the tracking of key performance indicators to assess services in terms of quality and efficiency of the provided care and ensure their constant improvement.

Performance indicators are essential variables to the measurement and analysis of the implemented processes, usually already available in the OR's IS of the hospital (Fixler and

Wright 2013) (Dewes 2018). These are used to revaluate, replan, and reorganize activities to help with decision-making and the verification of the efficiency and effectiveness of the operational processes (Jerico Mde, Perroca, and da Penha 2011). The monitoring of these quantitative measures is then of extreme importance for the guidance of OR managers and for the proper allocation of OR time to each service and specialty (Macario 2006). In addition to this, it is also known that KPIs should be benchmarked both internally against performance over time and externally against established best practices to ensure ongoing improvement (Fixler and Wright 2013).

As stated by Dewes (2018), "an integral part of performance improvement is establishing the KPIs on which to focus". However, according to Fixler and Wright (2013), one challenge of healthcare institutions is determining which indicators are most relevant in terms of quality when analyzing the OR's efficiency and performance. In recent years, there have been a lot of controversies on the usefulness of indicators and on the understanding of these indicators definitions, which vary significantly from hospital to hospital and, as mentioned before, from stakeholder to stakeholder. In addition, OR managers face the constant challenge of collecting the most reliable data possible in real-time. This is because different stakeholders are involved in the collection and insertion of data into the IS, which can sometimes result in errors made. It is then crucial to create indicators that allow OR managers to collect enough information to establish a strategic planning over processes (Pereira 2014).

Based on previous research studies, several KPIs need to and can be considered when analyzing the efficiency, uncovering inefficiencies, and improving processes and procedures that carefully help to avoid bottlenecks and converge into a reorganization of the OR (Marjamaa, Vakkuri, and Kirvela 2008).

It is possible to see under *APPENDIX B: Four categories of KPIs identified in the studied literature*, a summarization of the KPIs found in the studied literature that help to analyse the weight and importance that each indicator may have (a cross means that the article or literature review considered the KPI in the developed study). In total, 28 KPIs were identified, which can be divided into four groups that directly or indirectly complement each other. The *Operating Room KPIs* are related to every process happening inside the OR, which directly influences the second set of KPIs, *Production KPIs*. Then we have some that can be classified as *Additional OR KPIs* since these are not permanent OR KPIs affecting the production levels but can happen and do it indirectly. Lastly, a set of KPIs related to the success of outcomes.

To determine this universe of KPIs, a set of seventeen papers (both empirical and literature reviews) from a broad period were analyzed, presented in the table under *APPENDIX B: Four categories of KPIs identified in the studied literature*.

Harders et al. (2006) studied how a significant portion of the OR time is consumed by non-operative activities (KPIs involved) and how the application of a process redesign could decrease non-operative time (NOT). As for Stahl et al. (2006), the study was focused on how an OR redesign, with the introduction of ORF features, could impact the throughput by reducing some of the most influential *Operating Room KPIs*, very similar to Morris et al. (2018) who studied how the overlapping of surgical procedures could affect the overall utilization of OR time and have a direct impact on the efficiency and production levels.

Macario (2006), Fixler and Wright (2013), and Marjamaa, Vakkuri, and Kirvela (2008), although different, all focused on analyzing the efficiency of an OR by identifying relevant KPIs and some key factors involved. Jerico Mde, Perroca, and da Penha (2011), differently from every other, focused their study on the turnover time and the impact it has on the overall OR time, and all activities happening inside this period (cleaning and setting up of OR).

Porta et al. (2013), Costa Ada et al. (2015), and Rothstein and Raval (2018), although different since they studied delays happening in the OR, quality indicators of both operative and non-operative activities happening in the OR, and the overall operating room efficiency, respectively, all of them suggested a set of improvement solutions to the most critical identified KPIs, while Attarian et al. (2013) designed a high-performance OR for a specific surgical procedure considering a set of relevant KPIs and categorizing possible OR inefficiencies.

Attigah et al. (2017), Casar Berazaluce et al. (2019), Jin and Liu (2022), and Jin et al. (2022) performed a deep comparison between an OR and a HOR and how the acquisition of ergonomic and new technology to the OR could affect some KPIs. Lastly, Lee, Ding, and Guzzo (2019) and Sonmez & Pintelon (2020) focused the study on improving operating room efficiency levels by considering a set of improvement innovations and the impact these could have on different operating room KPIs and on analysing the efficiency importance of ORs, while considering its typical workflow and every KPI involved to propose a new KPI, respectively.

Aside from all the KPIs presented under *APPENDIX B: Four categories of KPIs identified in the studied literature*, Sonmez & Pintelon (2020), proposed a new KPI designed for OR managers to determine the overall effectiveness. It emerged from a commonly used KPI in manufacturing systems, called OEE, which was then adapted into the operating room analysis, culminating into the creation of the OORE.

This new KPI involves three components that can be calculated from existing ones and, retrieved from the typical OR processes. The following figure, *Figure 2*, represents the typical processes and workflow of an OR that were considered in Sonmez & Pintelon (2020) research and used in the development of the OORE KPI. Besides this, and as possible to see, Sonmez & Pintelon (2020) took into account the delays that could occur on any phase of the OR's workflow, which are acknowledged with the OORE KPI and relevant when determining the overall efficiency levels. *Figure 2*, also includes a visual demonstration of the components.

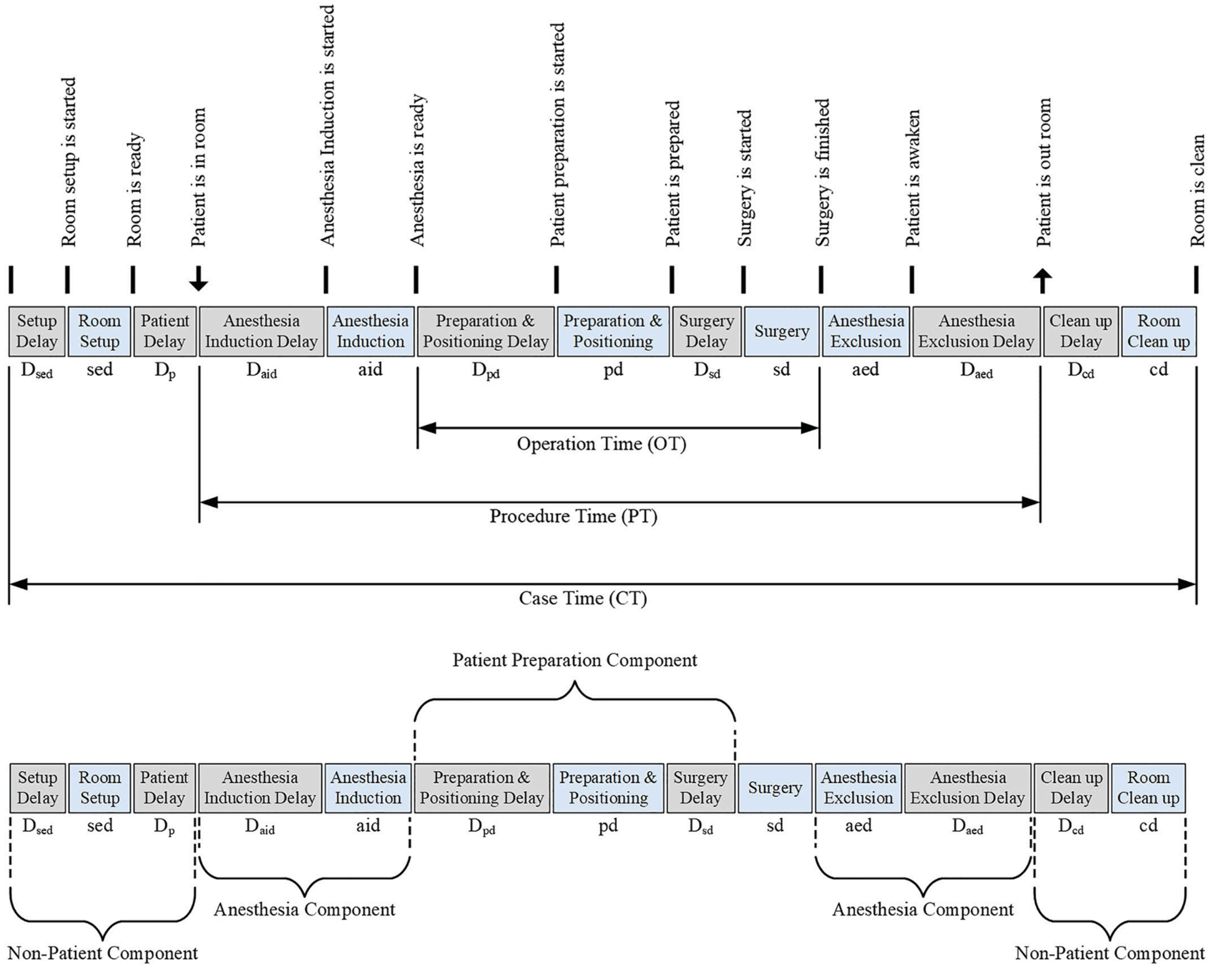


Figure 2. Visual representation of KPIs and the typical workflow of an operating room. OORE components (Sonmez &Pintelon 2020).

As mentioned above, the OORE is made of three components, which can be seen above: The preparation component, PC, anesthesia component, AC, and non-patient component, NC.

$$OORE = PC \times AC \times NC = \frac{Surgery\ Duration}{Operation\ Time} \times \frac{Operation\ Time}{Procedure\ Time} \times \frac{Procedure\ Time}{Case\ Time}$$

$$OORE = \frac{Surgery\ Time}{Case\ Time}$$

Retrieved from Sonmez & Pintelon (2020).

The OORE can be calculated from the equation above, and focuses on value-added processes, while reflecting some of the most important indicators such as *turnover*, *start time* performance and *non-operative times*. According to the authors, the ideal value of OORE is 1, however, in practice the value could never be 1. The low value of OORE indicates the existence of non-value-added activities whether they are necessary or not, which in this case are considered wastes. This KPI can also be used to analyze the *over* and *under-utilizations*, as well as to determine in which of the components, inefficiencies are happening the most (Sonmez & Pintelon 2020).

According to Dewes (2018), although the tracking of KPIs separately provide some value to the management of an OR, all the KPIs should be looked at in a collective manner to provide a clearer picture and greater insight into the efficiency of the department in question.

2.2.3 Understanding of KPIs among diverse hospitals, stakeholders, and authors

As mentioned above, OR managers have faced a problem of definition when it comes to KPIs, especially when it comes to their understanding among different hospitals, stakeholders, and as possible to see now, authors as well.

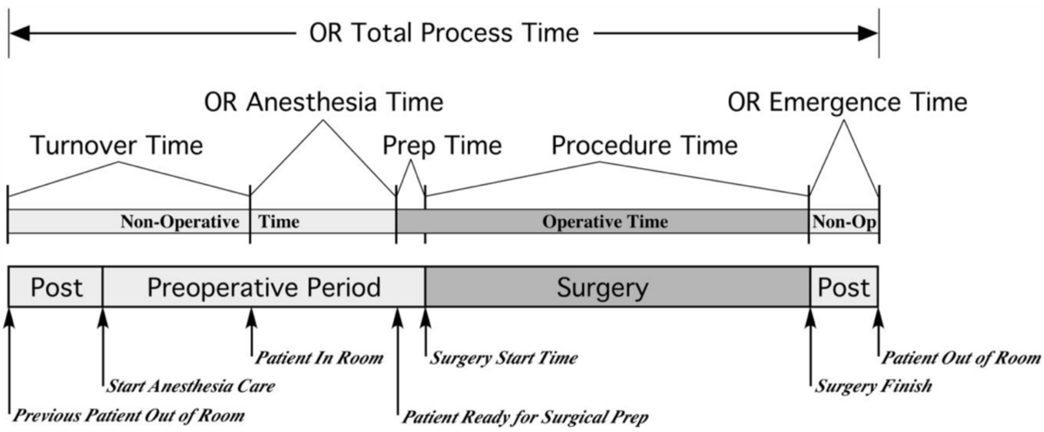


Figure 3. Visual representation of KPIs inside the OR, including demonstration of non-operative and operative periods (Sandberg et al. 2005).

Sandberg et al. (2005), for example, provided us with a visual representation of some of the most relevant KPIs in an OR, which intends to facilitate their understanding. However, it is essential to remember that the name attributed to the KPI, and their definition can vary from author to author, making it sometimes difficult for KPIs to be discussed and analyzed correctly.

Figure 3, represents the workflow of a typical OR considering all the *Operating Room KPIs* involved for Sandberg et al. (2005), while *Figure 2* represents the exact same typical workflow with the addition of possible delays to all the Operating Room KPIs for Sonmez &Pintelon

(2020). By looking at both figures and comparing them with the table under *APPENDIX B: Four categories of KPIs identified in the studied literature*, it is possible to identify some KPIs that, although meaning and being descriptive of the same processes of the OR, have different names attributed to them.

- The time from when the patient is anesthetized and ready for skin prep until the end of the surgical procedure is identified as “Operation Time” for Sonmez &Pintelon (2020), while for Sandberg et al. (2005) is called “Operative Time” which is the same used in Appendix C.
- The time consumed with the surgical procedure is identified as “Surgery” for Sonmez &Pintelon (2020), while for Sandberg et al. (2005) is called “Procedure Time” and in Appendix C, considered as “Operative Procedure Time”.
- The time from when one patient enters the OR until the time it exists or PACU assumes care is identified by Sonmez &Pintelon (2020) as “Procedure Time”, while in some of the studied articles of Appendix C, including Appendix C, is incorporated as “Total Patient OR Flowtime”.
- The time from when one patient enters de OR Suite until it leaves is identified as “Case Time” for Sonmez &Pintelon (2020), while for Sandberg et al. (2005) is called “OR Total Process Time” and in Appendix C considered as “Case Duration”.

This intensified what has already been proven, the necessity that all hospital stakeholders be aware of the hospital’s goal and needs, the internal KPIs definitions, and the processes in place to confer consistency to the hospital’s performance and responses (Dewes 2018).

2.3 Processes reengineering and redesign in healthcare

Key performance indicators provide institutions with a foundation on “how” a service is performing at a certain moment in time and help them clarify “what” points of the service possess a margin for improvement, which consequently helps with the process of decision-making. Furthermore, the measure of KPIs in the OR can help managers to drive the implementation of processes that improve the overall “patient safety, *throughput*, clinical outcomes, reduce of waste and inefficiencies, optimization of workflow and processes, and, performing prioritization of goals” (Dewes 2018).

As referred by Casaletto and Rajaratnam (2004), a process is a structured and measured set of activities that are designed to produce a specific output for a particular customer or market. It implies a strong emphasis on how work is done within an organization, and so, the concept of process reengineering appears too as an important and established tool for improving efficiency, rethinking, and restructuring a process to achieve dramatic improvements. This is why the proper OR management bases itself not only on the analysis of the KPIs but also on the constant optimization of the service through the introduction of new solutions to an entire chain of processes that are involved in the treatment of patients (Marjamaa, Vakkuri, and Kirvela 2008).

Following Casaletto and Rajaratnam (2004), the concept of reengineering is not new to any OR management team in healthcare. When it comes to surgical healthcare, for an institution to achieve significant efficiency shifts, all aspects of the healthcare provision must be looked into and improved, which means that improvements can and should happen at preoperative[4], intraoperative[5], and postoperative[6] levels (Fong, Smith, and Langerman 2016). Some approaches can and should be done at these three levels so that KPIs can be improved and the overall performance enhanced. Besides this, the role of stakeholders is also central to any efficiency improvement of surgical departments (see *APPENDIX C: Role of stakeholders in the process reengineering and redesign*).

Fong, Smith, and Langerman (2016), listed a set of solutions to the current processes that can be implemented to improve the efficiency of intraoperative levels and stated that designing and implementing an OR efficiency intervention can happen at three different ranges. A **small-scale efficiency intervention** represents the first line of improvement to an OR, usually easy to implement, followed by a **medium-scale intervention**, which according to the authors, requires the entire chain of processes of a team or floor to intervene, and lastly, **large-scale intervention,** which requires major institutional involvement. The solutions found in the literature can be seen in Table 1, already classified according to the levels of intervention proposed by Fong, Smith, and Langerman (2016). A detailed description of these solutions can be seen under *APPENDIX D: Definitions of the solutions presented in Table 1*.

Once again, to determine the best practices of the literature in improving processes inside the OR, nine papers (both empirical and literature reviews), comprising 1053 citations, were considered.

Harders et al. (2006), Stahl et al. (2006), Attarian et al. (2013), Marjamaa, Vakkuri, and Kirvela (2008), and Lee, Ding, and Guzzo (2019) have already been presented. The study of Casaletto and Rajaratnam (2004), was based on the application of process reengineering solutions to a

[4] Period between the decision to have surgery and the beginning of the surgical procedure itself.

[5] Period occurring during the course a surgical operation.

[6] Period following a surgical operation, usually until the moment of discharge.

specific surgical procedure, as well as standardizations and acquisitions of medical equipment's to improve the efficiency and reduce the "Operative Procedure Time".

Basto, Chahal, and Riedel (2019), Sandberg et al. (2005), and Fong, Smith, and Langerman (2016) all focused on the overall improvement of the OR by focusing on the application of parallel processing and the implications coming with it, on the introduction of ORF features when redesigning the OR, and by performing a systematic review on improvement efforts that can be applied to the intraoperative level, respectively.

Table 1. Proposed solutions by the literature to improve the OR's overall processes.

		Papers					Literature Reviews			
		Casalleto 2004 [(a)]	Harders 2006 [(b)]	Stahl 2006 [(c)]	Attarian 2013 [(d)]	Basto 2019 [(e)]	Sandberg 2005 [(f)]	Marjamaa 2008 [(g)]	Fong 2016 [(h)]	Lee 2019 [(i)]
	Number of Citations	14	246	131	51	8	257	175	127	44
	Number of Citations p/ Year	0.78	15.38	8.19	5.67	2.67	15.12	12.5	21.17	14.67
Class*	Solutions to Improve the Efficiency of Processes									
Small-Scale Efficiency Interventions	Workflow Redesign		x		x		x	x	x	x
	Standardization Processes & Instruments	x			x				x	x
	Team Huddles								x	
	Effective Scheduling Systems				x			x		
	Surgical Procedure Reenginering	x								
Medium-Scale Efficiency Interventions	Collection of Data & Outlining of Improvement Points (Monitoring of Overall Performance)				x			x	x	x
	OR / Procedure Checklists								x	
	Capacity Investments / Hiring Personnel					x	x	x		
Large-Scale Efficiency Interventions	Supply Chain Optimization								x	
	Real Time Locating Systems									x
	OR Space Redesign			x			x		x	x
	Parallel Processing		x	x	x	x	x	x	x	x
	Specialization Processes								x	
	Incorporation of New Technology	x	x	x			x			
	Acquisition of Medical Ergonomic Equipment	x	x	x						
	Incorporation of Pre Operative Clinics				x			x		
	Redesign of Processes		x	x			x	x		

*Intervention Classification according to Fong, Smith, and Langerman (2016).

Adapted from (a)Casaletto and Rajaratnam (2004), (b)Harders et al. (2006), (c)Stahl et al. (2006), (d)Attarian et al. (2013), (e)Basto, Chahal, and Riedel (2019), (f)Sandberg et al. (2005), (g)Marjamaa, Vakkuri, and Kirvela (2008), (h)Fong, Smith, and Langerman (2016), (i)Lee, Ding, and Guzzo (2019).

Research studies have proven that introducing new solutions such as the ones gathered in *Table 1* can improve some of the most relevant KPIs by improving the overall OR functioning. By far, and as possible to see, the adoption of parallel processing represents the most weighted solution. This solution comes heavily associated with the need to perform an OR space redesign, and the need to apply complementary solutions such as hiring new staff / specialized personnel and, consequently, a workflow redesign.

Parallel processing can be defined as the outsourcing of certain activities, meaning that, when redesigning the space and the processes, whenever possible, activities that do not require the OR are off-loaded to other locations, and activities that occurred serially in a typical OR setting would be made to run in parallel in the new OR space redesign (Sandberg et al. 2005).

In a conventional process, the OR follows a sequentiality of processes, which means that person 1 must complete task 1 before person 2 starts task 2, which imposes an artificial precedence that slows down work (Casaletto and Rajaratnam 2004). However, with parallel processing, a new workflow redesign is done, and task 1 can be done simultaneously with task 2 (Casaletto and Rajaratnam 2004).

These new functions give rise to the introduction of what are called operating rooms of the future, ORFs, since, as mentioned before, these possess features that allow for an innovative flow of work. Its architectural design can be seen under ANNEX A: Conceptual layout of the Operating Room of the Future (ORF) (Stahl et al. 2006). This design allows three phases usually performed inside the OR to be made in parallel since different rooms exist for different purposes, saving time in between.

2.4 Service design and the service blueprint

Service design is the process through which the service provided by an organization, as well as the allocation and consumption of resources is planned and designed. It is a "choreograph of processes, technologies and interactions driving the delivery of services, using people-centered perspectives" (Gomes 2019), focused on improving the value generated by an organization.

Service users no longer interact with brands in a single touchpoint, but instead, the complete user experience is made on the entire chain of processes involved in the delivery of the service (Xperienz 2022). The service design incorporates a multidisciplinary set of tools that help to bring everything, from people to props, and processes, together when addressing how the organization gets something done (Nielson Norman Group 2017).

According to Stickdorn et al. (2018), a set of tools and methods are used in service design. Service Blueprints represent one of those tools that "detail the processes of single departments or even employees/roles and how these processes are connected with each other and with customer activities.".

A service blueprint is a flowchart of processes emphasizing both visible and non-visible activities to the customer (Kumar and Steinebach 2008). It is "an operational tool that describes a service in detail", meaning that each activity happening during the service provision – service encounter – is mapped into a flowchart. In every service encounter, the customer, the patient, interacts with a concrete service interface. Besides this, it represents a visual tool where a better understanding of the service offerings can arise since it is more easily understood by involved stakeholders rather than verbal descriptions (Holdford 2019).

In addition, it is well known that the perception of a customer over a company's value, meaning the satisfaction or dissatisfaction with the provided service, is directly related to every contact between the customer (patient), and the company (medical institution). This because, services no longer offer their value embedded in tangible assets, but on the contrary, value is more often co-created when service encounters happen (Patrício et al. 2011). Because of this, service blueprints are helpful when needing to understand adding value activities of a firm's offerings and how to differentiate those offerings from competitors within the market (Patrício et al. 2011). These tools "are also helpful describing the competitive advantage of one innovation over another" (Holdford 2019).

As mentioned above, service blueprints represent a tool potentially used to conduct a detailed analysis of steps in the service provision, extremely used whenever there is a need to design new services or improve existing ones. Being healthcare such an important sector in any country's population, giving responses to great amounts of people, in constant evolution and consequently in constant need of outlining and improvement, it is possible to say that the use of service blueprints could benefit the service provision and monitoring of the processes value in this sector. However, if we look at it from the healthcare perspective, and although being essential and used in the development and improvement of established services and the way services are designed, service blueprints constitute a rare tool (Holdford 2019).

Kumar and Steinebach (2008), used a service blueprint to outline the medical errors that could happen when providing surgical care to patients in a US medical center and standardized the processes through which this provision was made to reduce the chances of stakeholders performing medical errors. Kumar and Steinebach (2008), have a total of 84 citations, from which nine also apply service blueprinting. Aside from this, some literature was found on how a service blueprint could be applied to concierge (Quadros et al. 2022) and pharmacy (Holdford 2019) (Silva et al. 2021) services of a hospital. However, no other evidence of service blueprints was found in the literature of surgical departments or in any of the articles that cited (Kumar and Steinebach 2008) related to healthcare.

It is possible to conclude the importance that the management of ORs has on the performance levels of the department as well as on the consumption and suitable allocation of the scarce resource that OR time is. Besides this, it is known that with different stakeholders, there are different perceptions and envisions on how an operating suite should be managed and what can be considered "efficient", from which it is necessary to clearly define goals.

Aside from this, KPIs represent an essential piece in managing ORs, efficiency analysis, and how these are directly related to the processes in place. Although having determined the existence of a problem of definition and the consequences that this problem can have among stakeholders of the same institution, it is known that with the right level of communication and involvement of all levels of stakeholders, institutions can reevaluate, replan, and reorganize the processes to achieve significant efficiency improvements.

Besides this, it can be acknowledged the weight that the OR workflow can have on the overall OR performance and how ORF features can provide a smarter workflow for operating room functioning, among many other solutions to the processes. Lastly, how the application of service blueprinting tools can help map the service and identify possible points of improvement, as well as easiness in getting all involved stakeholders to understand the solution.

3 Problem Characterization

Although in theory the healthcare in Portugal is supposed to respond to the patients in need, in the moment of need and in time of need, this is something not always easy to fulfill. The ability for the SNS to provide medical responses does not always accompany the needs of the Portuguese population, which leads Portugal's public healthcare to now rely on the integration of waitlists for the access of medical care.

The OR represents the environment directly affecting the performance of surgical activities, and although influenced by other factors, it is the main contributor to the surgical responsiveness to citizens. Being it the main contributor in terms of responsiveness means that the amount of surgical cases performed per day of work are related to the processes happening inside the OR, which means that fully understanding how the OR time is being utilized, what processes are in place, how should these be improved and how its maximization in terms of utilization is ensured, plays a role in determining its efficiency and performance level.

This research project stand right on top of the intention to make a contribution to that optimization of responses by fully understanding how ORs have been functioning and operating and how could these be improved based on the necessities of the Portuguese population, and with this as a foundation, propose a solution that fits the hospital, and that can directly contribute to the increase of surgical activities per day and per OR so that ultimately, contributes to the minization of waitlist. Needless to say that an efficient and maximized OR will allow for the performance of more surgical cases, and consequently help to fight waiting lists.

For this reason, it is **important for us to give answers to both research questions (1.2) which will support the determination of the current state and the best solution to apply based on the hospital needs**, while having in mind the overall objective of enhancing the surgical activities and reduction of waiting lists, and design an improvement proposal to the current service design, so that it:

- Provides a greater contribution to the surgical response of the population and consequently the reduction of waiting lists to access surgery – reduction of the Surgery Enrollment List (Lista de Inscritos para Cirurgia, LIC) = enhancing of *throughput* and *OR Utilization Rates*.
- Contributes and becomes economically sustainable = *reducing of under and over utilization*, *surgical cases performed*.

Waiting lists have been known for a very long time, however, with the Sars-Cov-2 pandemic, this problem has growned into a different dimension. According to an article posted by CNN Portugal (2022),*"In all, Portugal currently has 203 051 people in the Integrated System for Management of Enrollments for Surgery, SIGIC ... at least 42 000 people on the LIC have already exceeded the clinically defined TMRG. The average waiting time considered acceptable is 180 days – 6 months - for nonurgent and nononcologic surgeries."*.

Taking a look into the northen health region of Portugal, according to the Portal of Transparência (2022) in december of 2021, there was a total of 67 967 citizens registered for surgery, integrating the LIC, 33.5% of the total amount of registered people. From these 67 967 citizens, 61 588 citizens (90.6%) were still inside the Guaranteed Maximum Reponse Time (Tempo Máximo de Resposta Garantida, TMRG), which means that around 6 379 (9.4%) had already been waiting for surgery for more than 6 months.

It is important to acknowledge that the truthfulness of prediction has not been real, misleading patients and giving them a prediction far from the actual waiting time – people actually end up waiting far more time for a surgical response than the prediction (Supervisor inside CHUPorto). In addition to this, it is also important to recognize that people integrating the LIC, in one way or another, need the surgical care to be provided to them as soon as possible and it does not contribute for the patients wellbeing to have to wait months for a response, especially when some of them have their lifes on standby while waiting. Needless to say that this situation is not economically favorable either.

All this sums up into the necessity to **ensure a greater response and daily production** – *throughput*, *OR utilization rates* - in order to **fight the waitlists and increase the number of surgeries performed within the TMRG.** This requires greater efficiency on behalf of hospitals and especially surgical departments. A greater investment of resources to solve this problem is thus mandatory.

Another aspect that has to be considered is that **patients expectaction and lifestyle have changed and the society pressure as also increased**. People now, more than ever, are extremelly dedicated into their professional careers, and in cases, some are actually demanded to work harder than ever by their companies, which means that staying away from their jobs and active lifestyle is becoming less and less accepted. This because, the world has been evolving and consequently increasingly demanding a faster recovery from patients. Even patients, as more informed actors, also demand that a state-of-the-art service is provided to them, which in a surgical perspective tends to be less and less invasive.

It is thus important to take into consideration the **needs of the Portuguese citizens and while not forgeting economic traits, invest into better and quicker responses**.

3.1 Study site

CHUPorto is a central and university hospital thanks to its association with the Abel Salazar Institute of Science of the University of Porto (Instituto de Ciências Biomédicas Abel Salazar da Universidade do Porto, ICBAS), which aims at achieving excellence in all the performed activities in a global and integrated perspective of health (Centro Hospitalar Universitário do Porto Junho 2021). As mentioned in the *Introduction* section, the CHUPorto complex is made of four differentiated units, however this dissertation only incurred on the surgical department of the HSA unit.

The following table, *Table 2*, demonstrates the installed capacity of the entire complex, CHUPorto, in comparison to the installed capacity of the HSA unit, as well as the percentage of HSA installed capacity out of the whole complex. This way and as possible to see in *Table 2*, the HSA represents the biggest unit of the CHUPorto, having 77,7% of the available beds of the entire complex installed capacity, and 39,3% of the total number of operating rooms (considering that 7 of them are delivery rooms and so are a part of the CMIN unit).

Table 2. Installed capacity of the CHUPorto and HSA (Centro Hospitalar Universitário do Porto Junho 2021).

Installed Capacity		
CHUPorto	**HSA Unit**	**Percentage***
848 beds	659 beds	77,7%
46 beds in the Daycare Hospital	43 beds in the Daycare Hospital	93,5%
32 beds in the Intensive Care Unit	32 beds in the Intensive Care Unit	100%
35 operating rooms**	11 operating rooms	39,3%
68 beds in the Recovery Unit	23 beds in the Recovery Unit	33,8%

*Percentage of HSA installed capacity out of the total installed capacity of the whole complex, CHUPorto (including the four units).

**Includes operating rooms and 7 delivery rooms.

3.1.1 HSA operating suite

In June 2021, the HSA had a total of 14 operating rooms (Centro Hospitalar Universitário do Porto Junho 2021). However, in November 2021 a new reformulation was made as a consequence of the Sars-Cov-2 pandemic and with the purpose of giving support to specialties affected by the pandemic and in need of greater resources, which ended in the hospital having only 11 operating rooms available. As possible to understand, this situation is not ideal to the surgical production of any hospital, and although currently functioning this way, the ultimate goal of the hospital is to go back to the 14 operational OR's as soon as the situation allows it.

This way, the current HSA has then a total of 11 traditional OR's, also called conventional operating rooms, which can be divided into:

- 6 of them located in the Central Operating Suite (*Figure 4*).
- 3 of them located in the Orthopedics Operating Suite (*Figure 5*).
- 2 located in the Neoclassic Operating Suite (*Figure 6*).

From these 11 OR's, 9 operate during a period of **12h a day, from 8h to 20h, Monday to Friday** (in some cases Saturday morning as well) **performing elective[7] and additional[8] surgeries**, while the other 2 are allocated to the **emergency department**, meaning they operate a total of **24h a day, full week including weekends, for emergent surgeries**.

3.1.2 HSA operating suite layout

As mentioned above, the HSA has three different operating suites, where all the surgical activities of this unit take place.

The **Central Operating Suite** is composed with six operating rooms (D, E, F, G, H, I), see *Figure 4*, which each has their own scrubbing room. Besides this, it has five anesthesia induction rooms, a cafeteria, two changing areas and one PACU. It is, however, **important to note** that, although this operating suite has already physically designed and structured anesthesia induction areas, the functioning processes of the OR do not include it, meaning that **those areas are completely ignored by the OR staff and surgical teams.** Everything, from the start until the end of anesthesia, is performed inside the OR. This helps to sum up that although having some ORF features installed, the HSA unit still functions in a fully conventional way.

The following figure, *Figure 4*, is a visual representation of the Central OS where the physical layout can be seen. The arrows represent the place from where the patient enters.

---

[7] Surgery that is scheduled to take place on a certain day and at a certain time.

[8] Surgery that is performed in a scheduled way, but usually outside the normal working hours, scheduled for special block times, representing an additional activity for the hospital and surgical teams. Being an additional activity, it is also invoiced as an extra case.

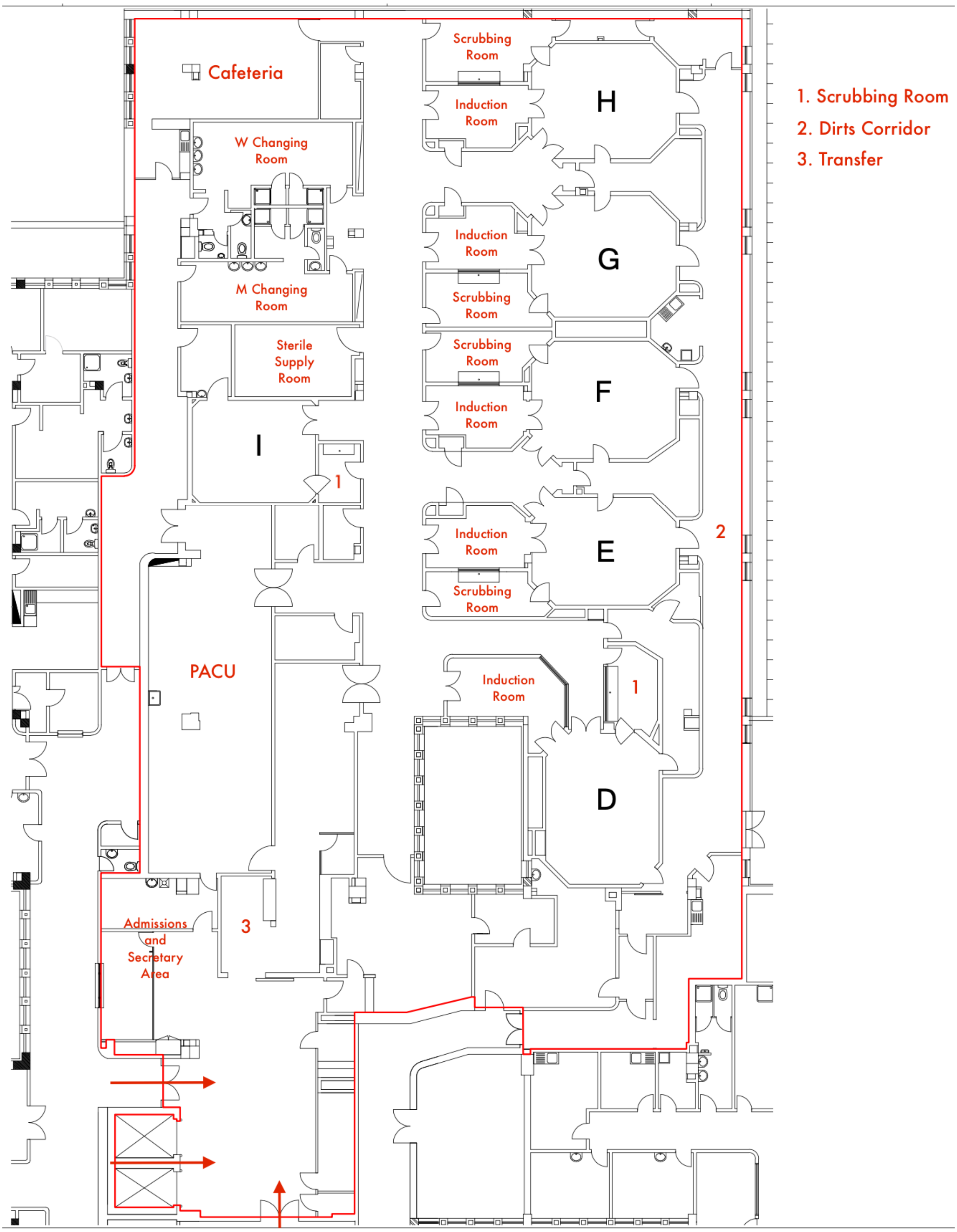


Figure 4. HSA, Central operating suite layout (retrieved and adapted from a document provided by the hospital).

The **Orthopedics Operating Suite** is located in the same floor as the Central OS and possesses a total of three ORs (A, B, C) with two induction rooms under the same conditions as the previous one (although physically having them, they are not incorporated in the OR functioning processes).

Besides these, *Figure 5*, shows how this OS also includes three sterile supply rooms (identified as sterile supply room and number 1, since it can include prosthetics and specialized orthopedics equipment's), two changing areas (identified with number 2 and 3) and one scrubbing room (identified with number 4) that is accessible to the three OR's.

Figure 5 is a visual representation of the Orthopedics OS where the physical layout can be seen. The arrows represent the place from where the patient enters the OS.

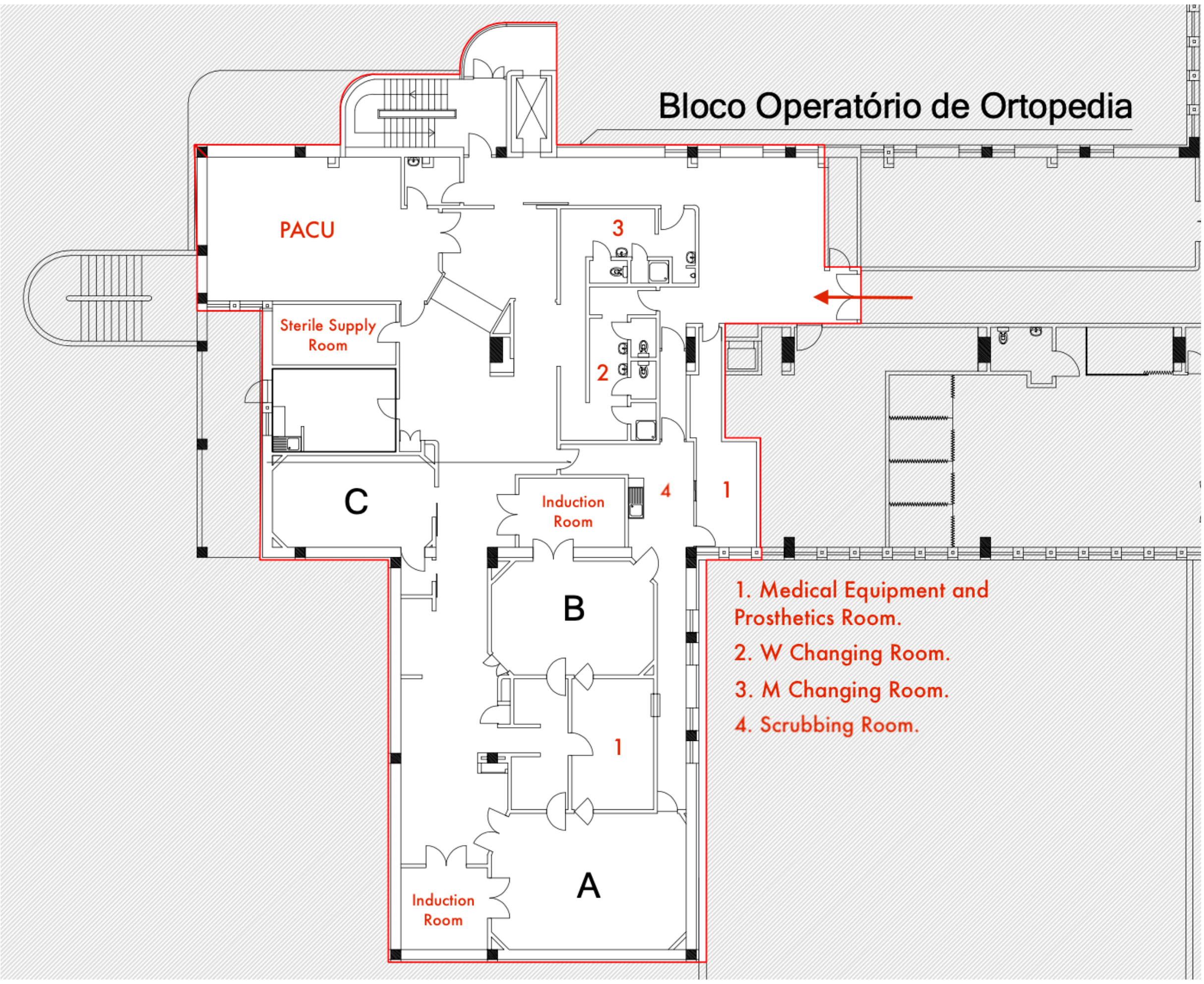


Figure 5. HSA, Orthopedics operating suite layout (retrieved and adapted from a document provided by the hospital).

Lastly, the **Neoclassic Operating Suite** is the smallest OS, possessing a total of two OR's (NC1 and NC2) which share the same scrubbing room and the same PACU. This OS has one sterile supply room and does not have any induction areas included, meaning that both the physical design and the processes in place are run according to a conventional OR setting.

Figure 6 is a visual representation of the Neoclassic OS where the physical layout can be seen. The arrows represent the place from where the patient enters the OS.

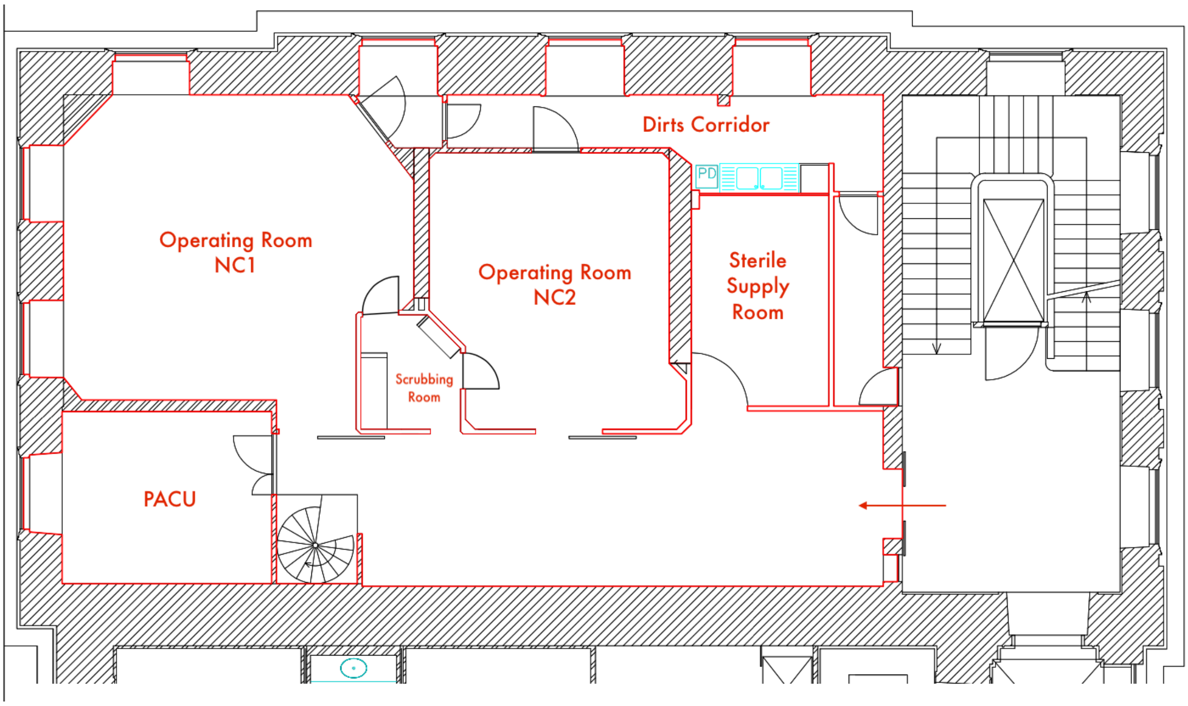


Figure 6. HSA, Neoclassic operating suite layout (retrieved and adapted from a document provided by the hospital).

Different surgical specialties collaborate together through these OR's to provide care from a total of 11 surgical areas, as seen in the following *Table 3*.

Table 3. Surgical specialties coexisting in the HSA OSs.

Central Operating Suite (*Figure 4*)	Orthopedics Operating Suite (*Figure 5*)	Neoclassic Operating Suite (*Figure 6*)
General Surgery	Orthopedics Surgery (ORT)	Plastic Surgery
Vascular Surgery (CV)		Neurosurgery (NC)
Urology Surgery (URO)		
Otorhinolaryngology Surgery (ORL)		
Ophthalmology Surgery (OFT)		
Obesity Surgical Treatment Unit (UTCO)		
Maxillo-Facial Surgery (CMF)		
Transplant		

3.1.3 OR block time allocation

As possible to see in *APPENDIX A: Surgical planning and scheduling,* and as mentioned in the *Literature Review*, by far the most important step in maximizing OR efficiency is to allocate OR time appropriately. The HSA follows both methods presented in the literature, in different situations, when allocating their OR Block Time.

For the 9 OR’s that perform elective and additional surgery, the OR time is allocated through the methodology of Block-Scheduling, meaning that Block Times are attributed to specialties which will then schedule their surgeries according to the rules of admission for surgery (severity and priority levels). On the other hand, the 2 OR’s that are allocated to the emergency department don’t have scheduled surgeries since the ones being performed here arise from emergent situations, which means that a method of Open-Scheduling is followed, combined with the normal rules of admission for surgery.

The current OR Block Time attribution to specialties followed in the HSA unit can be found in the following table, *Table 4*, which was updated last November of 2021.

Table 4. Current weekly OR block-time allocation to the different ORs (adapted from a document provided by the hospital).

Operating Suite (OS)	OR’s	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Neoclassic Operating Suite	NC1	NC / NC	NC / NC	NC / NC	NC / NC	NC / PEC NC	SIGIC NC	
	NC2	NC / SIGIC NC	NC / SIGIC NC	NC / SIGIC NC	PLASTIC / SIGIC NC	PLASTIC / PEC NC		
Orthopedics Operating Suite	A	ORT / ORT	ORT / ORT	ORT / ORT	ORT / ORT	ORT / PECC	SIGIC ORT	
	B	SU / SU	SU / URG DIF	SU / SU	SU / URG DIF	SU / SU	SU / SU	SU / SU
	C	ORT / SIGIC ORT	ORT / SIGIC ORT	ORT / SIGIC ORT	ORT / SIGIC ORT	ORT / PECC	SIGIC ORT	
Central Operating Suite	D	HBP / SIGIC OFT	COLON / COLON	HBP / HBP	ESOFGAS / SIGIC URO	HBP / SIGIC HBP		
	E	ORL / ORL	ORL / ORL	UTCO / SIGIC UTCO	URL-OFT* / SU	CV / SIGIC ORL	SIGIC ORL	
	F	SU / SU	SU / SU	SU / SU	SU / SU	SU / SU	SU / SU	SU / SU
	G	URO / URO	URO / LIVING DONER URO	ESOFGAS / SIGIC URO	COLON / SIGIC COLON	URO / SIGIC EXTRADIGESTIVE	SIGIC UTCO	
	H	CV / CV	CV / CV	URO / URO	CV / CV	URO / TRANSPLANT	SIGIC URO	
	I	URO / PLASTIC	CMF / SU	CMF / ORL	EXTRADIGESTIVE / EXTRADIGESTIVE	CMF / SIGIC OFT		

*On alternate weeks, during the morning period, the OR is reserved for URL or OFT.

In *Table 4*, it is possible to see the time attribution made to every OR of the three OSs, and how this distribution of time is made every day of the week. Besides this, it is possible to see how the OR Time it is distributed into two block times per day (the morning period and the afternoon period). The morning period which goes from 08h15 (time when the first patient of the day should already be in the OR) until 14h30, and the afternoon period starting at 15h15 (again, time when the first patient of the afternoon should already be in the OR) until 19h30. The fulfillment of these predefined block times, allow a margin of 15min before the first surgery of the day with the purpose of giving time for the circulating nurse to prep the OR in terms of instruments and a 30min window after the last surgery of the day for the cleaning team to clean everything and leave the OR ready for the next day.

Besides this, *Table 4*, also shows, highlighted in grey, the OR’s allocated to the emergency department which only performs emergent surgeries. In this situation, and as shown, the OR works for a period of 7 days a week 24h a day.

4 Methodology

According to Sousa, Driessnack, and Mendes (2007), a research design represents the framework through which a study is performed, analyzed, and implemented with the goal of answering determined research questions. Besides this, it is important to keep in mind that different studies and different research questions can require different types of research designs to be combined.

This research project focused on improving the current ORs of the HSA unit while analyzing the current processes in place (AS-IS) and, propose a new service design so that it would improve the overall performance of the department, give answers to the research questions and above all enhance the surgical activities and contribute to the reduction of waiting lists.

With this purpose, and while keeping in mind the goals of this dissertation, some research methods were selected. A quantitative research over relevant and important KPIs and OR processes was made. The collected and analyzed data, as well as all the processes gathered, allowed for a relationship to be made between KPIs and processes, outlining the improvement points in need of change when designing the surgical service. Throughout this dissertation, service blueprinting was applied to design the AS-IS (service blueprint with the incorporation of KPIs) and the improved proposal of the OR processes. The described methodology can be seen in the following figure, *Figure 7*, with the steps performed.

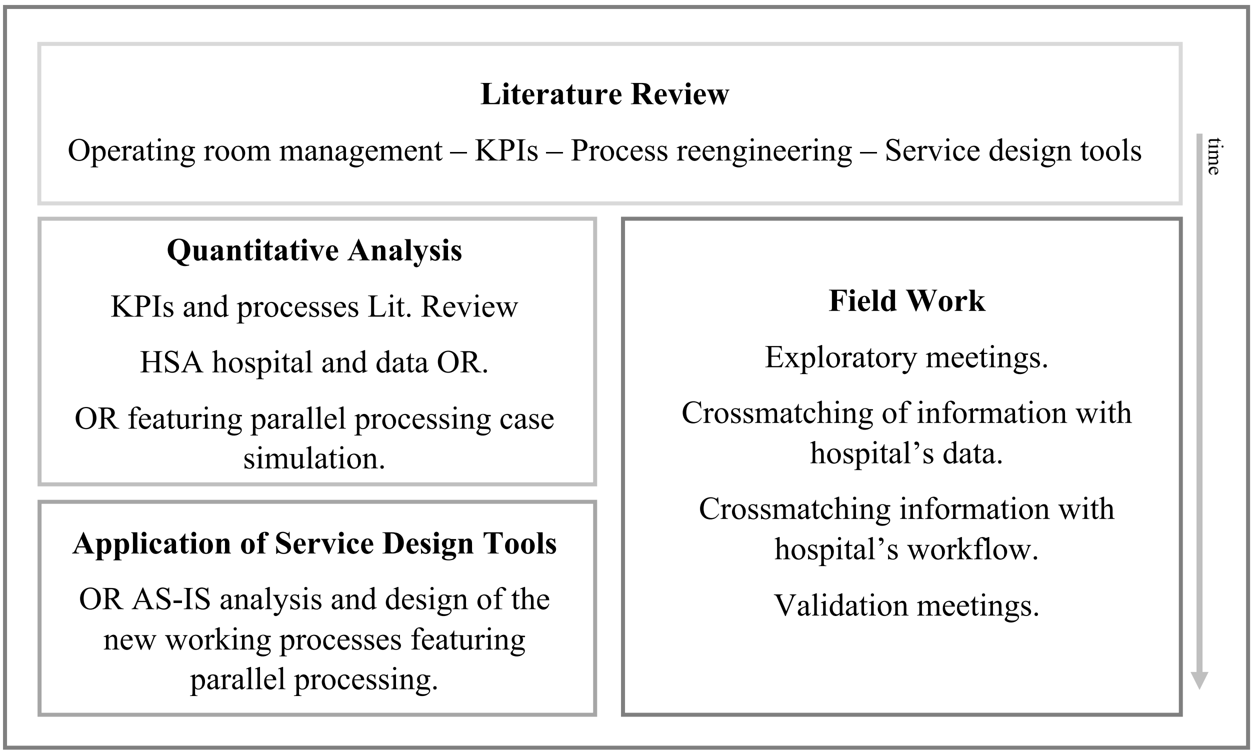


Figure 7. Research methodology followed through this dissertation.

4.1 Quantitative methods

It was extremely important to initially, in a first stage of this dissertation, collect a set of quantitative data to perform a retrospective analysis over the KPIs in a four-year window, from 2018 to 2021, and determine how these had been evolving over the course of times – the data was collected from ISs already in use inside the hospital, namely data gathered from the *AIDA BI (AIDA 2022)*, section *"Top Management of the OR" ("Gestão de Topo do Bloco").* However, and because it was acknowledged in the literature review the existence of a problem of definition and relevance on some KPIs, it was necessary to, with exploratory meetings and a critical sense over the gathered data, determine which KPIs were most relevant and important, and what processes were used along the dissertation (crossmatching of the information found under the literature review and the inside hospital's data).

According to Sousa, Driessnack, and Mendes (2007), a quantitative analysis revolves around numbers and intents in answering research questions in a reliable way since it settles on numerical relevant data (Pathak, Jena, and Kalra 2013).

Quantitative analysis belongs to the most dominant research framework and is essentially deductive, meaning that "measurements are made, analysis is applied and conclusions are drawn" (Watson 2015), which is essential since it helps to analyze data in terms of trends and relationships. This way, quantitative methods were then applied in three different and complementary stages of this dissertation:

- After collecting the data in the Literature Review, and gathering a set of well known KPIs and improvement solutions in the processes, it was necessary to crossmatch this information with the inside reality of the hospital (inside hospital's data) and inquire what KPIs were used inside the hospital and also, which processes were already in use, in course of implementation and possible to implement in a near future.
- Quantitative methodologies were applied to analyze the hospital's numerical data of the OR (of the KPIs used inside the hospital) in terms of trends and evolution to get a retrospective perspective and analysis over the state of some of the most relevant and decisive KPIs.
- Lastly, a quantitative analysis was applied to the simulation of the proposed solution to see what major differences could be seen in the behaviour of some KPIs and how these would affect the overall performance.

To analyze the collected data quantitatively, ®Microsoft Excel was used in both three phases of application.

4.2 Service design

As mentioned in the Literature Review, service blueprinting is a methodology that helps an organization to identify failure points, areas for improvement, and innovation opportunities (Bitner, Ostrom, and Morgan 2008). Because of services' intangible nature, service blueprinting represents an extremely relevant approach to their visual understanding between different stakeholders.

This tool was used in the development of this dissertation with the aim of fully master the service provision. Initially, the AS-IS processes were mapped and analyzed to evaluate how the OR processes had been functioning since studying the current processes helps to determine in which points the processes can be optimized to achieve a better and more efficient OR. It was also important to in an initial phase of design understand how the processes were related with the KPIs and incorporate them in the development of the Service Blueprint (AS-IS).

With the current processes designed and based on the literatures best practices combined with the hospital's needs, a performance improvement proposal was developed with the introduction of parallel processing. The design of service blueprints also visually allowed for a comparison to be made between the AS-IS and the new service design.

4.3 Exploratory and validation field work

A set of meetings in the hospital's facilities were performed with an exploratory and validatory sense. A list, as well as an exposition of the topics approached in each meeting, can be seen under *APPENDIX E: Exploratory and validation meetings, dates and topics*.

Topics as the following ones were approached during these meetings:

- Determination and discussion about KPIs definitions, and about which were used inside the hospital so that a crossmatching of that information with the literature findings could be done.
- Determination, in the same way as the previous topic, of the processes that were already being followed inside the hospital, which were in course of implementation, and which could be more interesting to the hospital's needs and the project main objective.
- Discussions on the numerical data gathered and validation on the performed analysis.
- Analysis, explanations, and discussions about how the current OR workflow was:
    - How the OR worked until now, the patient's circuit after entering the OR, who received the patients, the ORs layouts, how was the allocation of anesthetic teams made and how the following of the patient was done.

  - How was the surgical time allocated to the OR, which map of OR Time allocation was being followed at the moment.
- Analysis and discussions of the SB versions (both AS-IS versions and proposed solutions). Parallel processing validity and application in real life, as well as discussion over possible implications and downsides of the design. Validation of the SB results.
- Discussion on the parallel processing simulation.

This represented a parallel activity performed throughout the development of this dissertation, which contributed with insights and into the existing and internal data and information. Also allowed for a validation of each step to be made.

5 Results and Discussion

5.1 Key performance indicators

Under the systematic review that was made about previous research studies and presented in the second section of this dissertation, *Literature Review*, it was possible do determine a set of KPIs intensely significant when analyzing the efficiency of overall OR performances.

From *APPENDIX B: Four categories of KPIs identified in the studied literature*, it is possible to see that a total of 28 KPIs were identified in the literature, from which some are useful to the measurement of efficiency and performance levels, and others can be more easily associated with the monitoring of success of outcomes. However, although having determined 28 KPIs in the existing literature, based on the data gathered from the hospital's IS, it was possible to determine that only some KPIs are used to analyze the performance of the ORs inside the hospital unit, and also that not every KPI used presents a relevancy to the study in case.

Table 5. KPIs used inside the HSA unit and KPIs considered in the dissertation.

		Papers										Literature Reviews						
		Harders 2006 [a]	Stahl 2006 [b]	Macario 2006 [c]	Jerico 2011 [d]	Porta 2013 [e]	Attarian 2013 [f]	Fixler & Wright 2013[g]	Costa 2015 [h]	Attigah 2017 [i]	Morris 2018 [j]	Marjamaa2008[k]	Rathstein 2018 [l]	Casar 2019 [m]	Lee 2019 [n]	Sonmez 2020 [o]	Jin & Liu 2022 [p]	Jin 2022 [q]
	Number of Citations	246	132	261	15	48	51	51	16	9	8	177	75	6	44	2	11	4
	Number of Citations p/ Year	15.4	8.3	16.3	1.4	5.3	5.7	5.7	2.3	1.8	2.0	12.6	18.8	2.0	14.7	1.0	11.0	4.0
KPIs	KPIs Description																	
Total Patient OR Flowtime	Time between the entry of the patient in the OR until the exit of the patient from the OR or until PACU assumes care.		x		x				x					x		x		
Operative Time	Time between the patient ready for surgical prep and the end of the operating procedure.								x					x		x	x	x
Non-Operative Time	Time when no operative activities take place. Includes TOT + AIT + AET.	x							x			x				x		
Turnover Time	Time from when one patient exits an OR until the next patient enters the same OR. Time needed to clean and get the OR ready for next surgery.	x	x	x	x		x	x	x		x	x	x		x	x		
Anaesthesia Induction Time	Time from when the patient enters the OR until it is ready for skin prep. Anesthesia administrated to patient.	x	x			x			x			x		x		x		
Anaesthesia Emergence Time	Time between the end of na operative activity and the patient out of the OR.	x										x				x		
First Case Start Time Accuracy	Measures the percentage of first cases of the day that start on time. An on-time start is usually defined as the patient being in the OR at the scheduled start time.						x	x	x				x		x			
Under & Over Utilization	OR usage when compared to the OR time which was budgeted. Includes the measuring of costs associated with underused or overused OR time.		x	x				x			x	x	x		x	x		
Throughput	Number of surgical cases per OR block time or per day.		x				x			x	x	x				x		
Cases per OR	Number of cases per OR.						x		x									
OR Utilization Rates	Occupancy Rate of OR time used against that which was budgeted.							x		x	x		x		x		x	x
Surgical Safety Check Rate	Safety inside the OR. Filling of safety forms before, during and after the surgical procedure.																	

Adapted from [a]Harders et al. (2006), [b]Stahl et al. (2006), [c]Macario (2006), [d]Jerico Mde, Perroca, and da Penha (2011), [e]Porta et al. (2013), [f]Attarian et al. (2013), [g]Fixler and Wright (2013), [h]Costa Ada et al. (2015), [i]Attigah et al. (2017), [j]Morris et al. (2018), [k]Marjamaa, Vakkuri, and Kirvela (2008), [l]Rothstein and Raval (2018), [m]Casar Berazaluce et al. (2019), [n]Lee, Ding, and Guzzo (2019), [o]Sonmez & Pintelon (2020), [p]Jin and Liu (2022) and [q]Jin et al. (2022).

A total of 11 KPIs are used inside the hospital unit and considered in this dissertation, that can be seen in *Table 5*, which is an adaptation of the table under *APPENDIX B: Four categories of KPIs identified in the studied literature*, representing 37.5% of the total 28 KPIs identified in the literature and having more than half the total number of citations, around 55.2%. In addition, the HSA also considers a KPI called "Surgical Safety Check Ratio" – highlighted in grey on the table presented above, *Table 5* - which appeared as a method of ensuring safety at all times during the surgery, especially due to the increasing surgical volume in later years. This checklist can be seen under *ANNEX B: Surgical Safety Checklist (WHO 2010)*.

5.2 Data analysis

As mentioned above, before the reformulation the HSA unit used to operate with 14 functional ORs, while in 2021 only 11 continued to operate. However, although having a lower number of operational ORs, it is possible to see from *Table 6*, that 2021 did not represent the year with the lowest number of surgical block times. *Table 6* represents the analysis of data regarding surgical activities, surgical block times and throughput of the last four years.

Table 6. Data analysis (KPIs: surgical activity + surgical block times + throughput).

KPI	2018	2019	2020[9]	2021
Surgical Activity (Base + Aditional)	7546	9107	6706	7782
Number of Surgical Blocktimes	3382	4055	3172	3452
Operational OR's	14	14	14	11
Throughput	2.23	2.25	2.11	2.25

Comparing the most recent years data (2021) with 2019, it is possible to see that the lower number of operational ORs resulted, as a consequence, in a lower number of surgical block times in 2021 (not lower than 2018 though, which is impossible to understand what might've happen during that year). However, although having a lower number of block times, the hospital performed at a much higher performance level in 2021 achieving an equal throughput (around 2.25 patients per block time).

[9] It is important to consider the presence of the virus Sars-Cov-2 in 2020, which represented an impediment to the elective surgical activity during that year and the redirection of resources, which is probably the reason why that same year presents the lowest number of surgical blocktimes and lowest value of performed surgical activity.

With an equal *throughput* in 2019 and 2021 it is then important to ask why and how. **Why did the *throughput* was the same and how did this happen when a lower number of operating rooms were operating?**

Throughput, as mentioned before, represents the number of surgical cases performed per OR block time or per day, where a higher throughput means that the OR is performing more surgical cases per block time, which means less time is being lost in non-operative activities, meaning, time management was more efficient, especially when a lower number of ORs were working – more cases were performed by OR (2019 = 650.5 cases p/ OR; 2021 = 707.5 cases p/ OR).

To better understand how, there are other KPIs that need attention. The throughput is majorly affected by the turnover since this one represents a non-operative activity.

Focusing on Turnover time, which represents the time from when one patient exits an OR until the next patient enters the same OR, this metric is measured in minutes, usually direct, and can vary from specialty to specialty, depending on the surgical procedure that just happened and on the complexity of the following one. This because turnover time consists of the time needed to clean the OR and get it ready for the next surgery, whose complexity varies. *Table 7* presents an analysis of the turnover time over the last four years of surgical activity.

For example: Ophthalmology Surgery = average turnover of 9.73min; Neurosurgery = average turnover of 20.98min; Data collected from the year of 2021. The full table can be seen under *APPENDIX F:Data analysis of surgical specialties (KPIs: surgical activity + surgical block times + throughput + turnover time + OR utilization rates)*.

Table 7. Data analysis (KPI: turnover).

KPI	2018	2019	2020	2021
Turnover ≤ 20 minutes (%)	77.9	76.05	72.13	70.37
Turnover between 20 and 40 minutes (%)	16.84	17.11	20.28	21.74
Turnover > 40 minutes (%)	5.26	6.84	7.59	7.89
Average Turnover (min)	15	14.80	15	17.6

According to the literature, the ideal turnover stays under a 20-minute window, however, some can exceed. When turnover stands between 20 and 40 min it is still considered acceptable although not ideal since more time is being wasted in non-operative activities, while a turnover above 40 minutes represents a red flag since too much time is being lost in non-value-added activities when it should be used with operative activities (performing of surgical cases).

As for the OR Utilization Rates, these are directly influenced by the time that is consumed for non-operational activities as well. This value represents the percentage of the total time available that is being used to perform surgical cases. *Table 8* shows how the utilization of OR time as evolved over the course of the last four years, with and without considering the turnover.

Table 8. Data analysis (KPIs: utilization rate + utilization rate without turnover time).

KPI	2018	2019	2020	2021
Utilization Rates (%)	84.10	82.80	81.20	88.80
Utilization Rates w/o Turnover Time (%)	79	77.60	76.50	83.10
Percentage of time consumed with Turnover (%)	5.10	5.20	4.70	5.70

By analyzing the table above, the overall utilization rate of 2021 was higher than in the previous years, even without the turnover value, which on average increased. The increased percentage of time consumed with the turnover time, as possible to see in *Table 8* and confirmed in *Table 7*, where the average turnover in 2021 was of 17.6min, demonstrates that activities performed during this period took longer than in previous years, which can be due to the increased concern with cleaning standards that emerged during the Sars-Cov-2 pandemic. Although higher, the turnover of 2021 does not represent a concern since it continues to be under 20 min.

It is then understood from the data that, although having a lower number of available ORs in 2021, the department's throughput was equal to 2019 – the highest of the last four years, not because of a minimization of the turnover time (turnover actually increased), but probably because available OR time was utilized more efficiently.

Comparing 2019 to 2021 (both years with the same throughput), it possible to conclude that:

- 2019: higher number of operating rooms (positive factor), with a lower percentage of time consumed with turnover (positive factor) = however, 77.6% of utilization rate.
- 2021: lower number of operating rooms (negative factor), with a higher percentage of time consumed with turnover (negative factor) = 83.1% of utilization rate, OR time monetized.

Overall, when trying to maximize the performance of any operation room, the time available should be monetized so that the maximum amount of time gets spent in operative activities and consequently, that the minimum amount of time gets spent in non-operative activities or dead periods of time. In general, this can ultimately be achieved if processes of the OR get optimized, turnover gets minimized and OR utilization rates get maximized. **In this situation's hospital,**

where the average turnover stands, with a significant difference, **under 20min, and the ORs utilization rates stands around 89%**[10]**,** the main focus should be made on **maximizing the usage of the ORs available time by redirecting processes.**

5.3 Workflow and functioning processes

The HSA ORs currently follows a linearity in terms of processes – activities are performed sequentially. This because, as mentioned before, although having physically designed support rooms, all the stakeholders involved perform all surgical tasks inside the same room (in this case, inside the OR).

This way, to better understand the workflow of the OR under this method of working and to avoid problems regarding the KPIs definitions and more easily identify them, *Figure 8* was developed with the same terminology considered in this dissertation. *Figure 8* is a combination between the diagrams, *Figure 2* and *Figure 3,* presented in the Literature Review.

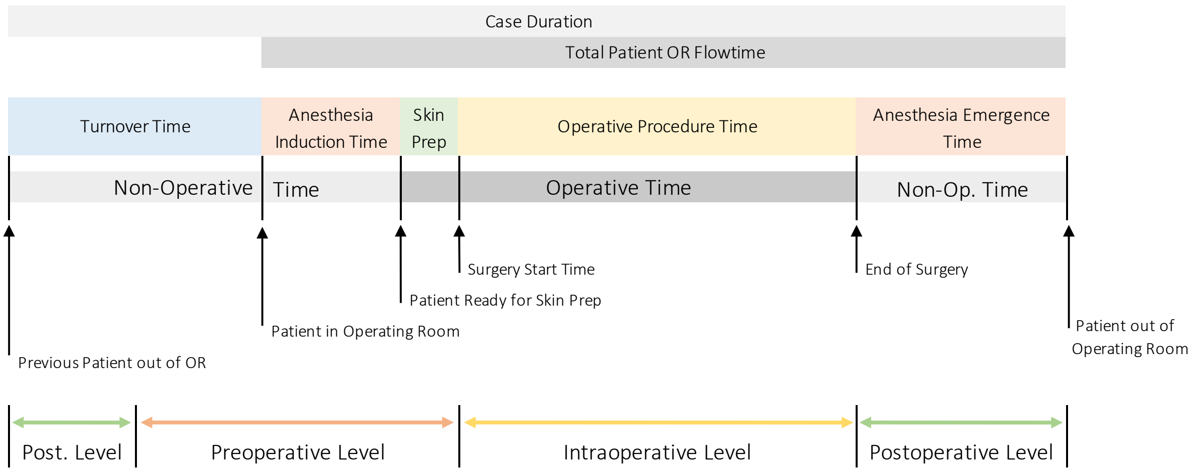


Figure 8. Workflow and representation of KPIs (adapted from (Sandberg et al. 2005), (Stahl et al. 2006) and (Sonmez & Pintelon 2020).

Aside from the *Throughput*, *Turnover Time* and *OR Utilization Rates*, there are other KPIs, as possible to see in *Figure 8*, and factors that are directly related to the flow of work and can interfere with the overall efficiency (interfere with the *throughput* itself).

As mentioned before, and to give answer to the first research question, it was possible to determine 28 KPIs in the literature review, from which the HSA has applied 11 to the

[10] 11% of the available OR time is being lost, which in a day represents around 80min. This value can obviously be improved. However, it stays under a very acceptable value. That is why, the real improvement goes beyond theoretically minimizing and maximizing KPIs. In order for these to change, new solutions to the workflow needed to happen.

monitoring of the ORs. From these KPIs, and has it has been stated along this dissertation, there is an existing problem of definition and relevancy associated to some KPIs. As seen in *APPENDIX B: Four categories of KPIs identified in the studied literature* and in *Table 5*, a special focus has been made among authors into specific KPIs. *Turnover time*, *Anesthesia induction time*, *Under & Over utilization*, *Throughput* and *OR utilization rates* represent the KPIs with the highest number of citations among the analyzed articles and literature reviews, demonstrating their importance, their qualitative relevancy, and the need to keep them under a controlled and continuous analysis.

Besides these KPIs mentioned above, and having the most weighted number of citations, it is also important to, when analyzing efficiency and performance levels of KPIs to look at every *Operating Room KPIs* (possible to see in *Figure 8*) from a global and individual perspective since these will allow for a determination on which processes are being done efficiently and which points can be improved.

5.3.1 AS-IS process analysis

To more easily demonstrate the current set of tasks that are performed in every surgical activity of the hospital, and to understand the points of improvements more easily, an AS-IS service blueprint of the current workflow was designed.

Figure 9, represents the service blueprint of the entire set of tasks that are performed from the moment that the service managers schedule the patient's surgery, and he receives the convocation letter until the moment when surgery is finished, and the patient recovers in the hospitalization facilities before ready for discharge. However, this one is only to give some context over how everything happens – the full set of processes. Besides this, *Figure 9* incorporates every possible failing points of the set of processes, marked with a red circle.

To highlight the most important part of the service blueprint, and the one where a special focus was given, an orange rectangle was added to *Figure 9*. A more detailed service blueprint was then developed while being combined with *Figure 8*. *Figure 10*, represents a more detailed version of the processes happening inside the OS (AS-IS processes), as well as a combination with the KPIs in study, where it is possible to see that patients enter the OR first, and are then anesthetized, surgically operated, and emerged from anesthesia before leaving to the PACU. Important to note that the combination of service blueprints with KPIs represent a scarce application in the literature.

According to the hospital's records, the average time for the tasks currently happening inside the OR, and shown in *Figure 10*, are as follows:

- The average time consumed with *"Anesthesia Induction Time"* is 30 min.
- The average time of *"Operative Procedure Time"* is 1h50[11].
- The average time consumed with *"Anesthesia Emergence Time"* is 10min.

Average *Total Patient OR Flowtime* (*Figure 8*) = 30 min + 110 min + 10 min = 150 min.

Average *Case Duration* (*Figure 8*) = 30 min + 110 min + 10 min + 17.6 min = 167.6 min.

On average, **every patient takes 167.6min of OR Time**, in a **sequentially manner**.

[11] The *skin prep time* cannot be measured independently since they register it as a part of the *Operative Procedure Time*.

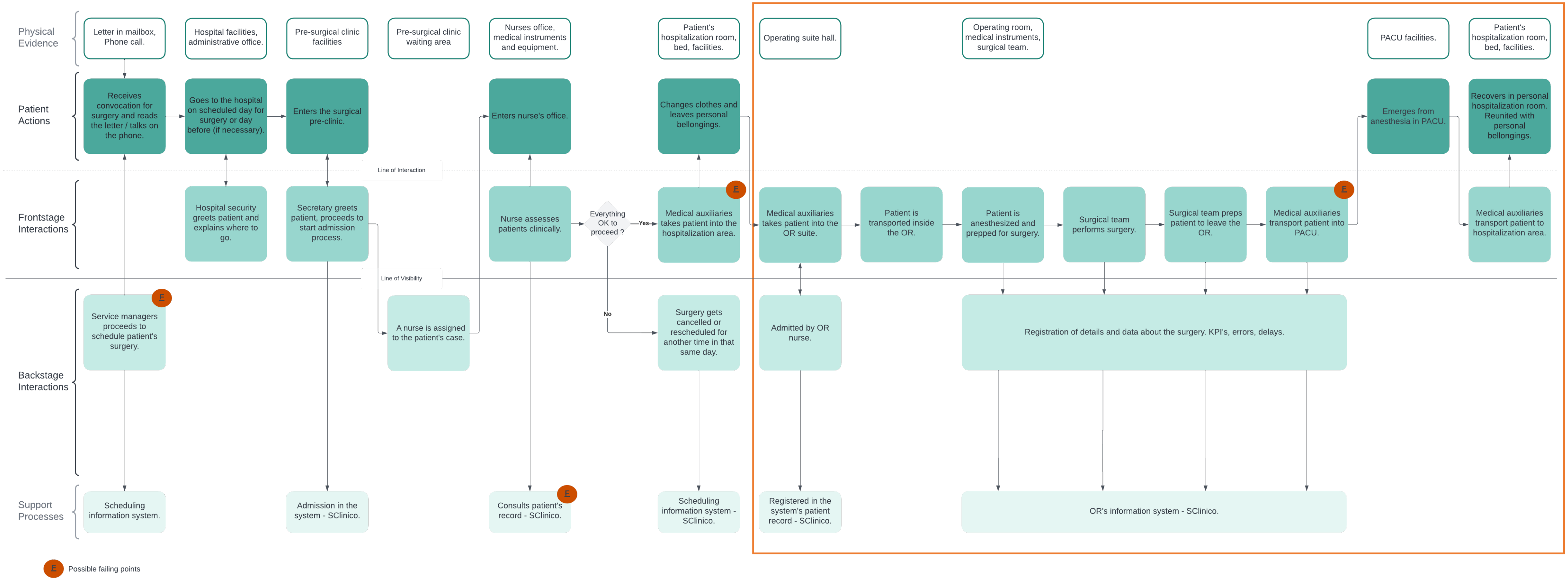


Figure 9. Service blueprint of the current and entire set of processes (from admission to post-surgical hospitalization).

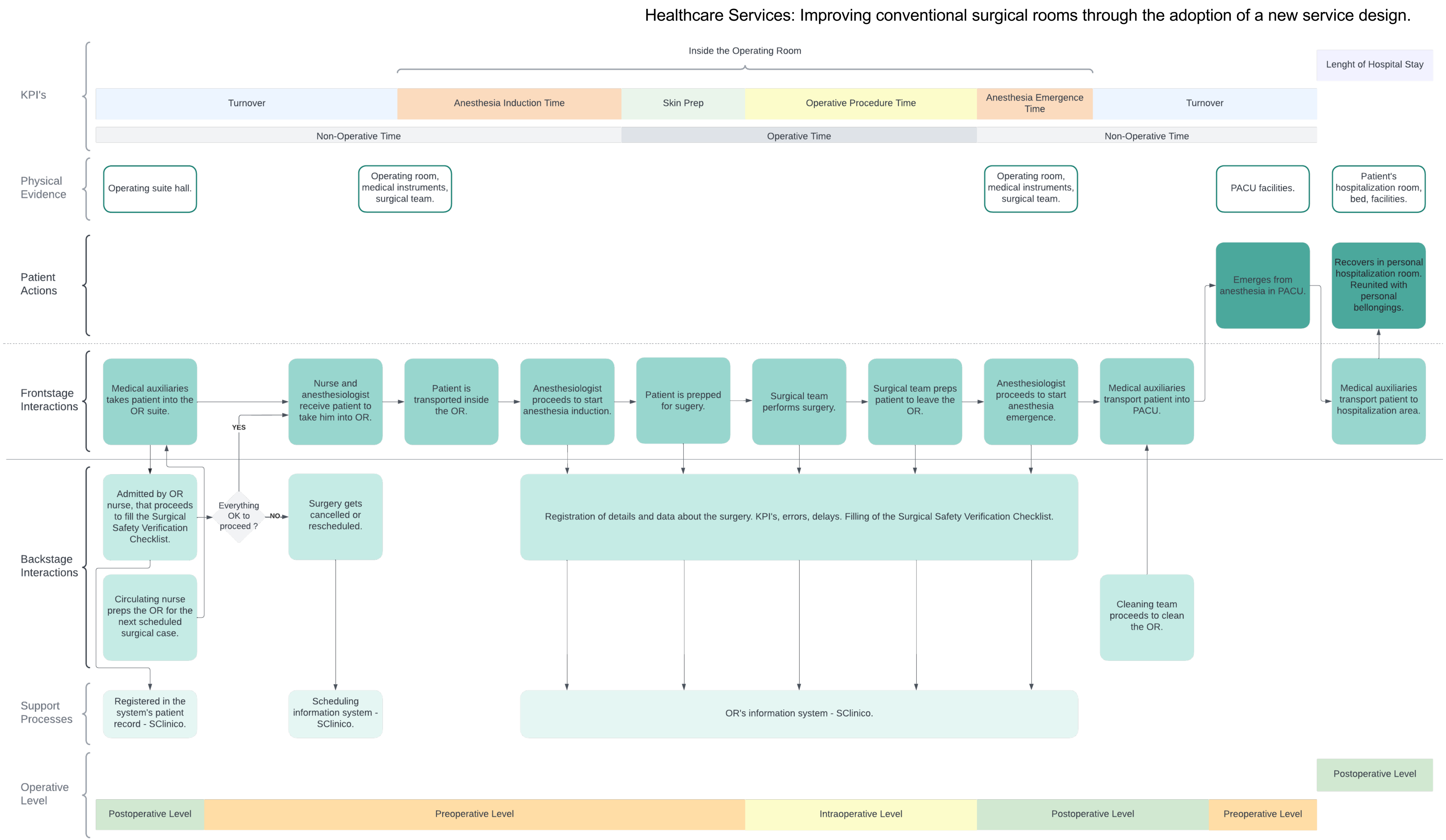


Figure 10. Detailed AS-IS service blueprint of the processes happening inside the OR, with incorporation of KPIs.

As discovered by Sonmez & Pintelon (2020), OORE[12] = $\frac{Surgery\ Time}{Case\ Time}$. However, according to the terminology of *Figure 8*, OORE would be the division of the *Operative Procedure Time* by *Case Duration*. From this equation it is possible to understand that, when trying to maximize the performance of any OR, turnover, anesthesia inductions and emergences should be minimized. However, and as seen in the data analysis section, the turnover time stands under a very acceptable value, from which the focus is not to maximize the OR Utilization by reducing turnover, but instead, **maximize the throughput through a better monetization of the utilized OR time** – focus on every process happening inside the OR.

This way, OORE was adapted so that it could focus on the *Total Patient OR Flowtime* (total time inside the OR). Adapted OORE = $\frac{Surgery\ Time}{Total\ Patient\ OR\ Flowtime}$.

In a **conventional situation**, as seen in *Figure 10*, when all activities are performed inside the OR, the anesthesia induction time and the anesthesia emergence time will have a direct impact in the OORE's value. According to the authors, this value should ideally be 1, which would mean that the amount of time that the patient stayed inside the OR was mostly consumed to perform the surgical procedure, however, no patient enters and exists the OR at the exact beginning and end of the operating procedure – at least not when following a linearity in terms of processes.

$$\text{Adapted OORE} = \frac{Operative\ Procedure\ Time}{Total\ Patient\ OR\ Flowtime} = \frac{110\ min}{150\ min} \approx 0.73$$

At this stage, it was important to understand what exists in the literature regarding process improvement solutions for a hospital and surgical setting.

5.3.2 Process improvement solutions

To better understand in which ways the OR could be improved, and what kind of solutions had been proven in the literature to improve functioning processes, a research over existing evidence was made. After determining a set of improvement solutions, it was extremely important to identify which solutions were already in use or in course of adoption inside the hospital, so that a narrow set of improvement solutions could be gathered and the most relevant for this study chosen.

This way, in the literature review it was possible to identify a total of 17 solutions to improve the efficiency of processes. As possible to see in *Table 9*, from a crossmatching between the

[12] Overall Operating Room Effectiveness

literature's information and the analysis of the current set of processes it was possible to determine that 6 of the 17 solutions are currently in use inside the HSA, 5 in course of implementation and adoption and 4 could be considered interesting to incorporate in this project (with 46% of the total number of citations, demonstrating the weight of the solutions) while having in mind the main objectives.

Table 9. Processes improvement solutions crossmatched with data from HSA (solutions already in use, in course of implementation, interesting to the study and not in the horizon).

Class*	Sollutions to Improve the Efficiency of Processes	Literature review of Processes	Currently in use	In course of implementation	Possible to adopt alongside imp. intervention	Not in the horizon	Notes
Small-Scale Efficiency Interventions	Workflow Redesign	6			x		
	Standardization Processes & Instruments	3	x	x			(1)
	Team Huddles	1				x	(2)
	Effective Scheduling Systems	2		x			
	Surgical Procedure Reenginering	1		x			
Medium-Scale Efficiency Interventions	Collection of Data & Outlining of Improvement Points (Monitoring of Overall Performance)	4	x				
	OR / Procedure Checklists	1	x				
	Hiring Personnel	3				x	
Large-Scale Efficiency Interventions	Supply Chain Optimization	1				x	
	Real Time Locating Systems	1				x	(3)
	OR Space Redesign	4			x		
	Parallel Processing	9			x		
	Specialization Processes	1	x				
	Incorporation of New Technology	4	x	x			(4)
	Acquisition of Medical Ergonomic Equipment	3		x			
	Incorporation of Pre Operative Clinics	2	x				
	Redesign of Processes	4			x		

(1) HSA has been gradually changing the preparation of surgical activities by incorporating new projects that aim to standardize the processes through which the OR is prepped and standardize the set of instruments for each surgery. Since it has been gradually applied to surgical specialties, and the standardization of instruments is different for different set of surgeries, this process can be considered already "in use" for some surgical specialties and "in course of implementation" for others.

(2) HSA already performs team meetings and case discussions before surgical cases, if assessed as necessary by a surgeon, however, it is not a mandatory process in place that surgical teams need to follow at all times, before and after each surgical case and there is no change regarding this topic in the horizon.

(3) Real time locating systems has been a topic of discussion among managers of the hospital unit, however, it still represents a very green topic from which it was considered to be "not in the horizon".

(4) Any medical facility benefits from incorporating new technology at all times. The HSA has not been different and has been known for adopting several technological innovations into their service. Because of this, it was considered as being in use and in course of implementation.

In response to the second research question, when trying to improve a service it is important to keep in mind the necessities, as well as the resources that the hospital as already available, and match the possible solutions and points of improvement to that reality.

As mentioned before, in this situation, the main goal was to monetize the time that is already being consumed for surgical activities to increase the *throughput*.

- Turnover could be a point of focus if superior to 20 min which on average it has been under this window for the last 4 years.
- OR Utilization Rates could be improved, however, it already stands very acceptable.

The goal was to perform more surgical cases per OR, per block of time, meaning improve the *throughput*.

According to the literature, the workflow redesign, redesign of processes and the incorporation of parallel processing represents the most weighted solutions. Considering the conclusion of the data analysis that the main focus should be made on **maximizing the usage of the ORs available time by redesigning processes**, these seemed to be the ones fitting the overall goal of the project.

Besides this, if analyzed closely it is possible to acknowledge that:

- Parallel processing represents, according to the literature evidence, **one of the most effective ways to monetize the available OR time** and perform more surgical cases p/ block time.
- The **hospital physical structure already has what could be induction rooms designed**, they just don't use them (the processes in place completely ignore the presence of this room).
- If the hospital already has induction rooms for what seems to be most of the ORs, then there would be **no need to invest in construction** and to stop the surgical activity of the hospital for this purpose.

5.4 Proposed service design

The understanding of the possible improving solutions represented a foundation to the choice of what would be the most suitable one to this hospital's situation.

Figure 11, represents the proposed service blueprint incorporating the reengineered OR flow, where anesthesia induction is designed to be run in parallel to all the other activities. This means that, anesthesia induction should now be done simultaneously to an Operative Procedure, but in a separate room.

From APPENDIX G to I, it is possible to see the same service blueprint but zoomed in separate parts.

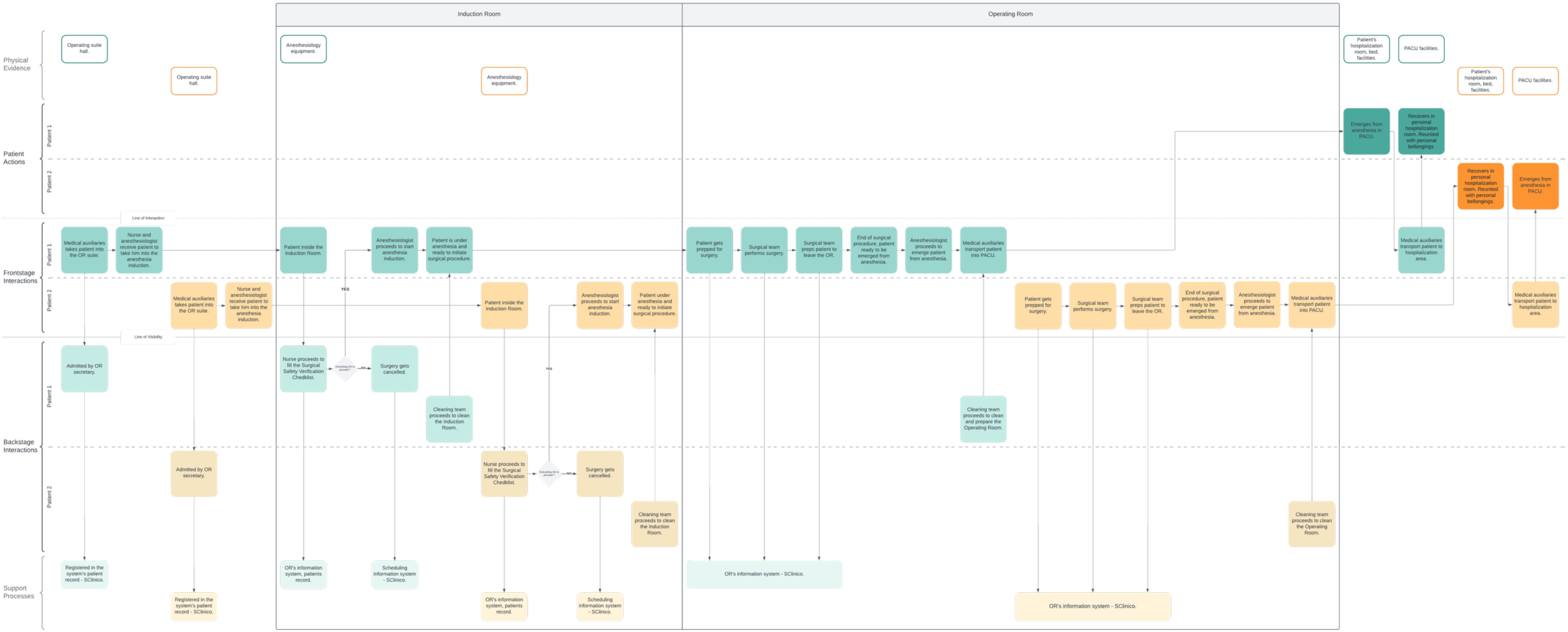


Figure 11. Propose service blueprint, featuring parallel processing of anesthesia induction.

How do activities happen in this reengineered design? As seen in *Figure 11*, the proposed solution intents to allow for two patients to be simultaneously seen in different phases.

- This solution would mean that now instead of everything being performed inside the OR, there would be two separate rooms – Induction Room (where anesthesia would be administered to the patient) and OR.
- The first patient of the day goes through the normal process of being anesthetized in a separate room, and then transported inside the OR where the surgical activity and initial emergence from anesthesia happens.
- The goal is to monetize OR time by performing the anesthesia induction of the following patients of the day (2,3,…,n) simultaneously to the surgical intervention of the previous one, so that once patient 1 leaves the OR, patient 2 is ready to go inside, see *APPENDIX J: KPIs of three simultaneous patients with the introduction of parallel processing (behaviour of KPIs with the proposed solution, Figure 11)*.
- Less time is consumed with activities happening inside the OR (*Total Patient OR Flowtime* is lower p/ patient) and the time consumed with anesthesia induction does not add to the overall time being consumed per case since it happens in parallel.
- **This will allow for an average of 30min to be saved per case (average time for anesthesia induction) and possibly perform one extra case per day of working, per OR (increase the *Throughput by 1 patient per OR*).**

To better understand how three different patients would consecutively behave regarding processes of the OR, *APPENDIX J: KPIs of three simultaneous patients with the introduction of parallel processing (behaviour of KPIs with the proposed solution, Figure 11)* was created. It is important to understand, when talking about the Anesthesia Induction Time of the proposed solution, that patient 2 and 3 and the following ones, would have the *Operative Procedure Time + Anesthesia Emergence Time + Turnover Time* of the previous patient to be anesthetized, however, the patient anesthesia would only start depending on the time needed for that procedure. By this it is meant that, for example, for a simple surgery it could take 30min to anesthetize the patient, while for a neuro complex surgery it could take up to 4h.

5.4.1 Adapted OORE

With **parallel processing** applied as seen in *Figure 11*, and as described above, less OR time is consumed per patient which means that the amount of time that the patient stayed inside the

OR would now be mostly consumed to perform the surgical procedure. The adapted OORE value would behave as follows:

On average, every patient takes 137.6min of OR time, with parallelization, since:

$$\text{Average Total Patient OR Flowtime} = 110 \text{ min} + 10 \text{ min} = 120 \text{ min}.$$

$$\text{Adapted OORE} = \frac{Operative\ Procedure\ Time}{Total\ Patient\ OR\ Flowtime} = \frac{110\ min}{120\ min} \approx 0.92$$

5.4.2 Modifications required alongside proposed solution

With every innovation, in every field, there are changes that need to happen so that the improving solutions can indeed succeed. The same with workflow and redesigning of processes.

With the introduction of parallel processing for the anesthesia induction and presented in *Figure 11*, the following adjustments would need to be considered:

- A **new parametrization would need to be made into the software that is used for the scheduling of surgical activities** and block time attribution. This because, with the new design, surgeries would need to be scheduled based on not only the time each patient consumes inside the OR, but also on the *Anesthesia Induction Time* needed for each surgery.
- A **stronger coordination between stakeholders** involved in the surgical activity, and also between cleaning teams since the frequency of turnovers would be higher.
- **Hiring of both nurses and anesthesiologists to maybe the double amount.** This because, with every surgical procedure there is always the need for an anesthesiologist to be present during the entire *Operative Procedure Time*. In a sequential manner, one anesthesiologist follows the patient through the whole surgical case (from entry until exit of OR). If the anesthesia induction starts to be made in parallel, then two situations can incur: One anesthesia team per patient, meaning they follow the patient from anesthesia induction to the surgical procedure, and since two different patients will be, at a certain stage, simultaneous, then the second patient would also have an anesthesia team allocated to them. Second option is one anesthesia team is permanently allocated to the induction room and one permanently to the OR, teams don’t follow the patient. Either way, it is possible to see that two anesthesia teams would be necessary per OR, since two patients can simultaneously coexist.

5.4.3 Expected gains from the proposed solution

With the introduction of parallel processing, *Figure 11*, it would be expected to have gains in terms of the number of surgical cases performed, contribution to the reduction of waitlist and even in terms of economic traits, as follows:

- With parallel processing, and as mentioned before, the time consumed per patient inside the OR is reduced by the time that the anesthesia induction would consume in a sequential manner. ***Total Patient OR Flowtime*** **would be reduced by 18% per patient**.
- If the time consumed inside the OR per patient, *Total Patient OR Flowtime,* is reduced this gives a wider window for at least one extra surgical case to be performed per OR. If currently the throughput stands in 2.5 per block time, and each day of work is made of two block times, then the **current throughput per day stays between 4/5 cases** (average). This would mean that throughput could now possibly stand, on average, between **5/6 cases per day (with an improvement standing between 25% and 20%, respectively).**
- In a best scenario, where 1 extra case is performed per OR per day of work, 6 extra cases per day would be performed in the overall OS (if applied only to the Central OS), a significant value over a year, efficiently contributing to the reduction of waitlists.
- Even with the need to hire more nurses and anesthesiologists (no need to hire surgeons or other medical professional categories) and considering that no investment would need to be done on physical infrastructure, there would still be gains in economic terms.

5.5 Practical simulation of parallel processing

For a better understanding of the proposed solution, a practical simulation is presented. Performed considering the average times for each process of the OR, mentioned above:

- The average time consumed with *"Anesthesia Induction Time"* is 30 min.
- The average time of *"Operative Procedure Time"* is 1h50.
- The average time consumed with *"Anesthesia Emergence Time"* is 10min.

In a **conventional setting**, where all tasks (anesthesia induction + surgery + anesthesia emergence) are made inside the OR, one patient has to leave the OR, so that after the cleaning and OR preparation – *Turnover Time* – the next patient can enter.

Total Patient OR Flowtime = 150min

Case Duration = 167.6min

Table 10, shows the daily utilization of the OR time in a conventional setting and considering the average values mentioned above.

Table 10. Daily OR Utilization of a 12h working day, in a conventional setting.

OR Time Available = 12H = 720min								
150 min	17.6 min	151 min	17.6 min	150 min	17.6 min	151 min	17.6 min	**49.6 min**
Total Patient OR Flowtime	Turnover	Total Patient OR Flowtime	Turnover	Total Patient OR Flowtime	Turnover	Total Patient OR Flowtime	Turnover	**Under Utilized OR Time**

Scenario 1: In a 12h working day, with an average 150min needed per patient inside the OR with the average turnover needed to clean and get it ready for next surgery of 17.6 min, an OR, without accounting for possible delays (in a perfect scenario), is able to perform a total of 4 surgical cases and be left with 49.6min – the OR would be left of 49.6 minutes of *under-utilization*.

Table 11, shows the daily utilization of the OR time when parallel processing is introduced. Still considering the average values mentioned above for each process.

Table 11. Daily OR Utilization of a 12h working day w/ parallel processing.

OR Time Available = 12H = 720min												
30 min	120 min	17.6 min	120 min	17.6 min	120 min	17.6 min	120 min	17.6 min	120 min	17.6 min	**2 min**
Anesthesia Induction	Operative Time w/ Anesthesia Emergence	Turnover	Operative Time w/ Anesthesia Emergence	Turnover	Operative Time w/ Anesthesia Emergence	Turnover	Operative Time w/ Anesthesia Emergence	Turnover	Operative Time w/ Anesthesia Emergence	Turnover	**Under Utilized OR Time**

Scenario 2: In a 12h working day, where anesthesia induction is outsourced and not performed inside the OR, meaning the average time needed per patient inside the OR is 120 min with the average turnover needed to clean and get it ready for next surgery of 17.6 min, an OR, without accounting for possible delays (under a perfect scenario), is able to perform a total of 5 surgical cases and be left with 2min of *under-utilization*.

Important to note that in this situation, anesthesia induction is only counted for the first surgical case of the day, since all the others will be performed simultaneosly in another room while the previous patient is being surgically operated and the OR is cleaned.

For the first scenario to perform the same amount of surgical cases as the second scenario, the OR would have to go 118min of *over-utilization*.

6 Conclusion and Future Research

It is known that surgical departments are highly specialized environments, complex and one of the costliest fields, with a significant influence on the global overall hospital performance and competitive advantage. Having a clear significant weight on the surgical responses that are given to the portuguese citizens, the OR represents the environment directly affecting the performance of surgical activities, and although influenced by other considerable factors, it is still the main contributor to the surgical responsiveness to citizens. This means that, as mentioned along this dissertation, the management of the OR represents a crucial intent in the maximization and monetization of OR time and resources.

This dissertation intended on contributing to the optimization of responses given to the Portuguese citizens and in a certain way contribute to the reduction of surgical waitlist by proposing a solution that would improve the surgical service design and the overall *Throughput*. People have been misled in terms of surgical wait times, being guided to believe that they will need to wait a certain amount of time when in fact end up waiting far more than expected. Needless to say, that this situation is not ideal for anyone. People should not have to wait for medical care to be given to them, especially when very commonly in pain and with their social and professional lives on standby. Hospitals, on the other hand, should not have to consume far more resources than necessary, which is something that happens far more commonly than expected when the patient has to wait for a very long time to be surgically intervened. This because, sometimes the surgical study as already been finished, the set of necessary exams and tests are done, the patient is then ready to be surgically intervened, but since they wait for infinitive periods of time, when the surgery actually comes all of the exams that were previously done are no longer up to date and there is the necessity to revise everything.

This overall objective could only be achieved by fully understanding how the AS-IS of conventional surgical services of the hospital were functioning, what relevant KPIs should be considered and how were they related to the processes happening in the OR. Also, their behavior (KPIs) over the last years to determine how these could be improved in terms of operating so that production levels could be maximized and the impact that certain processes could have on the overall optimization. Quantitative analysis combined with the application of service design tools (applied to the AS-IS with a combination of KPIs, and later applied to the new proposed service design), while performing exploratory and validatory meetings throughout the development of this dissertation represented the research methodologies adopted.

Along this dissertation, it was possible to determine how the goal of every OR management, as well as the way an OR can indeed get improved is by reducing *Turnover* times, increase the *OR Utilization rates* and consequently improve the *Throughput* – representing these, some of the most relevant and influential KPIs to consider. Besides these, a special focus needs to be made on *Operating Room KPIs* as a way to determine which changes to the processes of the OR can be implemented, and which processes are being done less efficiently, to achieve the ideal performance, since these directly interfere with the monetization of the OR.

With an analysis over the necessities of the hospital and by combining it with the overall goal, alongside the analysis of the AS-IS OR processes and their combination with KPIs (through the design of a service blueprint), it was possible to determine how the incorporation of parallel processing would be the most advantageous solution. This has not only been confirmed by the Lit. Review, since according to what was studied, parallel processing is one of the most weighted solutions in improving the *throughput* by reducing the amount of time consumed per patient inside the OR, as it also matches the hospital's necessities and available resources, since they already have physically designed induction rooms for most of their operating rooms, meaning that there would be no need to invest into infrastructural changes for most of their ORs. Besides this, and by applying the solution into a simulation (considering a best scenario and considering the average values for each of the processes of the OR), it was possible to determine that without parallel processing, besides performing less surgical cases, the chances of leaving the OR in a situation of *under-utilization* was higher. While with parallel processing, the time was smarter utilized and monetized to the performance of an extra case. Important to note that as determined, for the first scenario (without parallel processing) to perform the same number of surgical cases, the OR would most likely go *over-utilization*.

This way, parallel processing would allow the **reduction of *under-utilization* of OR Time** and for the **extra case to be performed without the need to go into *over-utilization* of OR Time**. Although having some modifications that need to be considered such as the adaptation of the software parametrization, the better coordination and articulation of staff members and teams, and specially the hiring of nurses and anesthesiologists, parallel processing would **reduce the Total Patient OR Flowtime** by the time that the anesthesia would consume. Consequently, it would give **more time for an extra surgical case to be performed**, since with this solution, an improvement of 1 extra patient per OR, per day, would be expected – an improvement standing between 20% and 25% per day. A detailed description of this dissertation contributions can be seen under *APPENDIX K: Most important contributions* of this dissertation (highlights).

It is then possible to say that, with the **right management** in place, **parallel processing could improve the maximization of OR time** by significantly **reduce the time consumed per patient**, consequently **increase the *throughput* of surgical services and consequently the cases performed per OR**, which in a long term perspective could significantly **contribute to the improvement of responses and hopefully the reduction of waitlists.**

6.1 Limitations

- The lack of reliability in some of the collected data due to human error in the process of insertion or the lack of consistency in terms of what data to register could have significantly manipulated the analysed KPIs.
- It would have been important to apply the proposed solution to two different possible real simulations, to truly acknowledge the validity of the solution when considering long and short surgical procedures. However, data on this behalf could not be collected.
- The research study did not acknowledge the possible delays that can happen in every process of the OR, from which it would be important to investigate the validity of the proposed solution when accounting delays (applied only in a perfect scenario).
- It was not possible to perform an observational approach over how processes are truly happening inside the OR, which could have been important since there are details that could have been acknowledged in the design that can only be seen when observing.

6.2 Future Work

Future work should focus on other aspects directly affecting the efficiency levels of surgical services, going beyond processes happening inside the OR.

- The **surgical scheduling method** should be one of the main focus when trying to understand if an OR is being used at a high level or if OR time is being allocated to surgical services in an intelligent way. This because, waiting lists vary from specialty to specialty, as well as, different specialties require different amounts of time and resources.
- It as been acknowledged the influence that non-operative activities have on the OR maximization. This way, **sugical preparation** should also be considered a focus of analysis. Being able to reduce the amount of time that is consumed with the OR prep, could significantly impact the amount of time that is consumed with non-operative activities and consequently increase the throughput. Besides this, standardization of

instruments (as seen in the analysis of processes) can also help with reducing the amount of unecessary resources that are open and not consumed.

- The **management of patient's hospitalizations** represents another major factor when performing an analysis over OR efficiency levels. This because, the OR and the hospitalization area are directly influencers of each other. Without open spots in the hospitalization area, the OR cannot perform more surgerical procedures although possible having time available.
- The workflow that is followed inside the OR should also represent a main focus, since the way tasks are performed can significantly impact the amount of time that is consumed with a certain activity. Besides this, certain steps in any workflow could be performed when being unecessary, and others could very well be replaced with enhanced and more efficient ways of doing the same thing.
- A combination of service blueprint of the new proposed solution, with the incorporation of KPIs also represent a possible future work to determine the existance and emergence of new KPIs that have came from the new design.

This way, the surgical preparation, the management of patient's hospitalizations and the scheduling should be points of focus as a continuity of this project. Besides these, efforts should be made into the optimization of data registration in the IS in terms of reliability.

Furthermore, future research should study the application of this solution to short and long procedures in order to acknowledge its true potential.

References

AIDA. 2022. Agência para a Integração, Difusão e Arquivo de Informação, conceito e BI (Business Intelligence).

Attarian, D. E., J. E. Wahl, S. S. Wellman, and M. P. Bolognesi. 2013. "Developing a high-efficiency operating room for total joint arthroplasty in an academic setting." *Clin Orthop Relat Res* 471 (6): 1832-6. https://doi.org/10.1007/s11999-012-2718-4. https://www.ncbi.nlm.nih.gov/pubmed/23208123.

Attigah, Nicolas, Serdar Demirel, Maani Hakimi, Hans Bruijnen, Oliver Schˆffski, A. M¸ller, Uwe Geis, and Dittmar Bˆckler. 2017. "Hybrid operating rooms versus conventional operating rooms : Economic comparisons in vascular surgery using the example of endovascular aneurysm repair." *Der Chirurg; Zeitschrift fur alle Gebiete der operativen Medizen* 88 7: 587-594. https://doi.org/10.1007/s00104-017-0431-2. https://pubmed.ncbi.nlm.nih.gov/28466153/.

Barros, Pedro Pita. 2019. *Economia da Saúde: conceitos e comportamentos*. 4th ed., edited by S.A. Edições Almedina: Edições Almedina, SA.

Basto, J., R. Chahal, and B. Riedel. 2019. "Time-driven activity-based costing to model the utility of parallel induction redesign in high-turnover operating lists." *Healthc (Amst)* 7 (3): 100355. https://doi.org/10.1016/j.hjdsi.2019.01.003. https://www.ncbi.nlm.nih.gov/pubmed/30770190.

Bitner, Mary Jo, Amy L Ostrom, and Felicia N Morgan. 2008. "Service blueprinting: a practical technique for service innovation." *California management review* 50 (3): 66-94. https://asu.pure.elsevier.com/en/publications/service-blueprinting-a-practical-technique-for-service-innovation.

Brainlab. 2021. "Hybrid O.R., Integrated O.R., Digital O.R.: The Differences (and Similarities) of these Types of Operating Rooms." Accessed 10 June https://www.brainlab.com/journal/hybrid-integrated-digital-o-r-differences-similarities/.

Casaletto, J. A., and V. Rajaratnam. 2004. "Surgical process re-engineering: carpal tunnel decompression--a model." *Hand Surg* 9 (1): 19-27. https://doi.org/10.1142/s0218810404002066. https://www.ncbi.nlm.nih.gov/pubmed/15368621.

Casar Berazaluce, Alejandra M., Rachel E. Hanke, Daniel von Allmen, and John M. Racadio. 2019. "The State of the Hybrid Operating Room: Technological Acceleration at the

Pinnacle of Collaboration." *Current Surgery Reports* 7 (4): 7. https://doi.org/10.1007/s40137-019-0229-x.

Castro, Flávia Simone Cardoso. 2021. "Análise económica, ambiental e de custo-benefício da implementação de "Packs Cirúrgicos" no Centro Hospitalar Universitário do Porto (CHUP)." Mestrado Integrado em Engenharia Biomédica – Ramo de Engenharia Clínica, UMinho, Escola de Engenharia, Universidade do Minho.

Centro Hospitalar Universitário do Porto, EPE. Junho 2021. *Plano de Atividades e Orçamento 2021.* https://www.chporto.pt/documentos/Instituicao/bom_governo/plano_atividades_e_orcamento/Plano_de_atividades_e_Orcamento_2021.pdf.

Costa Ada, S., Jr., L. E. Leao, M. A. Novais, and P. Zucchi. 2015. "An assessment of the quality indicators of operative and non-operative times in a public university hospital." *Einstein (Sao Paulo)* 13 (4): 594-9. https://doi.org/10.1590/S1679-45082015GS3289. https://www.ncbi.nlm.nih.gov/pubmed/26761557.

Dewes, A. 2018. "Improving Performance Measures With Perioperative Analytics." *AORN J* 107 (2): 189-198. https://doi.org/10.1002/aorn.12021. https://www.ncbi.nlm.nih.gov/pubmed/29385245.

Dexter, F., and R. H. Epstein. 2005. "Operating room efficiency and scheduling." *Curr Opin Anaesthesiol* 18 (2): 195-8. https://doi.org/10.1097/01.aco.0000162840.02087.15. https://www.ncbi.nlm.nih.gov/pubmed/16534338.

Estatística, Instituto Nacional de. 1 July 2022 2022. *Conta Satélite da Saúde* https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_destaques&DESTAQUESdest_boui=540875581&DESTAQUESmodo=2&xlang=pt.

Fixler, Tamas, and James G. Wright. 2013. "Identification and use of operating room efficiency indicators: the problem of definition." *Canadian journal of surgery. Journal canadien de chirurgie* 56 (4): 224-226. https://doi.org/10.1503/cjs.020712. https://pubmed.ncbi.nlm.nih.gov/23883490 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3728239/.

Fong, A. J., M. Smith, and A. Langerman. 2016. "Efficiency improvement in the operating room." *J Surg Res* 204 (2): 371-383. https://doi.org/10.1016/j.jss.2016.04.054. https://www.ncbi.nlm.nih.gov/pubmed/27565073.

Gomes, Sofia. 2019. "Presenting Service Design and why you should care about it." https://www.imaginarycloud.com/blog/what-is-service-design/.

Group, Nielson Norman. 2017. "Service Design 101." Accessed 15 August. https://www.nngroup.com/articles/service-design-101/.

Harders, M., M. A. Malangoni, S. Weight, and T. Sidhu. 2006. "Improving operating room efficiency through process redesign." *Surgery* 140 (4): 509-14; discussion 514-6. https://doi.org/10.1016/j.surg.2006.06.018. https://www.ncbi.nlm.nih.gov/pubmed/17011897.

Holdford, D. A. 2019. "Using Service Blueprints to Visualize Pharmacy Innovations." *Pharmacy (Basel)* 7 (2). https://doi.org/10.3390/pharmacy7020043. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6630975/.

Jerico Mde, C., M. G. Perroca, and V. C. da Penha. 2011. "Measuring quality indicators in the operating room: cleaning and turnover time." *Rev Lat Am Enfermagem* 19 (5): 1239-46. https://doi.org/10.1590/s0104-11692011000500023. https://www.ncbi.nlm.nih.gov/pubmed/22030590.

Jin, H., and J. Liu. 2022. "Application of the Hybrid Operating Room in Surgery: A Systematic Review." *J Invest Surg* 35 (2): 378-389. https://doi.org/10.1080/08941939.2020.1838004. https://www.ncbi.nlm.nih.gov/pubmed/33146589.

Jin, H., L. Lu, J. Liu, and M. Cui. 2022. "A systematic review on the application of the hybrid operating room in surgery: experiences and challenges." *Updates Surg* 74 (2): 403-415. https://doi.org/10.1007/s13304-021-00989-6. https://www.ncbi.nlm.nih.gov/pubmed/33709242.

Kerr, R. S. 2020. "Surgery in the 2020s: Implications of advancing technology for patients and the workforce." *Future Healthc J* 7 (1): 46-49. https://doi.org/10.7861/fhj.2020-0001. https://www.ncbi.nlm.nih.gov/pubmed/32104765.

Kumar, S., and M. Steinebach. 2008. "Eliminating US hospital medical errors." *Int J Health Care Qual Assur* 21 (5): 444-71. https://doi.org/10.1108/09526860810890431. https://www.ncbi.nlm.nih.gov/pubmed/18785345.

Lee, D. J., J. Ding, and T. J. Guzzo. 2019. "Improving Operating Room Efficiency." *Curr Urol Rep* 20 (6): 28. https://doi.org/10.1007/s11934-019-0895-3. https://www.ncbi.nlm.nih.gov/pubmed/30989344.

Lopes, Inês Ventura. 2020. "Otimização do Bloco Operatório." Mestrado em Engenharia Biomédica, Escola Superior de Biotecnologia da Universidade Católica Portuguesa, Universidade Católica Portuguesa.

Macario, A. 2006. "Are your hospital operating rooms "efficient"? A scoring system with eight performance indicators." *Anesthesiology* 105 (2): 237-40. https://doi.org/10.1097/00000542-200608000-00004. https://www.ncbi.nlm.nih.gov/pubmed/16871055.

Marjamaa, R., A. Vakkuri, and O. Kirvela. 2008. "Operating room management: why, how and by whom?" *Acta Anaesthesiol Scand* 52 (5): 596-600. https://doi.org/10.1111/j.1399-6576.2008.01618.x. https://www.ncbi.nlm.nih.gov/pubmed/18419711.

Médico, Jornal. 2021. "CHUP instala tecnologia de ablação tumoral por laser para tratar cancro e epilepsia." https://www.jornalmedico.pt/atualidade/41303-chup-instala-tecnologia-de-ablacao-tumoral-por-laser-para-tratar-cancro-e-epilepsia.html?fbclid=IwAR3S6ZLe8gSZpbu-tQlOlS9aknP7ZFlgJSeSfEVXhpfXfPkrJfZpthP2d4A.

Médico, Jornal. 2022. "SNS realizou 654.711 cirurgias entre janeiro e novembro de 2021, número mais elevado em 10 anos." O jornal de todos os médicos. Accessed 4 September https://www.jornalmedico.pt/atualidade/41951-sns-realizou-654-711-cirurgias-entre-janeiro-e-novembro-de-2021-numero-mais-elevado-em-10-anos.html.

Morris, A. J., J. A. Sanford, E. J. Damrose, S. H. Wald, B. Kadry, and A. Macario. 2018. "Overlapping Surgery: A Case Study in Operating Room Throughput and Efficiency." *Anesthesiol Clin* 36 (2): 161-176. https://doi.org/10.1016/j.anclin.2018.01.002. https://www.ncbi.nlm.nih.gov/pubmed/29759280.

Pathak, Vibha, Bijayini Jena, and Sanjay Kalra. 2013. "Qualitative research." *Perspectives in Clinical Research* 4 (3): 192. https://doi.org/10.4103/2229-3485.115389. https://www.researchgate.net/publication/256453037_Qualitative_research.

Patrício, Lia, Raymond P. Fisk, João Falcão e Cunha, and Larry Constantine. 2011. "Multilevel Service Design: From Customer Value Constellation to Service Experience Blueprinting." *Journal of Service Research* 14 (2): 180-200. https://doi.org/10.1177/1094670511401901. https://journals.sagepub.com/doi/abs/10.1177/1094670511401901.

Pereira, Helena Carla Magalhães. 2014. "Modelo de Gestão do Bloco Operatório." Mestrado em Gestão de Empresas, Departamento de Ciências Económicas, Empresariais e Tecnológicas, Universidade Autónoma de Lisboa.

Pintelon, Sonmez &. 2020. "A survey on performance management of operating rooms and a new KPI proposal." *Quality and Reliability Engineering International. John Wiley & Sons, Ltd* vol. 36, no. no. 8: pp. 2595–2609. https://doi.org/10.1002/qre.2739. https://onlinelibrary.wiley.com/doi/abs/10.1002/qre.2739.

PORDATA. 2013. O que são NUTS?

Porta, C. R., A. Foster, M. W. Causey, P. Cordier, R. Ozbirn, S. Bolt, D. Allison, and R. Rush. 2013. "Operating room efficiency improvement after implementation of a postoperative team assessment." *J Surg Res* 180 (1): 15-20. https://doi.org/10.1016/j.jss.2012.12.004. https://www.ncbi.nlm.nih.gov/pubmed/23298950.

Portugal, CNN. 2022. "Hospitais: as 25 listas de espera de cirurgias mais atrasadas do país." *CNN Portugal*, 5 April 2022. https://cnnportugal.iol.pt/saude/lista-de-inscritos-para-cirurgia/hospitais-as-25-listas-de-espera-de-cirurgias-mais-atrasadas-do-pais/20220405/624611d70cf2cc58e7eb87ea.

Quadros, Deise Vacario de, Giulie Anna Baldissera Leitte-Teixeira, Sabrina Letícia Couto da Silva, and Maria Auxiliadora Cannarozzo Tinoco. 2022. "The serviscape in the user experience: evaluation of perceptions in hospital concierge services." *Research, Society and Development* 11 (2): e57911225911. https://doi.org/10.33448/rsd-v11i2.25911. https://rsdjournal.org/index.php/rsd/article/view/25911.

Rothstein, D. H., and M. V. Raval. 2018. "Operating room efficiency." *Semin Pediatr Surg* 27 (2): 79-85. https://doi.org/10.1053/j.sempedsurg.2018.02.004.

Sandberg, W. S., B. Daily, M. Egan, J. E. Stahl, J. M. Goldman, R. A. Wiklund, and D. Rattner. 2005. "Deliberate perioperative systems design improves operating room throughput." *Anesthesiology* 103 (2): 406-18. https://doi.org/10.1097/00000542-200508000-00025. https://www.ncbi.nlm.nih.gov/pubmed/16052124.

Saudemais. 2022. "Hospital de Santo António e Ministério da Saúde lançam laboratório em saúde digital." Accessed 24 September. https://www.saudemais.tv/noticia/40271-hospital-de-santo-antonio-e-ministerio-da-saude-lancam-laboratorio-em-saude-digital.

Silva, Hágabo Mathyell, Mariana Martins Gonzaga do Nascimento, Carina de Morais Neves, Isabela Viana Oliveira, Carla Martins Cipolla, Grazielli Cristina Batista de Oliveira, Yone de Almeida Nascimento, and Djenane Ramalho de Oliveira. 2021. "Service blueprint of comprehensive medication management: A mapping for outpatient clinics." *Research in Social and Administrative Pharmacy* 17 (10): 1727-1736. https://doi.org/https://doi.org/10.1016/j.sapharm.2021.01.006. https://www.sciencedirect.com/science/article/pii/S1551741121000292.

Sousa, V. D., M. Driessnack, and I. A. Mendes. 2007. "An overview of research designs relevant to nursing: Part 1: Quantitative research designs." *Rev Lat Am Enfermagem* 15 (3): 502-7. https://doi.org/10.1590/s0104-11692007000300022. https://www.ncbi.nlm.nih.gov/pubmed/17653437.

Stahl, J. E., W. S. Sandberg, B. Daily, R. Wiklund, M. T. Egan, J. M. Goldman, K. B. Isaacson, S. Gazelle, and D. W. Rattner. 2006. "Reorganizing patient care and workflow in the operating room: a cost-effectiveness study." *Surgery* 139 (6): 717-28.

https://doi.org/10.1016/j.surg.2005.12.006.
https://www.ncbi.nlm.nih.gov/pubmed/16782425.

Stickdorn, M., M.E. Hormess, A. Lawrence, and J. Schneider. 2018. *This Is Service Design Doing: Applying Service Design Thinking in the Real World*. O'Reilly Media.

Transparência, Portal da. 2022. "Inscritos em LIC dentro do TMRG, Serviço Nacional de Saúde." Accessed 28 March https://transparencia.sns.gov.pt/explore/dataset/inscritos-em-lic-dentro-do-tmrg-180-dias.

Trials, Portugal Clinical. 2021. "Centro Hospitalar Universitário do Porto." Accessed 2 May https://portugalclinicaltrials.com/pt/centros-de-investigacao-clinica/centro-hospitalar-universitario-do-porto/.

Watson, R. 2015. "Quantitative research." *Nurs Stand* 29 (31): 44-8. https://doi.org/10.7748/ns.29.31.44.e8681. https://www.ncbi.nlm.nih.gov/pubmed/25828021.

Website, CHUPorto's. 2022. "CHUPorto." Centro Hospitalar Universitário do Porto. Accessed 4 April. https://www.chporto.pt.

WHO. 2010. Lista de Verificação de Segurança Cirúrgica.

WHO, and DGS. 2010. *Portugal Health System Performance Assessment* Regional Office for Europe of the World Health Organization, (WHO Regional Office for Europe). https://www.euro.who.int/__data/assets/pdf_file/0006/131766/E94518.pdf.

World Health Organization, Organisation for Economic Co-operation and Development, and The World Bank. 2018. *Delivering Quality Health Services: A global imperative for universal health coverage.* World Health Organization, OECD and International Bank for Reconstruction and Development/The World Bank. ISBN 978-92-4-151390-6 WHO.

Xperienz. 2022. "Service Design." https://www.xperienz.pt/services/service-design.

APPENDIX A: Surgical planning and scheduling

According to Dewes (2018), OR blocks can be assigned in different styles, to surgical specialties, surgeon groups, individual surgeons or to a combination of these three.

The process of scheduling and attributing OR block time to specialties represents a major step in the management of OR's and consists in programming the surgeries happening on each day with the purpose of efficiently use the available resources and reduce the risk of cancelations. Deciding on this OR block time attribution with the right advance and preparation, such as data analysis, is crucial for the preparation of the OR's with the adequate personnel and correct materials, especially because different specialties and different surgeries require different times and resources (Pereira 2014). The use of KPIs supports the analysis of the OR's consumption of time by each specialty, culminating in a better allocation of the time based on retrospective analysis.

According to the research made by Pereira (2014), there are two strategies to the planning and scheduling of OR Time. **Block-Scheduling** represents the first method of allocating OR Block Time by designating time to surgical specialties, which will then internally distribute among surgeons and consequently these will schedule their surgeries. **Open-Scheduling** represents the second method, where there is no allocation of operating times, neither to surgical specialties nor to surgeons, which means that the OR's are open to all patients, and surgical interventions are scheduled as long as there are rooms and surgical times available.

It is, however, always important to consider that, especially with the first method, services fill their allocated OR time at different rates, which means that the way that then each institution proceeds to manage the available OR time can result in a maximization or *over/under utilization* of time. According to Dexter and Epstein (2005), instead of an OR going into *over-utilization*, OR efficiency is higher if an extra case is performed instead in an OR block time that was allocated to another service that has likely *under-utilized* hours on the day of the surgery. This method ensures that surgical cases are scheduled based on maximizing OR efficiency.

APPENDIX B: Four categories of KPIs identified in the studied literature

		Papers										Literature Reviews							
		Harders 2006 (a)	Stahl 2006 (b)	Macario 2006 (c)	Jerico 2011 (d)	Porta 2013 (e)	Attarian 2013 (f)	Fixler & Wright 2013 (g)	Costa 2015 (h)	Attigah 2017 (i)	Morris 2018 (j)	Marjamaa 2008 (k)	Rathstein 2018 (l)	Casar 2019 (m)	Lee 2019 (n)	Sonmez 2020 (o)	Jin & Liu 2022 (p)	Jin 2022 (q)	
	Number of Citations	246	132	261	15	48	51	51	16	9	8	177	75	6	44	2	11	4	
	Number of Citations p/ Year	15.4	8.3	16.3	1.4	5.3	5.7	5.7	2.3	1.8	2	12.6	18.8	2	14.7	1	11	4	
KPIs	**KPIs Description**																		
Total Patient OR Flowtime	Time between the entry of the patient in the OR until the exit of the patient from the OR or until PACU assumes care.		x		x				x					x		x			
Operative Time	Time between the patient ready for surgical prep and the end of the operating procedure.								x					x		x	x	x	
Operative Procedure Time	Time between the start and finish of an operating procedure.		x			x			x	x		x		x		x	x		
Non-Operative Time	Time when no operative activities take place. Includes TOT + AIT + AET.	x							x			x				x			
Turnover Time	Time from when one patient exits an OR until the next patient enters the same OR. Time needed to clean and get the OR ready for next surgery.	x	x	x	x		x	x	x		x	x	x		x	x			
Pre Cleaning Time	Period from the time the patient leaves the room up to the arrival of the cleaning service personnel.				x														
Cleaning Time	Time from when the cleaning personnel enters the OR up to the end of the concurrent cleaning.				x											x			
Room Setup Time	Time spent from when the cleaning personnel leaves the OR to when the circulating nurse completes setting it up to admit the next patient.				x											x			
Anaesthesia Induction Time	Time from when the patient enters the OR until it is ready for skin prep. Anesthesia administrated to patient.	x	x			x			x			x		x		x			
Anaesthesia Emergence Time	Time between the end of na operative activity and the patient out of the OR.	x										x					x		Operating Room KPIs
Cancelations	Number of canceled surgical cases. Sometimes adressed as a percentage.								x			x			x	x			
Throughput	Number of surgical cases per OR block time or per day.		x				x			x	x	x				x			
Cases per OR	Number of cases per OR.						x		x										
OR Utilization Rates	Occupancy Rate of OR time used against that which was budgeted.							x		x	x		x		x		x	x	
Under & Over Utilization	OR usage when compared to the OR time which was budgeted. Includes the measuring of costs associated with underused or overused OR time.		x	x				x			x	x	x		x	x			Production KPIs
First Case Start Time Accuracy	Measures the percentage of first cases of the day that start on time. An on-time start is usually defined as the patient being in the OR at the scheduled start time.						x	x	x				x		x				
Start-Time Tardiness	Tardiness of Start Times for Elective Cases. An on-time start is usually defined as the patient being in the OR at the scheduled start time.			x			x					x				x			
Case Duration	Duration time assigned for a certain procedure in OR scheduling, from entrance in OR suite until exit.											x							
Case Duration Accuracy	Percentage of OR cases with duration that are accurately estimated. Bias in case duration indicates whether the estimate is too high or too low.			x				x					x		x				
Delays	Delays happening when compared to the OR scheduling. Can either be avoidable or unavoidable *	x		x		x	x		x			x		x		x			
Same-Day Cancelations	Measures the percentage of surgical procedures cancelled or rescheduled on the day of surgery			x				x					x						
Percentage of Unplanned Closures	Measures the percentage of OR time lost owing to unplanned closures, which can result from the unavailability of human resources or hospital resources.							x					x		x				
Lenght of Hospital Stay	Amount of time a patient needs to stay in the hospital from the moment of admision.						x			x									Additional OR KPIs
Operations Sucess Rate	Measures the rate of successfull operating procedures.																x	x	
Complication Rates	Measures the rate of operating procedures that suffer complications.											x				x	x	x	
Mortality Rates	Measures the rate of mortality during surgical procedures.																x	x	
Mix of Cases	Mix of procedures of the total number of surgical cases per OR block time or per day.									x									
Severity of Cases	Complexity of hospital production.									x									Success of Outcomes

*Delays encountered can be categorized as avoidable or unavoidable. E.g., delays due to late arrival of patients or abrupt changes in clinical conditions, respectively.

Adapted from (a)Harders et al. (2006), (b)Stahl et al. (2006), (c)Macario (2006), (d)Jerico Mde, Perroca, and da Penha (2011), (e)Porta et al. (2013), (f)Attarian et al. (2013), (g)Fixler and Wright (2013), (h)Costa Ada et al. (2015), (i)Attigah et al. (2017), (j)Morris et al. (2018), (k)Marjamaa, Vakkuri, and Kirvela (2008), (l)Rothstein and Raval (2018), (m)Casar Berazaluce et al. (2019), (n)Lee, Ding, and Guzzo (2019), (o)Sonmez & Pintelon (2020), (p)Jin and Liu (2022) and (q)Jin et al. (2022).

APPENDIX C: Role of stakeholders in the process reengineering and redesign

The role of stakeholders is central to the efficiency improvement of any surgical department. It is known that involved stakeholders, such as surgeons, anesthesiologists, nurses and even OR managers possess different opinions on what points need to be improved and how these improvement processes should happen. In fact, it becomes rather the challenge for top managers to effectively manage the OR, control the efficiency levels and gather relevant data because of this divergency of perceptions.

It is extremely important to understand that independently of the solution and vision of the stakeholder, reengineering and redesigning processes work best when stakeholders actually get involved in the creation and implementation processes (Casaletto and Rajaratnam 2004). This because, according to Casaletto and Rajaratnam (2004), forcing the reengineering process from managerial levels separates the design and work from its execution which automatically represents a “recipe for failure”.

In addition to this, and as mentioned in the Literature Review, it is extremelly essential to properly define and communicate the internal information with key stakeholders (including processes, KPIs and goals of the institution). Openly communicating and sharing information with key stakeholders is an essential component of any improvement procedure (Dewes 2018).

APPENDIX D: Definitions of the solutions presented in Table 1

Class*	Proposed Solutions	Definition
Small-Scale Efficiency Interventions	Workflow Redesign	Redesigning the intraoperative processes of the surgical workflow patterns and reassigning tasks within the institution can result in efficiency improvement and reduce wasted time and resources, which can have a significant positive impact. A workflow redesign can happen due to the introduction of other solutions that require a new reorganization.
	Standardization Processes & Instruments	Standardization processes have represented an approach through which hospitals can improve the overall workflow due to consistency and speed with repetition in standard procedures, resulting in immediate time saving opportunities. In addition, it is also known that "standardization processes is an important step to reduce medical errors (Kumar and Steinebach 2008). Besides the standardization of surgical procedures, it is also important to mention that the standardization can happen at two other different levels such as the standardization of surgical trays, and the standardization of surgical teams (Fong, Smith, and Langerman 2016) (Lee, Ding, and Guzzo 2019). Standardization of surgical trays – "Standardizing and reducing surgical instruments for each procedure can improve operating room efficiency by reducing operative costs, setup and counting time, processing costs, and turnover time." (Lee, Ding, and Guzzo 2019). Besides this, it can avoid unnecessary delays associated with incorrect postings or missing instruments. Standardization of surgical teams – "Having the same operating room staff that is familiar with the particular procedures and surgeon preferences can improve operating room efficiency and decrease operative times." (Lee, Ding, and Guzzo 2019)
	Team Huddles	Assessment of the team's performance after a case to understand intraoperative delays. "Before and after each case, surgeons can use team huddles to improve efficiency, by reviewing the OR plan, goals, anticipated flow, and supply needs with the surgical team, at the onset of the case." (Fong, Smith, and Langerman 2016)
	Effective Scheduling Systems	Rational scheduling of the ORs and the use of support OR management information systems ideal for patient and resource tracking. The implementation of a scheduling template for each surgeon could improve the overall allocation of OR time since it would use their specific historical OR performance data. (Marjamaa, Vakkuri, and Kirvela 2008) (Attarian et al. 2013)
	Surgical Procedure Reengineering	Surgical procedure reengineering is one of the keys to improving operating room efficiency since it interferes and helps to minimize the time a surgical procedure consumes and can consequently reduce the cost of the procedure. Besides this, it contributes for the accommodation of more procedures in a given time period, and it becomes beneficial to the patient directly as discomfort is reduced by shortening procedure time. (Casaletto and Rajaratnam 2004)
Medium-Scale Efficiency Interventions	Collection of Data & Outlining of Improvement Points	The gathering of initial workflows and performance data allows OR managers to perform an efficiency analysis to present to the efficiency committee and continuously outline efficiency intervention targets. It also represents a key solution, since "to maintain the achievements, monitoring should be frequent, if not real time." (Marjamaa, Vakkuri, and Kirvela 2008) (Attarian et al. 2013)
	OR / Procedure Checklists	"Development and validation of an observer-administered checklist that assesses completion of key efficiency-related OR tasks during each stage of general surgical procedures." (Fong, Smith, and Langerman 2016)
	Capacity Investments / Hiring Personnel	"Sometimes the workflow can be improved by changing the ratio of nurses and doctors: an extra nurse may enable efficient use of induction room with the same number of anesthesiologists." (Marjamaa, Vakkuri, and Kirvela 2008) Besides this, the implementation of other new solutions may require institutions to hire new skilled personnel for specific tasks being redesigned.
Large-Scale Efficiency Interventions	Supply Chain Optimization	"Supplies are a voluminous and costly component of surgical work (…) Intraoperatively ensuring that the right items are available and that unnecessary items remain unopened has the potential to reduce OR equipment delays, decrease labor costs to pull and restock unused items, and improve doctors' and nurses' focus on clinical care. To reduce the presence of unnecessary items, the surgical team can estimate instrument needs from past cases and can track wasted (opened-but-unused) supplies. Using this information to revise pick lists and standardize OR setups and implement solutions that contribute for a supply chain optimization."
	Real Time Locating Systems	"Real-time locating systems with radiofrequency identification (RFID) or Bluetooth technology, among others, can be used to track and visualize operating room flow and process in real-time. These can then be used to identify inefficiencies or bottlenecks, and could ideally provide automated responses or interventions in real-time to address those inefficiencies (…) the utilization of RFID can be used to track the quantity and location of specific supplies so that specific items can be delivered at the right time for the right procedure" (Lee, Ding, and Guzzo 2019).
	OR Space Redesign	The physical redesign of ORs, as well as the redesign of processes and workflow can result not only in a parallel processing of certain procedures but also in an introduction of new functions into the OR. This means that, for the introduction of certain solutions it is required for the OR space to be redesigned. Needless to say, that the hospital facilities design plays a relevant influence in the patient flow and flexibility. (Fong, Smith, and Langerman 2016)
	Parallel Processing	Parallel processing can be defined as the outsourcing of certain activities, meaning that, when redesigning the space and the processes, whenever possible, activities that do not require the OR are off-loaded to other locations, and activities that occurred serially in a typical OR setting were made to run in parallel in the new OR space redesign (Sandberg et al. 2005).
	Specialization Processes	"Some groups have implemented specialized personnel, programs, instruments, and ORs to improve efficiency." (Fong, Smith, and Langerman 2016)
	Incorporation of New Technology	The incorporation of new technology into the OR can contribute to the reduction of operative procedure time and procedure complications. It allows for the possibility to perform complex techniques intraoperatively with multi-specialty collaboration by creating new approaches to procedures that were not possible to meet with previous technologies.
	Acquisition of Medical Ergonomic Equipment	Changes can be made in terms of the acquisition of medical ergonomic equipment's and materials, to improve the time spent in certain tasks. During patient transfer from the ward trolley to the operating table, a considerable amount of time was wasted, which becomes a great example of this solution. The acquisition and use of mobile exchangeable OR tabletops would eliminate the need to transfer a patient from a gurney to the OR table before and after surgery, since these would be used for both transport and as the operating table. These changes would facilitate rapid movements between the different OR areas, which could reduce non-operative times. (Casaletto and Rajaratnam 2004) (Harders et al. 2006) (Stahl et al. 2006)
	Incorporation of Pre-Operative Clinics	"A well-functioning pre-operative clinic enhances OR efficiency by reducing the number of cancellations and delays." It quite often happens that patients who have been in waitlist for a very long time require a new checkup, reevaluation, before deciding on surgery procedures and methods of intervention. Having a pre-operative clinic responsible for efficient check-in processes at the admissions office, followed by on-time preparation in the preoperative holding area can contribute positively to the OR functioning. Marjamaa e attarian
	Redesign of Processes	

*Intervention Classification according to Fong, Smith, and Langerman (2016).

APPENDIX E: Exploratory and validation meetings, dates and topics

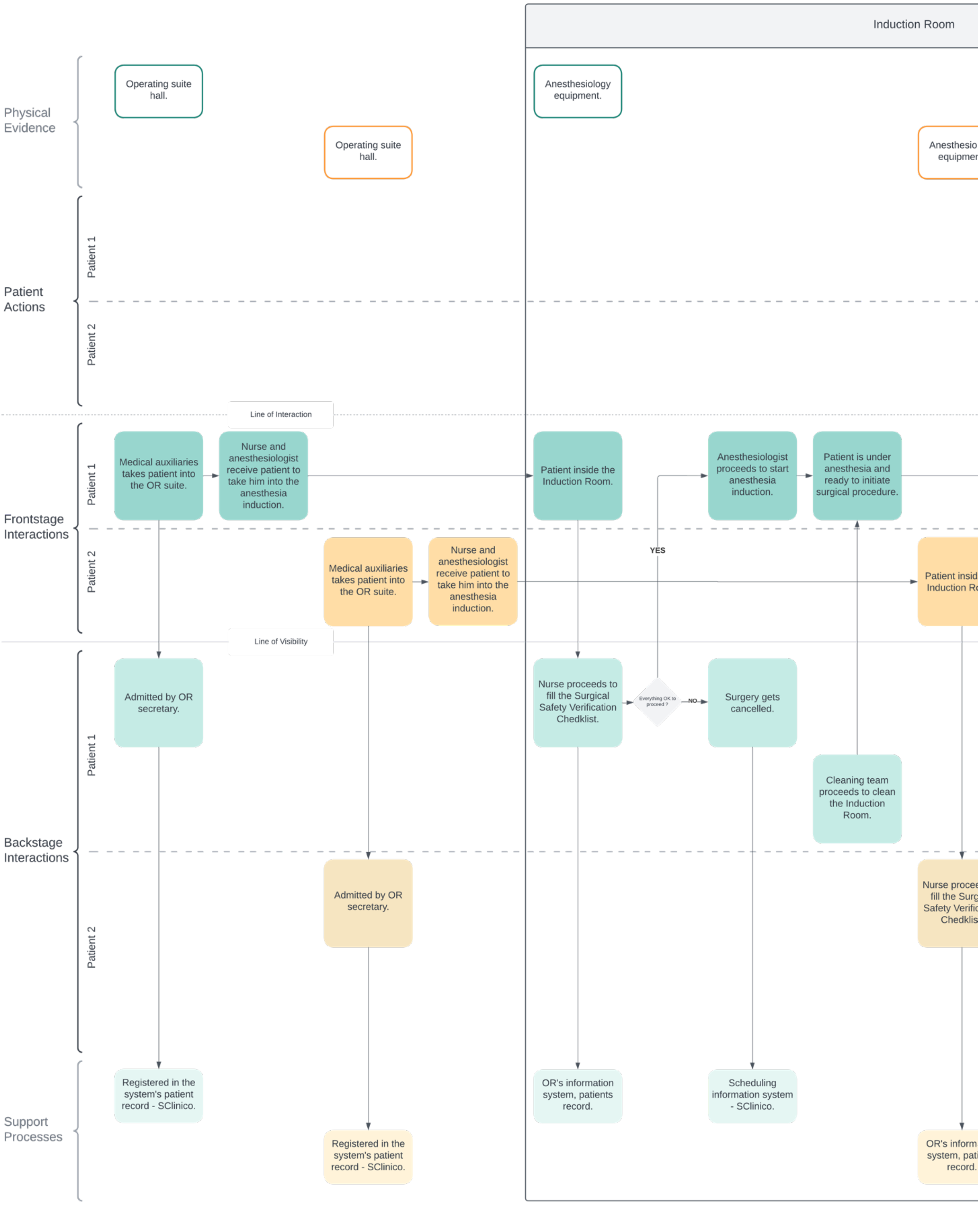
Meetings	Date	Participants	Discussed Items and Topics
1	28/10/2021	Dep. Cirurgia	Discussion and first structuring of the possible theme.
2	08/10/2021	Dep. Cirurgia	Necessary changes to the inicial theme, as well as final preparation for the proposition submission.
3	19/01/2022	Dep. Cirurgia	Filling of formal documents related to the authorizations needed from the hospital to carry out the dissertation.
4	11/02/2022	Dep. Cirurgia	Filling of more documents related to the authorizations needed from the hospital to carry out the dissertation.
5	14/03/2022	Dep. Cirurgia	Discussion of the literature review already started in terms of KPIs. Collection of quantitative data from the hospital's IS, from the years of 2018-2019 and 2020-2021
6	22/03/2022	Dep. Cirurgia	Collection of reports of the department from November of 2021 and the year of 2021
7	11/04/2022	Dep. Cirurgia	Clarification of doubts related to: - The current ORs and the patient circuit. - OR Time attribution to surgical specialties. - HSA capacity. Collection of the OSs layout.
8	25/05/2022	Dep. Cirurgia	Discussion of the processes literature already started, as well as the current solutions. Discussion about the best method to analyze the processes.
9	27/05/2022	Dep. Cirurgia Bloco Operatório	Clarification of doubts. Discussion of the 1V of the service blueprint of the current OR functioning processes.
10	27/05/2022	Bloco Operatório	Analysis of functioning processes of the OR.
11	03/06/2022	Dep. Cirurgia	Autonomous work. Clarification of doubts.
12	31/06/2022	Dep. Cirurgia	Clarification of doubts.
13	12/07/2022	Dep. Cirurgia	Data analysis.
14	15/07/2022	Dep. Cirurgia	Data analysis and discussions of the 2V Service Blueprints.
15	29/07/2022	Dep. Cirurgia	Clarification of doubts. Discussion of parallel processing by using anesthesia induction rooms. Analysis of the proposed Service Blueprint.
16	23/08/2022	Dep. Cirurgia	Discussion of the application of parallel processing into small/long surgical procedures.
17	20/09/2022	Dep. Cirurgia	Clarification of doubts regarding: - The implications of parallel processing. - The anesthetic team. Provisional version of the first 4 chapters of the dissertation.

APPENDIX F: Data analysis of surgical specialties (KPIs: surgical activity + surgical block times + throughput + turnover time + OR utilization rates)

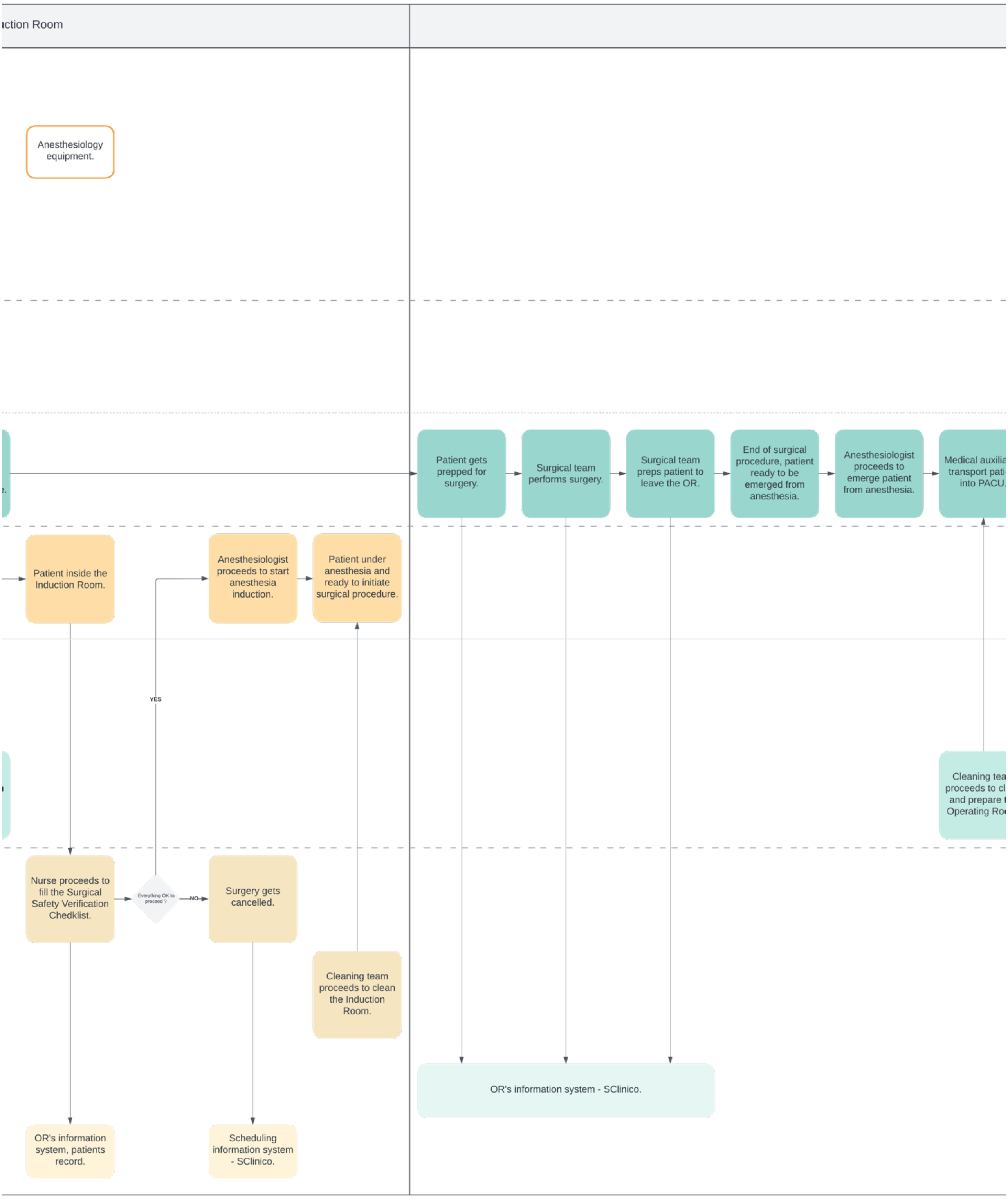
KPI	Vascular Surgery	General Surgery (GS 1 + GS 2 + GS 3)	Plastic Surgery	Maxillo-Facial Surgery	Neurosurgery	Ophthalmology	Orthopedic Surgery	Otolaryngology	Urology (Urology + Lithiasis Urology)	UTCO
Surgical Activity (Base + Aditional)	1061	1064	192	200	1019	488	1804	534	1127	290
Number of Surgical Blocktimes	257	514	110	110	624	92	734	257	459	110
Throughput	4.13	2.07	1.75	1.82	1.63	5.30	2.46	2.08	2.46	2.64
Average Turnover (min)	25.48	13.1	16.33	16.73	20.98	9.73	16.65	22.67	16.92	12.35
OR Utilization Rates (%)	82.67	91.43	75.51	84.77	91.29	97.24	85.35	84.13	83.53	92.8

Data from the year of 2021.

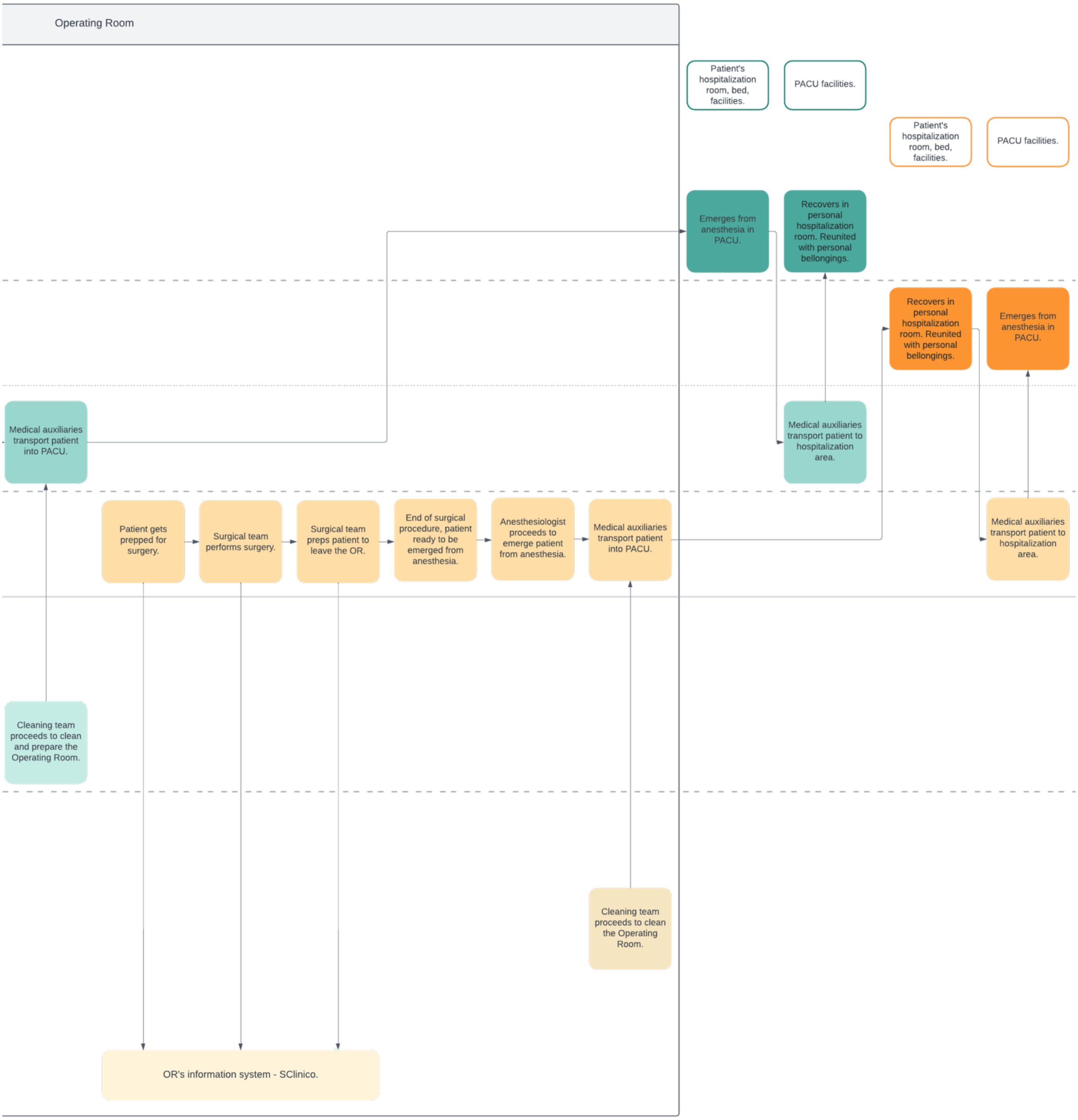
APPENDIX G: Figure 11, part 1



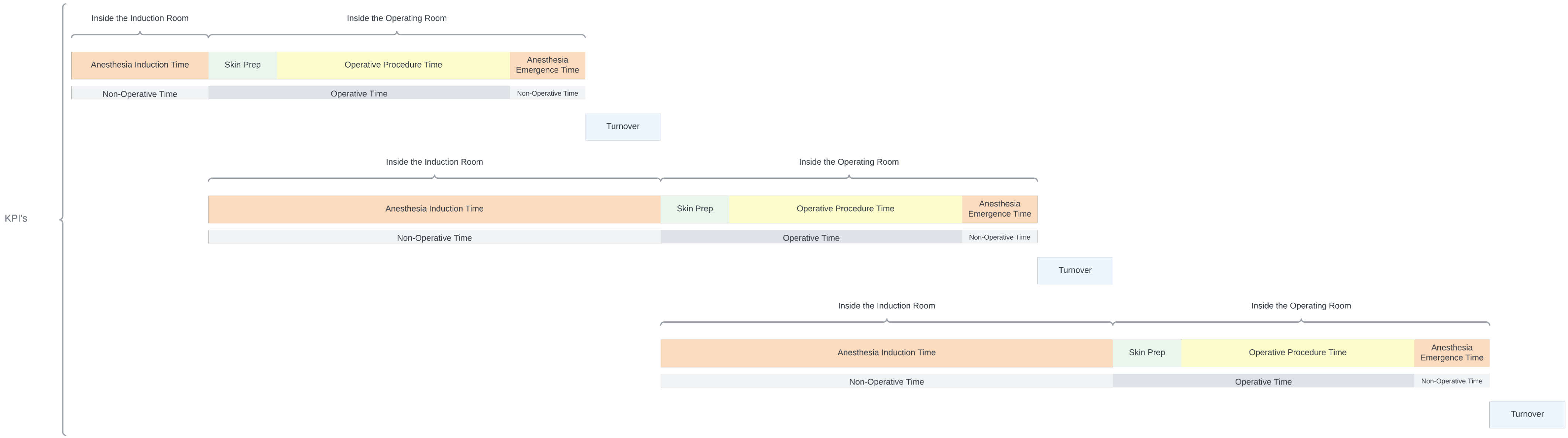
APPENDIX H: Figure 11, part 2



APPENDIX I: Figure 11, part 3



APPENDIX J: KPIs of three simultaneous patients with the introduction of parallel processing (behaviour of KPIs with the proposed solution, Figure 11)

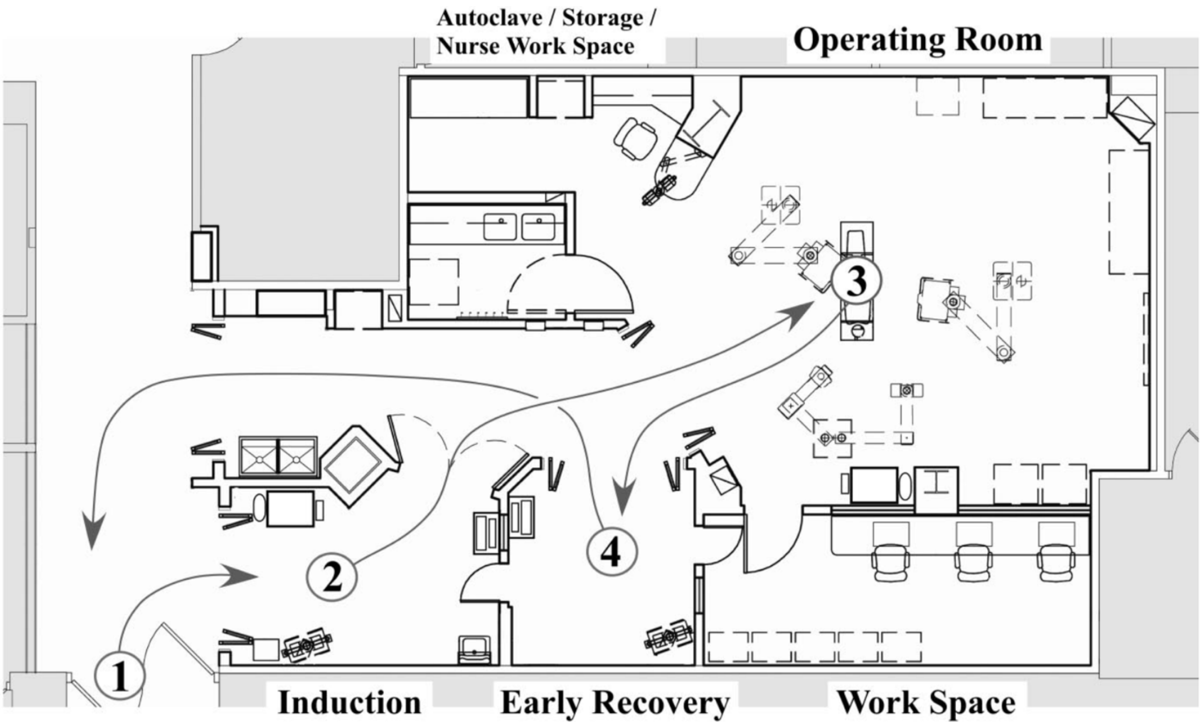


APPENDIX K: Most important contributions of this dissertation (highlights)

Some of the contributions arising from this dissertation are:

- Literature review over the most relevant and weighted KPIs in the literature and the working processes of the OR, as well as existing evidence of improvement solutions to the OR working processes.
- Identification of the most used KPIs inside HSA, as well as an identification of all the processes currently in functioning.
- Identification of a rather existing problem of definition whit KPIs, and the development of a new workflow and representation of KPIs diagram *Figure 8*.
- Application of service blueprinting tools into healthcare, but especially the application of a service blueprint while being combined with KPIs to design the AS-IS of the hospital (the incorporation of KPIs in the design of service blueprints represent a scarce application).
- Practical simulation over the proposed solution.

ANNEX A: Conceptual layout of the Operating Room of the Future (ORF) (Stahl et al. 2006)



The design allows for a flow of work that starts with the patient being transported inside the Induction Room, from number 1 to 2, where it will be anesthetized. After being anesthetized in number 2, the patient is transported inside the OR (number 3) where the surgical activity happens and is later transported into the early recovery (number 4) before going outside the OR into the hospitalization ward. Different patients can coexist with this arquitectural design.

ANNEX B: Surgical Safety Checklist (WHO 2010)

Direcção-Geral da Saúde
www.dgs.pt

Lista de Verificação de Segurança Cirúrgica

World Health Organization | Patient Safety
A World Alliance for Safer Health Care

Ministério da Saúde

Antes da Indução da Anestesia
(Sign in)

(Na presença de, pelo menos, o enfermeiro e o anestesista)

O doente confirmou a sua identidade, o local, o procedimento e deu consentimento ?
☐ Sim
O local está marcado?
☐ Sim
☐ Não aplicável
A verificação do equipamento de anestesia e da medicação está concluída?
☐ Sim
O oximetro de pulso está no doente e em funcionamento
☐ Não
☐ Sim

O doente possui:
Alergia conhecida?
☐ Não
☐ Sim
Via aérea difícil ou risco de aspiração?
☐ Não
☐ Sim e equipamento/assistência acessível

Risco de perda> 500ml de sangue (7ml/Kg em crianças)?
☐ Não
☐ Sim e :
2 acessos IV/central e administração de fluidos planeada
Tipagem e sangue disponível

Antes da incisão da pele
(Time out)

(Na presença do enfermeiro, do anestesista e do cirurgião)

☐ **Confirmar que todos os elementos da equipa se apresentaram indicando os seus nomes e funções**
☐ **Confirmar o nome do doente, o procedimento e o local da incisão**
A profilaxia antibiótica foi administrada nos últimos 60 minutos?
☐ Sim
☐ Não aplicável
A profilaxia tromboembólica foi administrada?
☐ Sim
☐ Não aplicável

Antecipação de eventos críticos
O cirurgião enuncia em voz alta
☐ Quais são os passos críticos ou fora da rotina
☐ O tempo planeado para o caso
☐ Qual a perda de sangue prevista
O Anestesista enuncia em voz alta
☐ Há alguma preocupação específica com o doente?
A equipa de enfermagem enuncia em voz alta
☐ A esterilização (incluindo os indicadores) foi confirmada?
☐ Existem problemas com os equipamentos/ dispositivos ou qualquer outra preocupação?
Estão visíveis exames imagiológicos essenciais ou outros?
☐ Sim
☐ Não Aplicável

Antes do doente sair da sala de operação
(Sign out)

(Na presença do enfermeiro, do anestesista e do cirurgião)

O enfermeiro confirma verbalmente

☐ O nome do procedimento
☐ As contagens de instrumentos, compressas e corto-perfurantes
☐ A rotulagem dos produtos biológicos ou outros (ler os rótulos das amostras em voz alta, incluindo o nome do doente)
☐ Se existem problemas com os equipamentos ou outros a resolver

O cirurgião, anestesista e enfermeiro indicam
☐ Informação relevante a transmitir à equipa de recobro e as principais preocupações/ necessidades do doente