A socio-technical approach to assist the selection of medical devices in hospital settings:
Process improvement in an anesthesiology context

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Declaration

I declare that this document is an original work of my own authorship and that it fulfills all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

Preface

The work presented in this thesis was performed at Centro de Estudos de Gestão do Instituto Superior Técnico and Hospital Santa Maria of Universidade de Lisboa, during the period March-October 2019. The thesis was supervised at Instituto Superior Técnico by Prof. Mónica Duarte Correia de Oliveira and co-supervised by Dra. Filipa Maria Nogueira Lança Rodrigues.
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Abstract

The innovation in health technologies demands their constant evaluation to guarantee their ability to deliver the upmost care, quality, safety and value for money. However, few medical devices are evaluated in hospitals within structured formats integrating the views and perspectives of hospital stakeholders, especially in the anesthesiology context. Multicriteria Decision Analysis (MCDA) has been increasingly explored within Health Technology Assessment, but few studies have been developed in hospital settings.

This study aims to develop a socio-technical approach to improve the process of evaluating anesthesia kits currently applied at Hospital Santa Maria through inclusion of relevant experts, to promote consensus, and use of technological tools to bring innovation and support to a more transparent and structured evaluation process.

A MCDA socio-technical approach for process improvement in the evaluation of anesthesia kits, named MD – Evaluation tool, was designed. Therefore, exploratory interviews were made with anesthesiologists to understand their views and concerns on anesthesia kits. Then, the MACBETH approach was applied to build individual quantitative evaluation models with anesthesiologists, capturing each perspective, and then to build a compromise group model through qualitative protocols of questioning, using web-based platforms and a decision-conference.

The aftermath of this study is the improvement of the evaluation process through a decision-support tool, composed by an Excel tool and the MACBETH software, suitable to guide the DM during the evaluation and selection process of anesthesia kits.

The validation of this tool in the anesthesiology context indicates that it could be adapted and implemented to improve evaluation processes for other medical specialties.

Keywords: MCDA; Decision Support Model; Anesthesiology; MACBETH; Procurement; Hospital-based HTA; Medical Devices

MCDA; Anesthesiology; MACBETH; Hospital-based HTA; Medical Devices
Resumo

A inovação das tecnologias da saúde exige a sua avaliação para garantir que presta o máximo cuidado, qualidade, segurança e relação qualidade-preço. Contudo, poucos dispositivos médicos são avaliados em hospitais em formatos estruturados, integrando as perspetivas das partes interessadas, especialmente no contexto da anestesiologia. A Análise de Decisão Multicritério é cada vez mais explorada na Avaliação de Tecnologias em Saúde, mas poucos estudos foram desenvolvidos no âmbito hospitalar.

Este estudo tem como objetivo desenvolver uma abordagem sociotécnica para melhorar o processo de avaliação dos kits de anestesia atualmente aplicados no Hospital Santa Maria através da inclusão de especialistas, incentivar consenso e uso de ferramentas tecnológicas para trazer inovação e estrutura ao processo de avaliação.

Foi desenvolvida uma abordagem sociotécnica para melhoria do processo de avaliação de kits de anestesia, denominada MD Evaluation-tool. Portanto, entrevistas foram realizadas a anestesiologistas para entender as perspetivas destes sobre os kits de anestesia. Depois, MACBETH foi aplicada para construir modelos individuais de avaliação quantitativa com anestesiologistas, capturando cada perspetiva, para, de seguida, construir um modelo de grupo por meio de protocolos qualitativos de questionamento, usando plataformas online e conferência de decisão.

O resultado é a melhoria do processo de avaliação por uma ferramenta de apoio à decisão, composta por uma ferramenta Excel e software MACBETH, adequado para orientar o decisor durante o processo de avaliação e seleção de kits de anestesia.

A validação desta ferramenta em anestesiologia indica que ela pode ser adaptada e implementada para melhorar os processos de avaliação de outras especialidades médicas.

**Palavras-chave:** MCDA; Modelo de Suporte à Decisão; Anestesiologia; MACBETH; Aprovisionamento; HTA hospitalar; Dispositivos médicos
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Abbreviations

AIMS        Anesthesia Information Management Systems
API         Application Programming Interface
BIS         Bispectral Index
BPR         Business Process Reengineering
CCP         Código de Contratos Públicos
CDS         Clinical Decision Support
CE          Continuous Epidural
CSE         Combined Spinal-Epidural
CSF         Cerebrospinal Fluid
DM          Decision Maker(s)
DSS         Decision Support System
ERAS        Enhanced Recovery After Surgery
EUnerHTA    European Network for Health Technology Assessment
EVIDEM      Evidence and Value: Impact on Decision Making
HTA         Health Technology Assessment
ISPOR       International Society for Pharmacoeconomics and Outcomes Research
IT          Information Technology
MACBETH     Measuring Attractiveness by a Categorical Based Evaluation Technique
MADM        Multi-Attribute Decision-Making
MCDA        Multi-Criteria Decision Analysis
MAVT        Multi-Attribute Value Theory
MODM        Multi-Objective decision-making
PCLS        Physiologic Closed-loop systems
1. Introduction

Nowadays, the research and innovation in healthcare technology as well as its broad adoption are majorly driven by the need to guarantee a continuous improvement in healthcare quality. However, healthcare technology acquisition faces some challenges, since being responsible for a significant increase in health expenditure and fixed costs as well as facing resistance within the health institutions in terms of management, system and culture [1]. In fact, hospitals are considered complex social systems that embrace structural and technological aspects and that need to consider individual entities as well as the cost-effectiveness trade-off [2]. All these aspects only contribute to the notion of the how intricate it is to proceed with alterations within hospital settings. Nevertheless, healthcare innovation models are still integrated in hospital organizations, usually due to studies proving their validity [1].

The healthcare decisions are usually carried out by decision-makers (DM), which must consider the conflicting trade-offs between options as well as balance the multiple objectives [3]. The amount of information and evidence to be considered in decisions usually is quite overwhelming, therefore proving difficult to process and systematically evaluate options that take place in multiple hospital settings. Since this task may include several DM, the difficulty increases due to the individuals’ different views and perspectives. To overcome these adversities and increase the consistency and legitimacy of decisions, one must introduce a structured approach to provide support in decision-making, known as multiple criteria decision analysis (MCDA) [3]. The MCDA approach encompasses several methods which appraise alternatives according to multiple criteria to reach a decision with multiple goals.

MCDA approaches have been known to have value within health technology assessment (HTA) to aid in the evaluation of medical devices [4] [5]. HTA can act as a bridge between clinical research and effective prioritization [6] during decision-making. Thus, it involves a thorough assessment of evidence that can help the DM understand the relative value of health technologies [6], such as medical devices.

An exhaustive research revealed that not only there are scarce studies developing MCDA approaches, but also that the existing ones are mostly centered on the evaluation of pharmaceutical and general health interventions [7]. The same study shows that MCDA studies evaluating medical devices are not common, as well as studies being developed in hospital settings. Naturally, the same applies for evaluations related to anesthesiology devices and interventions.

Overall, within this thesis, a socio-technical approach named MD – Evaluating tool was designed and tested to improve the process of evaluating anesthesia kits at Hospital de Santa Maria, and a decision-making support tool was developed for the context. This tool was inspired by concepts as evidence-based clinical decision-making, multicriteria decision analysis, health technology assessment, business process reengineering and consensus.

1.1. Main challenge and objectives

The present dissertation addresses the process of evaluation and, subsequently, acquisition of medical devices in hospital settings. This type of process is quite complex because not only so many
requirements need to be upheld, as is the case for the safety and quality of the care delivery to patients, but also there are a vast number of aspects that influence the selection, going from budget constraints to diversity of perspective and clinical experience regarding a certain medical device. In the specific case of anesthesiology department at Hospital Santa Maria, it has an evaluation process in place, which is performed mostly in a paper-hand approach and solely decided by a DM. In addition, nowadays more and more, there is a demand to have access to more sophisticated medical devices which, in turn, usually implicates more aspects to evaluate.

Therefore, the aim of this study is the development of a new socio-technical approach - based upon MCDA and value measurement concepts - that improve the process of evaluating anesthesia kits currently applied at Hospital Santa Maria. The approach is designed to include relevant experts in evaluation, to promote consensus among those experts, as well as the use of technological tools to bring innovation and support to a more transparent and structured evaluation process.

To achieve these objectives, ultimately, a user-friendly decision-support tool, named MD-Evaluation tool, was developed to assist and operationalize the whole anesthesiology decision-making process regarding anesthesia kits. This tool combines a clinical decision-support Excel tool and the MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) software. The final motivation was to apply it to the anesthesiology context to assist in a real-life evaluation and acquisition process of anesthesiology medical devices at Hospital Santa Maria.

The proposal of a novel DSS (Decision Support System), the MD-Evaluation tool, continues with the current tendency of exploring the association between hospital-based HTA and MCDA approaches and taking advantage of it. Since in the anesthesiology context there is a scarcity of hospital-based HTA and MCDA studies dealing with medical devices, this study has the potential to contribute with a valid approach, able to merge the technical assessment and the social value evidence, and yet tailored to the necessities of the hospital settings.

### 1.2. Thesis outline

This thesis is organized in a total of 6 chapters that follow. In chapter 2, a contextualization provides a background of concepts, statistics and application cases of several topics regarding anesthesiology and clinical decision-making.

In chapter 3, a literature review of multiple concepts related to multicriteria decision analysis (MCDA) in healthcare was made to provide insight on this topic and understand the pros and cons of the multiple methods that MCDA entails. Besides, it presents the benefits of the connection between the MCDA approach and the social component as well as application of MCDA alongside HTA. In the end, it explains the concepts within neuraxial anesthesia as well as the relevant decrees laws in the Public Contract Code.

In chapter 4, the current process of evaluation and selection of medical devices is presented and assessed. Then, a new socio-technical approach based – named MD-Evaluation Tool - on the
MACBETH technique is developed. To that purpose, the development and implementation of an individual and group multicriteria model are explained in detail.

In chapter 5, the main outcomes and results of this socio-technical approach are exposed by comparing the modelling of individual and group choices and, afterwards, when demonstrating the application case of this socio-technical approach to the acquisition process of medical devices in neuraxial anesthesia. Moreover, the use of the resulting tool combing the Excel tool and the MACBETH software is explain in detail, enabling the its proper use in future acquisition process of medical devices.

In chapter 6, some remarks and advantages brought on by this methodology development and implementation are discussed as well as the limitations encountered are described.

Finally, in chapter 7, the main conclusions of this thesis are drawn and future work is suggested.
2. Context

Throughout this chapter the main ongoing aspects of concern in clinical decision-making, and then specifically in anesthesiology, will be approached. To be enlightened about this medical specialty, a small introduction to anesthesiology specialty will be made, followed by the challenges in anesthesiology decision-making and, then, an assessment of the outcome indicators in anesthesiology. Furthermore, several evidence are presented showing that, although there is a general perception of the current state and challenges in decision-making in anesthesiology, it seems that in reality not much has been done to addressed them.

2.1. Anesthesiology and Clinical Decision-Making

2.1.1. Challenges in Clinical Decision-Making

In health practice, there is a broad spectrum of decisions to be made but the two major topics mainly regard diagnoses and, consequently, the respective treatment plans. On a general overview, although one relies that the correct clinical decision process is met, the diagnostic failure rate is estimated to be between 10% to 15% [8]. These may arise from multiple causes, but the major source is associated to cognitive errors. Additionally, it has been acknowledged that a vast variety of biases, such as gender [8], age [8], race [8] and socioeconomic status [8], influence the rational decision process [9]. However, cognitive failures may be addressed through methods that promote clinical critical thinking [9].

The clinical decision-making process is massively entangled within its own multidimensional problems. To smooth the burden of the complex decisions that decision-makers (DM) need to make, they often adopt intuitive or heuristic approaches [10]. These mental shortcuts allow fast, intuitive and associative information processing based on a quick sense of the surrounding environment and clinical experience without proper rational thinking [11]. Although heuristics usually are useful and can speed up the process without necessary lead to erroneous decisions, they are extremely dependable on the physicians’ clinical experience and the way they assimilated evidence in their own way of thinking, which increases variability [11]. In addition, they may lead to exclusion of choices due to an ad-hoc priority setting process [10]. Thus, to overcome the sources of variability, it is necessary to sought out tools to reach consensus as well as the implementation of more standardized guidelines and protocols. In addition, heuristics may fail and result in an incorrect judgment and erroneous decisions, i.e., cognitive bias. These facts highlight the existing miscommunication or lack of better understanding of fellow physician’s decision making process, that arise from the necessity of implementation of tools to improve communication and teamwork.[11]

In addition, variability in decision-making may be influenced by personal and environmental factors such as sleep deprivation, workload and need of reaching a decision under stressful conditions.
2.1.2. Anesthesiology

The concept of anesthesia usually is automatically associated with medical procedures that require the suppression or absence of pain and possible unconsciousness. However, the anesthesia practice has witnessed a major evolution over the years, denoting an expansion of its medical scope and major advances in safety, quality and technology. Currently, the term anesthesiology specifies the practice of medicine that deals with “relief and prevention of pain during and following surgical, obstetric, therapeutic, and diagnostic procedures, monitoring and maintenance of normal physiology during perioperative period, management of critically ill patients, diagnosis and treatment of acute, chronic and cancer-related pain, clinical management of cardiac and pulmonary resuscitation and evaluation of respiratory function and application of respiratory therapy” (p.3) [12]. Thus, this medical specialty is present in many clinical practices and medical routine procedures ranging from the traditional perioperative care, since pre-anesthetic examination before surgery to postoperative care [13], to the emerging role of on-site prehospital care providers, delivering emergency medical services to trauma and disaster's victims [14]. Therefore, the anesthesiologist can perform the invasive procedures just as minimally invasive or non-invasive procedures performed outside the operating room, since their ability to execute airway management, suppress intraoperative pain, obtain vascular access, cardiopulmonary resuscitation, administration of drugs, carry out massive fluid and blood transfusion protocols, among many other tasks. Hence, their skill set and expertise of dealing with life-threatening situations, gives them the ability to assist in clinical decision-making of patients in several hospital settings, namely in the emergency department, in the operating room and in the intensive care unit [14]. In addition, as the health care system evolves and innovates, there is a demand for the anesthesiology specialty to broaden their medical scope and models of care to sustain their relevancy and value, which has already been observed with the expansion of anesthesiology role to overall critical care medicine, pain management, palliative care and sleep medicine as well as expertise subspecialties, such as obstetrical anesthesia, pediatric anesthesia or even cardiothoracic anesthesia [15].

2.1.3. Challenges in Anesthesiology Decision-Making

In the professional daily routine of an anesthesiologist it is vital that assertive and accurate decisions are made, especially in critical situations, as well as being able to quickly prioritize and swiftly switch between several medical circumstances and hospital settings. Anesthesiologists are no exception, and to be able to accomplish these goals, they often invoke heuristics [10] in the clinical decision-making process since they can be extremely helpful and life-saving, particularly in time-limited emergency medical situations where action is required immediately [11]. As already generally referred, these mental shortcuts’ prevalence may lead to erroneous thought processes. To assess the dynamics of heuristics in anesthesiology a study was conducted, where according to Maceina et al. [11], there are 3 main types of heuristics: representativeness, availability and anchoring and adjustment. Starting with the representativeness heuristic, it occurs when the decision is made based on information that usually or
most typically indicates a specific condition; in the case of availability heuristic, it is used when newly acquired knowledge or also a certain significant clinical experience is the basis of the reason to reach a final decision; finally, the anchoring and adjustment heuristic is identified when the decision-maker either focus on certain aspects without giving the adequate consideration to other alternatives or when it sets his mind on the initial hypothesis and doesn’t adjust it when new information comes to light. The study reached the conclusion that 32% to 38% of decision-making occurred in the form of heuristics and that, as clinical experience increases, the use of the availability heuristic reduces whereas the use of anchoring and adjustment heuristic increases [11].

Regarding sources of variability due to factors external to the rational thinking process, it has been reported in several research papers that anesthesiology is one of the most stressful medical specialties and, therefore, more prone to burnout. This work-related syndrome has reached disturbing levels, with a prevalence of around 50% [16]. It can be manifested in many ways such as demoralization, incompetence and fatigue [17]. This vulnerability to burnout has a significant influence in clinical decision-making [17] as physicians become more susceptible to erroneous thinking process.

Nowadays, healthcare contemplates a continuous increasing trend of patient-centered care safety and effort to decrease any possible clinical complications in overall aspects, such that anesthesiology is no exception. In fact, anesthesiologists are seen as leaders in patient safety movement [16]. However, an anesthesiologist is a human being trained in a medical specialty who relies on the perception of the clinical signs alone to guide anesthetic management, such as patient comorbidity, body mass index, hemodynamics or even genetics. An example of how this can become a tricky and intricate situation is the possibility of patient awareness during surgery, meaning that the correct state of depth of anesthesia may not have been achieved. This occurs because, even with the same dosage or settings, the depth of anesthesia can vary according to the patient individual condition. Thus, several tools, such as E-Entropy and Bispectral Index (BIS), have been developed to assist in depth anesthesia monitoring and allow the level of drugs to be optimized. Nevertheless, there is a lack of comparison between the effects of monitoring tools, which would be useful to aid in the selection of medical devices. [18] Overall, a high-profile challenge in anesthesia is medication safety. A recent study showed that 5% of perioperative medication administration result in a medication error, an adverse drug event or both, when around one third of medication errors identified was an avoidable adverse drug event [16].

Additionally, clinical complications can also result from lack of communication and wide variability in treatment protocols, specially in different departments. This lack of cooperation is then met by the increasing workload and variety of tasks that anesthesiologists must perform. Fortunately, a current field of great research and exploration is the Anesthesia Information Management Systems (AIMS) due to their role in developing clinical decision support (CDS) tools. These decision support systems can integrate data parameters due to electronic data management systems and then consider different clinical scenarios and assessments. Consequently, they aid in reliable and standardized decision-making by suggesting diagnoses and treatments options. [19] Take the example of administration of drugs and intravenous fluids via manual titration, executed daily and requiring constant vigilance. Yet, it is associated with a significant inter- and intrapractitioner variability. To optimize substance administration, several medical technologies have been developed as is the case of automated
physiologic closed-loop systems (PCLS). This medical device is able to monitor many variables and adjust various interventions, as drugs or fluids administration, using a feedback process. It has been demonstrated that PCLS can rapidly recognize physiological changes in the patient and personalize the drug or fluid delivery rate according to each patient's current requirement. Thus, PCLS can potentiate drugs and fluids administration, decrease inter- and intraindividual variability and, at the same time, allow the anesthesiologist to focus higher level clinical decisions. [20] In general, over time these CDS tools have become more accurate and timely and, when properly implemented, they are able to improve safety and efficacy when delivering anesthesia care and in perioperative management. However, many innovative tools still lack feedback data and is still necessary to conduct research to prove to which extent the decision support system improves patient outcomes. [21]

All of the mentioned factors demonstrate plenty of challenges in decision-making and, as already been alluded, practice variability is indicated as a major factor directly linked to the variance in clinical outcomes, morbidity, unnecessary treatment and increase in health care spending. [20] Therefore, it is extremely relevant to assess the current state of anesthesiology practice and, consequently, pinpoint and address the deficiencies and their link to quality, safety and cost as well as their trade-off with effectiveness.

2.1.4. Assessment of outcome indicators in Anesthesiology

To further contemplate the current quality and safety status in anesthesiology is necessary to go beyond the analysis of morbidity and mortality incidents, since they don't always directly derive from anesthesia complications. Therefore, measurement tools gained relevance, particularly clinical indicators that can measure nonquantifiable constructs such as quality of care. In 2009, the first systematic review of validity of only anesthesia-related clinical indicators was performed and, apparently, since then no other publications that extensive and solely considering clinical indicators directly linked to anesthesia have been published. [22] Clinical indicators should be based on robust scientific evidence and, consequently, be able to contribute with consistent and meaningful improvements in quality of care [23]. However, overall, few clinical indicators are well established to be used as true measures of evidence-based best clinical practice. [22] This is even more exacerbated due to lack of standardized and consensus definitions on clinical indicators. [24] Nevertheless, the emerging focus on value-based healthcare may lead to new quality metrics. [16]

2.2. Procurement

Public procurement is the process where competent authorities determine the goods and services to purchase or invest.[25] In the specific case of the healthcare sector, procurement dictates the adoption and diffusion of innovation of health technology, such as medical devices, or clinical services. [26] Usually, this process is controlled by legislation and policy mechanisms and counts on the intervention of several stakeholders, going from administrators to healthcare professionals. [25] [26]
Currently, there is a growing tendency of the applying procurement policies to enable the introduction and adoption of new health technology with the intent of obtaining a financially sustainable access. [27] In Europe, several policies are in place to guarantee an efficient and timely adoption and dissemination of new health technology. Thus, in principle, public procurement promotes the access to new health technology through a transparent purchase process of products with quality and added-value. [25] In Italy, the national health service, has a variety of combinations of implementation of HTA models and procurement programs. A study assessing the impact of these mechanisms reached relevant conclusions regarding centralized procurement, a “form of cooperation between two or more independent organizations that join together, (…) combining their individual requirements for purchased materials, services, and capital goods to leverage more value-added pricing, service, and technology from their external suppliers than could be obtained if each firm purchased goods and services alone.” (p. 90) [27]. Although centralized procurement does not have a significant impact of the medical device selection, its implementation was linked to a decrease in the medical device unit price, more precisely by a margin of 10.1% less. [27]

In reality, as known, the implementation of innovation in the healthcare setting is made at a slow pace and not always is satisfactory [26]. For instance, the expected adoption of innovation at the individual level may not coincide with the actual adoption decision made at the administrative level [26]. Therefore, a successful procurement process needs to have an accurate perception of the organizational context where the medical device is going to be implemented. For instance, addressing the conflicting logics as well as the social aspects is recognized as a likely way to improve understanding in public procurement.
3. Literature Review

Although progress has been made in developing numerous decision-making approaches and tools, the long crusade to reach optimal clinical decision-making methods is still ongoing. Hence, this chapter will start by justifying and illustrating the background of the chosen approach, the Multi-Criteria Decision Analysis (MCDA). Furthermore, the first section will still cover the applicability in healthcare and a vast spectrum of techniques within MCDA, emphasizing the underlaying benefits of their implementation. Then, the possibility of combining MCDA and Health Technology Assessment (HTA) will be presented. After, a review of the MCDA applied to anesthesia field will denote the lack of MCDA enforcement in this medical specialty, followed by an introduction to the neuroaxial anesthesia concepts. Lastly, an overview is made regarding the business process reengineering (BPR) scope as well as the Public Contract Code legislation. All in all, by reviewing the perks of MCDA when applied to health and by uncovering the lack of MCDA optimization tools in anesthesiology, one can come up with an appropriate method for modelling decision-making in anesthesiology.

The research and gathering of relevant information for this state-of-art were based on literature available on Google Scholar, PubMed, ScienceDirect, Web of Science, ResearchGate and B-on. The search keys used to encounter the articles were mainly clinical decision-making, MCDA, HTA, anesthesia and its combinations.

3.1. Multi-Criteria Decision Analysis (MCDA) in Healthcare

The health care system is characterized by multicriteria and multi-objective settings, that often are conflicting and imply a need for trade-offs, which depicts the complexity in decision-making of health-related matters. These can range from high-level decision, as allocating limited resources, to a micro-level decision, as selecting the best treatment option for a patient. [3] [28] Moreover, the significant amount of complexity and uncertainty when facing decision-making in a health environment it is not up for dispute. In addition to the usual barriers in decision-making, as economic and technical, there is also a human perspective that cannot be neglected. To comprehend and address these issues, there is a growing tendency to develop MCDA studies in health settings [29].

MCDA frameworks have been successfully implemented to aid and support decision-making in a wide variety of fields, from sustainable energy to budgeting. The increasing application of MCDA is due to its potential for improving the quality of the decision process by leading a more explicit, rational and efficient path than deliberative processes. [29] Currently, as the extent of the MCDA scope is so vast, distinct subcategories can be singled out, which is the case of outranking methods and value-focused approaches. [30] Yet, it was in 1966 that Howard originally defined decision analysis as “a logical procedure for the balancing of the factors that influence a decision” (p.138) [10], considering already the influence of uncertainties, values and preferences. In 1976, Keeney and Raiffa also made attempts to develop a practical theory that analyzed the decisions with multiple and competing objectives as well as perform decision problems abstraction using decision trees. Since 1976, the implementation of the multi-
attribute theory has evolved and entailed a thorough understanding on how to structure the problem and objectives as well as measure achievements. [31]

Nowadays, MCDA approaches are often described as a set of methodologies that allow to simultaneously explore the multiple and conflicting decision-making criteria as well as try to measure the reliability and credibility of the possible alternative solutions. Thus, MCDA methods are used to appraise multiple clinical endpoints and structure complex decision problems in healthcare decision making. The main goal is to produce an optimal and transparent clinical decision process to, consequently, produce a consistent choice and increase the legitimacy of decisions, minimizing the responsibility of the final decision-maker. [28] [32] Furthermore, its essential to view MCDA as a sociotechnical design, as it is necessary to consider not only the social component, such as the DM and experts, but also the technical component, as which MCDA technique to employ. [33]

The underlying essence behind the conceptualization of the MCDA methods is the incorporation of value judgments, preferences and priorities of DM when facing, at least, two alternative options followed by a simplification of the decision problem to reach a decision. [32] Usually, the DM isn’t only a single person but a collective of interested stakeholders, ranging from patients, to specialists to even analysts. It must be taken into account that decision making bodies present different attitudes towards the risk and benefit trade-off as well as preferences, exposing one of the many degrees of complexity when processing and evaluating relevant alternative information. [3] Fortunately, MCDA can provide systematic and consistent support to quantify DM different perspectives towards medical decisions. This will improve the quality of the decision making-process since the set of techniques will bring clarity to the value attached to each criterion, also known as fundamental point of view, and how it adjusts to the intended framework, enabling DM to gain a better understating of the problem. [28]

Typically, value-based assessments are characterized as a sequential process, demarcated by some stages. Usually, the model will start by addressing the possible alternatives, followed by criteria selection and respective levels of impact, which will function as performance measures. To guarantee a credible outcome, it is imperative to ensure that criteria abides by the following properties [33]:

a) Completeness – representation of all factors relevant to the decision-making process;

b) Non-redundancy – elimination of any criterion deemed as unnecessary as is for the criteria that measure the same factor thus achieving the same level of performance;

c) Non-overlap – avoid double counting on correlated criteria to not overrate the weight on a certain value dimension;

d) Preference independence – the preference on a criterion cannot depend on the performance of another criterion.

In addition, the criteria must also be viable, mutually independent, [28] unambiguous, direct, understandable and operational. [33] Afterwards, weight is assessed as the relative importance of criteria when comparing alternatives. Thereafter, the decision matrix displays the performance of each alternative considering each criteria as well as the overall performance of each alternative. [28]

Throughout the whole MCDA proceedings, it is vital to guarantee the consistency, however there is still a lack of guidelines or information available, which is the case when dealing with DM or when
measuring the performance of alternatives. Therefore, the importance of multicriteria decision-aid methodological framework which is composed by three main phases (Figure 1).[34]

Figure 1 - The three main phases (Structuring, Evaluation, Creation of directions for action) in the multicriteria decision-aid methodological framework [34].

In MCDA, the methods can be distinguished between multi-objective decision-making (MODM) and multi-attribute decision-making (MADM) models. In the case of MODM a continuous range of solutions is considered whereas in MADM the number of alternatives is limited so a discrete solution set is considered [32]. Then, the MCDA modeling approaches can be aggregated and classified in three main groups: (I) value measurement, depicting a decision alternative preference against others through the comparison of numerical scores (overall value) [3] [32], which includes the Multi-Attribute Value Theory (MAVT) [10]; (II) outranking, typically involving pairwise comparison by considering individual partial-preferences functions for each criteria based on cardinal, ordinal or categorical scales [3] [32]; (III) reference-level [3] (also known as goal programming) [32], which relies on mathematical formulation of the suitable heuristic to search for the alternative able to achieve satisfactory levels of performance on each criteria. [3] [32] A schematization of some of the methods included in each of the three main categories is presented below (Figure 2). [32]

Figure 2 - Variety of MCDA approaches. [32]
Another useful classification is according to four categories: the Analytical Hierarchy Process/Analytical Network (AHP/ANP), the MAVT, outranking methods and goal and reference methods. The MAVT is characterized by quantitative methods but riskless, by their comprehensiveness and robustness as well as the reduction of possible ambiguity and motivational biases. Therefore, MCDA methodological processes are usually encouraged to be based on MAVT to build multi-criteria evaluation models. The MAVT methods include approaches such as the MACBETH and Simple Added Weighting.

The approaches to MCDA are numerous and these can be select according to the type of problem and defined criteria. There is a classification of the four main types of decision problems: (I) choice, leading to a small subset to be able to choose only the best action; (II) sorting, where each action is assigned to a category which, in turn, is defined as an advantage according to norms that deal with the final outcome of actions; (III) ranking, ordering the actions according to attractiveness; (IV) finally, description, with a real description of actions and their consequences. A study was conducted to verify the main MCDA methods used to aid in healthcare decisions when analyzing distinct types of problems, with the exception of description type of problem (Figure 3). From these findings, it is possible to observe that AHP is the most representative method chosen by researchers to support decision making. Besides, either AHP, the Fuzzy Logic or EVIDEM are applied to the three different problems. Apart from that, TOPSIS is also considered a very prominent tool and widely used, mainly in health and safety management as well as to ponder treatment and prevention options. However, from all the methods presented in the figure 3, only MACBETH falls under the MAVT methodological process.

![Figure 3 - Distribution of the studies according to the MCDA method used to aid in clinical decision of a certain type of problem.](image)

Furthermore, the systematic review study also assessed the dispersion of published healthcare articles throughout the years, which corroborated the increasing tendency of implementing a structured methodology as MCDA (Figure 4).
When establishing the decision criteria in health-related MCDA, subjective and objective data can be shaped into measurable attributes to directly value health or healthcare. In the case of health technologies, many outcome parameters are considered, such as mortality, morbidity and quality of life, as well as benefit dimensions in terms of improvement of health status, reduction of side effects and disease duration, life extension and improvement of process [32].

Since in healthcare decision-making and health-policy planning the number of alternatives available to choose from are usually fixed in advance, the DM frequently resort to MADM methods, more specifically value-measurement models (Figure 5). [3] These are widely used to quantify preferences and obtain trade-offs in complex healthcare decision-making processes. [5] [32] [33] As an overview of this trend, consider a bibliometric analysis regarding MCDA methods in healthcare that reached the conclusion that the set of techniques that is more abundantly used is AHP. This approach is included in the value-measurement models, confirming the trend of the predilect approach. [29]

Proceeding with the value-measurement approaches, they can be differentiated by the different implementation techniques. In the particular case of the most undertaken scoring and weighting methods used in healthcare, they can be divided in two group categories: (I) compositional, where the stakeholder’s preferences of criteria and alternatives are judged separately, for instance, the Best-Worst scaling methods; and (II) decompositional, which involves deriving the stakeholder’s preferences for weighting and scoring, for instance AHP and MACBETH. [33]

As already mentioned, the AHP approach has a broad range of application [28] [29], going from selection of medical treatments to priority setting. [29] [37] AHP makes use of the elicitation of pairwise comparison judgements, on a ratio scale, and the chance of voicing them. [7] [38] Although it is deemed as easily capturing the objective and subjective aspects of a decision, a major upside-down of AHP is
to be subject to rank reversal. [29] [7] This acknowledges that preferences do not need to be transitive which may drive changes in ranking of alternatives when a new alternative is introduced. [33] This means that the ratio-scale used in AHP do not always preserve the order condition of the respective preference intensities. [38] [7] This basic drawback of AHP shows the possibility of dealing with judgmental inconsistency since order preservation may not be guaranteed. [38] In addition, criteria are easier to operationalize in absolute scales rather than change estimates, as is the case with odds ratios, since it is necessary to beware of the baseline value. [33] Moreover, AHP adopts ordinal scales which do not display interval properties. Since interval properties, meaning equal increments have equal value, are associated with precision of scoring methods [33], this only reinforces the idea that AHP as a decision support tool is very problematic. [38]

Another noteworthy methodology is the Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH), a qualitative swing weighting approach. MACBETH is known as a cognitively friendly approach in empirical settings since it is based on an interactive survey where the DM is asked to give a qualitative judgement solely between two elements at a time (i.e. pairwise attribute comparison). [7] [10] This process acts as a facilitator factor among DM as it has been reported to have a positive impact to express their preference judgments qualitatively rather than numerically. [7] Therefore, when asking for value judgements, it leads to a reduction in the cognitive load which turns into a more natural evaluation process without the possibility of rank reversal, contrasting with the previous AHP technique. [10] [39]

The decision support methodologies, such as MCDA, can be used to investigate many health domains. Studies have a recurring focus in evaluation of health technology, precisely HTA. [28] Furthermore, healthcare decision support's articles regarding prioritization of interventions for reimbursement or coverage, selection of intervention, assessment for licensing and allocation of funds have lately increased. [5] [32] The usual communality between these types of assessments is the use of value measurement approach and scored performance with predefined scales, otherwise there is no pattern in the variety of approaches adopted. [5] Thus, the potential applications of MCDA support diverse types of healthcare decisions, such as understanding the value of alternatives or ranking of alternatives. [3] But, overall the ultimate aim is to continually optimize the entire health care machine.

Despite the willingness to apply the MCDA techniques in healthcare, there is still a lack of familiarity with the diversity of techniques as well as the fundamental theories on their basis. [7] [32] Additionally, there is a deficit of guidelines and standards of which technique to employ in a specific context. This is relevant especially to avoid deducing inaccurate evidence and misleading the DM. [32]

3.1.1. MCDA and the social component

In the course of the MCDA approach, the eliciting of DM’s judgements and perspectives is a crucial step of the social component that constitutes this sociotechnical approach. As stated before, the DM body usually is a group of people with different values, priorities and interests. [32] In MCDA, there is a commitment to guarantee the transparency of decisions and an effort to ease the understanding between DM and other possible involved stakeholders, by leading them to think through all the key
factors and share their rationale. In turn, this enhancement in communication should facilitate identification of gaps of data and generate consensus. [5] [40]

Currently, the standard pattern when approaching decision-making is to strongly rely on the information available to find a solution without giving the proper emphasis to the value positions behind that affect the decision-making.[41] This demonstrates that the demeanor implications have not been receiving the proper consideration, even though several issues due to disregarding them have been recognized.[42] In addition, it has been reported that DM have doubts regarding the generalizability and reproducibility of the approaches developed beyond a specific time and place of context. [5] This lack of repeatability is very typical of unstructured problems since there is uncertainty regarding components of the process, which may be the case with knowing how value positions arise. Therefore, the need for implementation of robust methods across all stages of data assessment that can be used in a systematic and repeatable manner. However, the suitability of a technique to a specific decision problem context is not easy to predict. [41]

Some of the methods presently used for the initial eliciting of points of view and values are Focus Group Discussion (FGD), Interviews, Q methodology, Nominal Group Technique (NGT), Delphi, Decision Conference, Surveys and Questionnaires. [41] An extensive assessment on what which method represents as well as their pros and cons was made (Appendix A – MCDA and the social component, Table 8). These techniques help to perceive the underlaying set of values and perspectives that shape decisions.

A research study comparing some of the techniques revealed that, when the conflict is high, the best techniques to elicit judgments were Q methodology and Delphi, due to the anonymously aspect. For example, since Delphi technique is mainly used by experts that may be of stronger will about their values and priorities, the fact that this technique is an anonymous and iterative tool make it more suitable for conflict management. On the other hand, when the conflict is low but demanding a prompt decision, the suggested technique was NGT.[41]

As the landscape of technology evolves, the approaches requiring collaborative participation become more and more sustained by all sorts of web-based platforms. This alongside internet proliferation, allows to enhance the variety of interaction tools as well as computer-based decision support systems (DSS). [43] [44] Therefore, combining web-based technologies with MCDA provides diversified communications channels and preference elicitation tools with the aim to attain more effective and structured approaches.[44] Hence, bearing in mind the different types of methods for elicitation of judgments, a research was made to find web-based platforms according to those methods to enhance communication and, subsequently, potentially enhance the MCDA process (Appendix A – MCDA and the social component, Table 9).

Even though employing eliciting methods in a face-to-face environment allows individuals to express their values and perspectives to then discussed them and reach a shared understanding, it also is denotable the chance for representativeness issues. [45] Through web-based platforms the possible scheduling issues are not so substantial since not only it allows bridging distinct locations but also may save time due to feature as sharing files. In addition, if the audio or video recording feature is applied it offers a possibility to transcend the issues surrounding lack of repeatability in unstructured approaches.
as well as the lack of reproducibility beyond a specific time. In the end, web-based platforms aim is function as an alternative to issues and, at the same time, support the knowledge management. [43]

An extremely important facet in elicitation techniques is the possibility of exposure to bias since those can reduce effectiveness and credibility of the model.[41, 42] The group-based techniques, as is the case of NGT or FDG, are susceptible to certain types of bias that are absent on individual-based techniques since some types of bias arise from group dynamics, such as the dominance effect of specific individuals over others. However, as a general overview, the groups actually present better rationale than only individual-based techniques, which depicts the collective power of minds in group. Although the biases are never completely erased, one must not disregard it. [41]

Overall, the most suitable elicitation methods are the ones not too cognitively demanding that may lead to the manifestation of unrealistic feedback, not excessively time consuming and fairly intuitive to understand. [42] Regardless, it is essential to keep in mind that collaborative participation in decision-making is a very complex and demanding process and as Rummler states: “Collective is not collaborative. Constructive collaboration needs active coordination, common goal synchronization, proper social technologies utilization and supportive cooperation.” (p. xix) [43].

### 3.1.2. Health Technology Assessment (HTA)

The HTA terminology encompasses distinct frameworks according to the criteria defined but, in general, it aims to implement an agreed set of principles to make judgements about the eventual reimbursement of new health technologies [3] such as drug therapies and medical devices. [46] Other prominent frameworks of HTA are related to priority-settings, reach clinical consensus or approval of guidelines for good healthcare practice. [7] The HTA's set of tools are widely used in improving efficiency in resource allocation due to the limited resources but urge to gain access to more technological and optimized health services. [10] In addition, the HTA has to aim to a decision-making transparency to guarantee a fair resource allocation. [3] Overall, HTA is bond to deal with a budget constraint since it has to consider the trade-off of willingness-to-pay value for benefits. However, this is a tricky interpretation since this approach may not capture correctly the opportunity cost of alternatives. [33]

All around the world, HTA is being increasingly performed by health care agencies. [46] A recent systematic review revealed that since 2008 the number of HTA studies started to rise, with a spike in the 2015 to 2017 period (Figure 6). Additionally, the overwhelming majority of studies that use MCDA integrated in HTA are in the pharmaceuticals field (42%), followed by health technologies (22,5%), health interventions (19,4%) and only then medical devices (12,4%). [7]
The undergoing HTA studies can be conducted using a wide variety of methods, mostly anchored to MCDA approaches. [10] This growing interest in using MCDA for HTA has been shown due to the current effort of making clinical decision-making process more transparent, especially in the case of reimbursement decision making to rank healthcare interventions (prioritization). [32] Several European countries already recommend MCDA techniques, as the case of Germany [5] [32], where AHP and a conjoint analysis have been indicated to weight multiple endpoints to support health technology decision making. [32]

Moreover, the Evidence and Value: Impact on Decision Making (EVIDEM) framework, which was initially created as a tool of decision support for drugs committees, has expanded its scope and combined the HTA and MCDA perspectives [32] [46] by promoting efficient MCDA-based solutions to healthcare decision making and priority setting. [32] EVIDEM is characterized by the inclusion of a criteria to reflect the impact of uncertainty in the results. It resorts to a negative penalty score that becomes more negative as the risk of not attaining the benefits of criteria increases. Additionally, also captures the stakeholder’s attitude towards risk through the score and weight of this specific criteria. [33]

An alternative methodological framework is the European network for Health Technology Assessment (EUnetHTA). For example, it has been coupled with EVIDEM approach and implemented in Lombardy, Italy, for HTA and coverage decisions. [32] This HTA framework prioritized technologies using EUnetHTA domain and included multiple criteria from EVIDEM to guarantee a constant systematic appraisal of the technology assessment to reach a decision. Since 2011, this hospital-based HTA dictates the introduction of diagnostics, devices, interventional procedures and drugs. [3]

Since technological evolution allegedly yields better outcomes, the health institutions try to bring to patients access to modern and more effective care. However, the intent of bringing innovative medical devices and approaches to patients is leaving healthcare institutions and systems struggling to maintain economic stability. Additionally, the medical devices are in a constant dynamic upgrading state and present a widely diversity of options. HTA aims to identify the health technologies with the most cost-effective profiles and aid in decision-making regarding allocation of resources, while trying to innovate at an economic sustainable rhythm. Therefore, a cost-effectiveness analysis was conducted in Italy to perceive the effect of the different implemented HTA when adopting new technologies. More precisely, compared the unit price paid for the same medical devices and determined the HTA that lead to the

![Figure 6 - Number of HTA-related articles published between 1990 and 2017. [7]](image)
lowest possible prices. It reached the conclusion, that hospital-based HTA is linked to a lower probability of acquiring costly devices when compared to regional or national-based HTA. [27]

Furthermore, the MAVT is overall the MCDA’s most recurrent method in HTA, mainly in the additive models for aggregation of alternative’s performance across multiple criteria. [10] [46] As already mentioned, MAVT is favored due to its comprehensiveness and robustness but also due to reducing ambiguity and bias. The appraisal of new technologies via HTA is basically an evidence-based assessment of their multidimensional value by evaluating their marginal benefits. [10]

As a general rule, the developed models in HTA are far from covering the entire scope of health technologies and interventions as well as decision contexts. Regarding the weighting criteria methods, one of the most frequent used is, as usual, the AHP. As mentioned, this method brings some reservations regarding consistency which can cause concerns in terms of the quality findings. Furthermore, it is well documented other challenges faced when dealing with the MCDA in HTA, thus the need to carefully seek robust methodologies to suppress the possibility of inconsistencies. [7]

3.2. MCDA in Anesthesiology

The application of MCDA in the anesthesiology scope, considering the research found up-to-date, is almost non-existing. In 2001, an article exploring the local anesthetics influence on human plasma briefly mentioned the use of a multicriteria decision-making approach to optimize the procedure conditions, followed by validation. [47] Only in 2017, an article primarily regarding the use of MCDA models in evaluating anesthesia methods options for circumcision surgery in pediatrics was published. [37] The conflicting criteria that specialists were faced with when selecting an anesthesia method and the lack of evidence of the most effective method, led to practitioner variability according to their own experience and possible disregard of some criteria. This counterproductive situation prompted the multicriteria evaluation to be applied. The MCDA tools used were fuzzy, very useful tool to transform linguistic terms into numerical assessments, coupled to AHP and also coupled to TOPSIS. In both of these mathematical decision-making methods, individual judgments were considered to obtain qualitative factors through the use of pairwise comparison matrix. A consensus was achieved and the established key priority was being able to rely on anesthesia choice to preserve the vital function of the organ above all. [37]

3.3. Neuraxial anesthesia

To be able to perform a wide variety of the medical procedures, the patient must undergo some type of anesthesia, which according to the clinical situation, either falls under the general or regional anesthesia category. Even though neuraxial anesthesia may modestly increase the intraoperative time, it is a viable alternative to general anesthesia since it has been reported to be more beneficial by having a lower mortality rate of in-hospital patients, lower incidence of postoperative pain and improvement of the complication rates.[48][49] Between the two main categories, the neuraxial anesthesia is characterized as regional anesthesia, also designated as loco-regional anesthesia. [50] Therefore, in
the case of the neuraxial anesthesia, the administration of local anesthetics can either trigger a loco-regional blockade in surgical procedures as well as provide pain management after surgery via epidural infusions, through a catheter. [50] [51]

The neuraxial anesthesia and analgesia techniques comprise spinal, epidural and combined spinal-epidural block. [48] [49] Therefore, the injection site of local anesthetics can be made in the spinal cord or the epidural space according to the intended effect of anesthesia. Then, specific efferent and afferent neuronal pathways within the spinal cord can be blocked by each one of the possible neuraxial anesthesia types. [49]

### 3.3.1. Epidural block

The epidural block can be administered to deal with chronic pain control, labor pain, as a main anesthetic for surgery in the inferior limbs, as a supplement to general anesthesia in surgery from the thoracic level down and even to provide postoperative analgesia. [52]

To provide the dose of anesthetics, a needle injection is performed in the lumbar or thoracic region usually with the patient in the sitting position. As the needle advances through the interspinous ligament there is resistance to injection until it reaches the epidural space and then there is a sudden change with a notable loss of resistance, being this the indication to stop advancing the needle. [52] [53] Hence, this loss of resistance technique, characterized by exerting pressure on the plunger of the syringe to cause the needle to advance until sudden change, will ultimately cause the content of the syringe, usually a saline solution, to be easily injected when the epidural space is reached. Regarding the local anesthetics, their injection has the same spread if the needle is either inserted through the paramedian or midline section. Even though it presents similar cephalad and caudad spread, the injection site is the key determinant of which dermatomes area will be blocked. In the case of the single-injection technique, if there is an intent to manage the affected area, the needle aperture may face cephalad or caudad according to the objective, thus producing a slight propensity of anesthetic’s spread towards the needle’s aperture direction. [53] In the case of being necessary a continuous incremental epidural medication dosage, one end of the catheter is introduced in the epidural space. Afterwards the needle is withdrawn and, in the other extremity of the catheter, a connector will be attached to allow the administration of anesthetics. [52]

During the procedure there is the possibility of accidental dural puncture which may lead to cerebrospinal fluid (CSF) leakage and, consequently, cause severe postdural puncture headaches in patients. [52] [54] This most likely occurs due to the tear caused by the large diameter of the needle used to try to reach the epidural space but instead punctures dural membrane and enters the subarachnoid space, leaking CSF and, therefore, loss of CSF pressure and cerebral venous dilation. [54] [55] The elderly patients are more prone to accidental dural puncture due to aging factors, going from arthritis to spinal canal stenosis where the narrowing of the epidural space complicates needle injection accuracy. [56] Moreover, the accidental dural puncture is also common in postpartum woman that underwent epidural anesthesia. [52] [54] [55]
3.3.2. Combined spinal-epidural (CSE) block

The CSE block is among the possible approaches when resorting to loco-regional anesthesia, combining the spinal and epidural block aspects. Both act in the central neuroaxis but while the spinal anesthesia component is defined by the successful and rapid onset of dense surgical anesthesia, the epidural anesthesia takes longer to set up and may not be dense enough for the patient to remain painless throughout the whole medical procedure. However, the epidural anesthesia component also offers valuable contributions since has the distinct advantage of lower incidence of postdural puncture headache and the ability to easily allow to extend the anesthesia effect when using a catheter technique that is also useful in long lasting postoperative analgesia. [53] Therefore, this combined spinal-epidural technique gathers the quick onset of analgesia and dense block of spinal anesthesia with the possibility of resorting to an epidural catheter to prolong the intraoperative or postoperative analgesia. [53] [57] In addition, this technique is also denoted for using lower dosages of local anesthetics and even a smaller incidence of motor blockade. [53]

During this medical procedure, patients are in a sitting position to receive a needle injection in the lumbar region, namely in the L2-L3 interspace. [57] This technique involves placement on an epidural needle followed by placing another needle, typically a pencil-point type of small-gauge, through the epidural needle to reach subarachnoid space. The pencil-point needle will detect the CSF and then local anesthetics and an opioid are administrated intrathecally, which allows faster pain relief. [55] Then, the spinal needle is removed and due to the placement of the epidural needle, a catheter is introduced in the epidural space, in the cephalic direction, to enable a continuous infusion of local anesthetic solution. [55] [57]

Among the vast applications of the combined spinal epidural block, one of the most recurrent is the obstetrics specialty where is used to induce labor pain relief. This technique is extremely helpful when giving birth since not only is known to promote maternal comfort but also prevent stress-related implications. [57] When comparing the CSE block with the continuous epidural (CE) block, achieved by a continuous infusion of, as a general rule, low concentration of local anesthetics and opioids, it was found that CSE block has a much higher the rate of spontaneous vaginal deliveries and significant less cases of cesarean intervention. [52, 57] Overall, the effectiveness of analgesia and pain relief in uterine contraction, until total cervical dilation and up to delivery are higher when using CSE block rather than CE block. Additionally, in the study performed comparing CSE and CSE block, not even one of the participants registered an headache afterwards. [57]

3.3.3. Raquianesthesia or Subarachnoid Spinal block

The subarachnoid spinal anesthesia is a quite simple technique applied to numb the abdomen, pelvis and inferior limbs, usually applied in not so long surgical procedures (up to 3 hours). [58]

The subarachnoid block starts with the patient either in a sitting or in a lateral position, receiving a needle injection in the lumbar region, typically between the L3 and L4 invertebral space. [58] [59] The needle, normally of small gauge, is inserted via midline or paramedian section. Then, the needle
advances slowly, with significant resistance, until piercing the dura mater followed by a sudden change in the resistance, pinpointing the subarachnoid space. Afterwards, local anesthetics are administrated via the intrathecal route into the subarachnoid space to reach the CSF. [58] [60]

Since smaller needle sizes are used to perform this procedure, there is a reduced post dural puncture headache. [60] However, one of the most serious potential complications of spinal anesthesia is the total spinal anesthesia that results from spinal anesthetic sensory block above the cervical region. Although usually unintentional, it is possibly very dangerous since may lead to respiratory arrest and, consequently, loss of consciousness. [53]

As a general overview of neuraxial anesthesia, there is an extreme concern on how the anesthesia device should be applied during the execution of the technique due to, for instance, morbidities as post dural puncture headache. This apprehension can be increased when the anesthesia device may be somewhat unreliable. However, these concerns cannot be adequately addressed when the anesthesia device selection is essentially based on technical specifications. Furthermore, a deeper insight on the study context allows to easily reach a greater understanding between the facilitator and the experts or DM.

3.4. Business Process Reengineering (BPR)

Starting off with the concept of process reengineering, it has been successfully applied not only in healthcare but also in other industries. Even if, at a first glance, industry may not be the first impression about healthcare, this huge sector involves a significant amount of logistical operations. When necessary, business process reengineering can be applied, for example, on purchasing and material management to produce a sustainable healthcare design. The concept of business process reengineering was first coined by Michael Hammer of Massachusetts Institute of Technology (MIT) in 1990. [61, 62] However, over the time the concept has evolved and not only has developed a wide-ranging scope but also gave origin to several variations of concepts dealing with process alterations. Due to the vast scope, there is also a broad interpretation and implementation of methodologies. [62]

With the advancement of information technology (IT), a growing partnership has been established between IT and BPR with IT playing a role as a facilitator and implementor of the process design. [61, 63] Thus, IT can provide the means to achieve breakthrough performances in processes since the biggest aim of BPR is to introduce improvements, which invariably mean changes according to the scope of the process reengineered. [62] The goals intended can be achieved through IT since it boosts the retrieval of information across functional levels, the inner cooperation and communication between departments, enhances the process performance and eases the assessing of results. [63]
3.5. Public Contract Code

The purchase and acquisition of materials and services by public institutions is regulated according to legislation stipulated by the government. Thus, when hospitals require the acquisition of medical devices, in this case anesthesia kits, they have to consider the current legislation in the selection process. The Public Contract Code, known as *Código de Contratos Públicos* (CCP), gathers the information necessary to consider during proposal assessment. According to the Article 139.º - ‘*Modelo de avaliação das propostas*’, the model evaluating the proposals prioritizes those that better fit the adjudication criterion of most economical advantageous proposal regarding the price-quality trade-off. This proposal’s evaluation model determines that each evaluating factor should have a score scale assigned. Then, for each proposal, a numerical global score is determined by the sum of each factor partial score multiplied by the respective ponderation coefficient. It is crucial to be aware that the evaluation model cannot be susceptible to data dependable of specific attributes of the existing proposals, except the attributes of the proposal being evaluated. [64]

Decisions in healthcare are deemed as very complex due to considering several conditions and having multiple outcomes to reach. Therefore, throughout this chapter an extensive research and assessment was made to get the underlaying idea of the available multi-objective and multicriteria methodologies. Within MCDA, since the MACBETH is, among other things, a method respecting the MAVT and not subject to rank reversal, thus, it seems to be a logical step to implement it. In the anesthesiology context, there is not a solid presence and implementation of MCDA approaches, with the ones applied being questionable since may not comply with the order preservation. In addition, since MCDA approaches have a fundamental social component and in era of technology, an assessment of web-based platforms was made to then integrate them as much as possible into the methodology of this study. As evaluation process improvement is still the proposed goal of this thesis, the fundamental concepts of business process reengineering (BPR) as well as screening criteria will be considered in the development of the socio-technical approach, the MD-Evaluation tool.
4. Methodology

This chapter will be composed by a categorization and diagnostic of the current evaluation process, meaning that, the current methods, data and process were performed for the anesthesia kits, followed by the development of a sociotechnical approach (Figure 7). Therefore, it will be explicitly portrayed the assessment of the current state of the evaluation process of proposals of anesthesia devices, followed by the complete rationale behind the developed sociotechnical approach – based upon the principles of MCDA and of MACBETH - to improve the current process. It includes a multicriteria decision-making approach, the MACBETH approach, combined with web-based platforms, such as SurveyMonkey. Then it will be tested and explained in detail its application to the anesthesiology department at Hospital de Santa Maria to facilitate the selection of the most adequate medical company to supply each type of anesthesia kits.

Throughout the formulation of the new method, several barriers and restrictions were faced due to the complexity and delicacy involving not only decision-making but also health related matters. Some of the setbacks would be:

▪ Which is the best course of action to redesign the current evaluation process of anesthesia kits based on BPR to obtain a sound socio-technical approach with a reliable outcome?
▪ Which is a web-based platform able to collect stakeholder’s input but, at the same time, consider physicians’ basically incompatible schedules?
▪ How to properly handle and incorporate the defined regulations and terms in the hospital and government legislation within the proposed sociotechnical approach?
4.1. Fundamental concepts

To reformulate the current process, it was necessary to investigate fundamental concepts integrated in effective implemented approaches which were aid to turnover similar situations.

4.1.1. Implementation of BPR

Among the vast scope of BPR approaches, in this specific case of healthcare, the relevant perspective it is the one that focus on “rethinking and redesigning business processes to obtain dramatic and sustaining improvements in quality, cost, outcomes and innovation.” (p.2) [65]. The methodology behind BPR can generally be summarized in 8 cycling steps [61]:

a) developing a vision and objective based on the assessment of the current situation;
b) understanding the existing process by distinguish between defective elements and the already efficient elements;
c) identify the process, establishing what needs to be eliminated or improved by reengineering;
d) develop the changing mechanisms;
e) implement the new process design;
f) sustain the new process, because implementation may face initial resistance and consequently the outcome may not be immediate;
g) evaluate the new process, by a thorough assessment and collection of feedback from the involved departments and individuals;
h) if necessary, make modifications to achieve improvement without deviating much from the goal.

To start implementing the BPR it is necessary to understand the current situation and the potential methodologies to, only then, build the vision before developing a thorough reengineered process. This assessment can be structured and documented using flowcharting and process mapping for the current and potential processes. [62] This allows to enlighten about the interconnections between processes stages. Consequently, these will be decisive to an added-value output and efficiency.

One may wonder why not start anew process and redesign from scratch. However, this kind of approach has its own inherent obstacles, since there is the possibility of designing another inefficient system and ignore the already effective steps embedded in the system. [62]

4.1.2. Screening criteria

Since the intuit of MCDA is to support the DM to choose, rank or sort the alternatives within a finite set according to criteria, the screening process is crucial in MCDA to exclude from the get-go some alternatives from a larger set and reach a smaller set of options that very likely contain the best choice. The implementation of a screening allows the DM to immediately eliminate the alternatives that do not follow the specificities that fit the best alternative. Therefore, it is of the most interest to incorporate screening into the decision support process. [66]
Consider that the basic structure of an MCDA approach is constituted by a set of \( n \) alternatives \( A = \{A^1, A^2, A^3, ..., A^i, ..., A^n\} \) and a set of \( q \) criteria \( Q = \{1, 2, 3, ..., j, ..., q\} \), where each criterion \( j \) is screened to verify if it is fulfilled by alternative \( A^i \). By doing this, each valid alternative going forward will be according to each preference of values. [66]

The screening can be formally defined as “any procedure \( Scr \) that always selects a non-empty subset of an alternative set \( A \)” (p.280) [66],

\[
\emptyset = Scr(A) \subseteq A
\]  

where \( Scr(A) \) denotes the remaining alternatives after the screening on the alternative set \( A \). [66]

By following the screening concept, the focus can be directed to the more attractive alternatives. In addition, the more information provided by DM, the more alternatives can be screened out. Thus, screening criteria it is useful to the DM since it assesses a variety of options with distinct attributes to make them standout as long as they respect the stipulated criteria. [66]

4.2. Modelling the current evaluation system

4.2.1. Exploratory interviews

To properly do a categorization and diagnostic of the current process, a qualitative research based on questions was conducted. The aim of these interviews wasn’t to seek statistical representativeness but rather a broad awareness of the involving situation. Therefore, semi-structured exploratory interviews were conducted following a flexible topic guide with open ended questioning. [67]

The intent was to inquire anesthesiology physicians about their perspective regarding the current evaluation process, gaining an insight on which aspects need to be enhanced. Thus, the exploratory interviews addressed the following topics:

a) Stages of the evaluation process;
b) Means and possibility of interaction between the DM and other anesthesiologists;
c) Conditions companies must follow to be eligible to participate in the public applications;
d) Challenges in the evaluation process:
   i. Product selection;
   ii. Variety of products and their interconnectivity and interchangeability;
   iii. Differences of perspectives between colleagues and different anesthesiology subspecialties practicing in different departments;
   iv. Goals and outcomes to achieve.

4.2.2. Assessment of the current evaluation process

After gathering credible information and performing exploratory interviews with stakeholders, it was possible to get a wide and detailed perception of the current process for evaluation of proposals of anesthesia kits at Hospital Santa Maria.
Proceeding according to the guidelines of process reengineering, to develop an assessment of the current situation it is encouraged to build a data flowchart (Figure 8).

**Figure 8 - Flowchart of the current evaluation model of proposals.**
It can be defined as a structured information system modeling technique which supports anew process-oriented view of a specific information system that can offer an more general or detailed process logic. [68] In this specific case, a flowchart schematizing the general overview of the current process that the DM follows during evaluation of medical companies’ proposals is presented below.

In this medical institution, there is at most one annual opportunity to purchase medical devices. The initial phase of this process entails receiving public applications from multiple medical companies that submit a proposal for each medical device they can provide. Therefore, each medical company sends extensive catalogue that display the characteristics of the proposed anesthesia kits for the multiple anesthesia techniques. Among the specifications mentioned by all medical companies the most valued are the type of needle point, needle size and gauge, application technique and eventually the price. However, each catalogue has its own specific template to present the relevant information, meaning that when joining all the proposals it amounts to a stack of papers without any structure (Figure 9). During the selection process it is necessary to consider that the hospital will only make a contract with one specific medical company to supply a certain type of the medical device.

![Figure 9 - Dossier regarding the acquisition process of anesthesia devices, combining all the paperwork (proposals, price’s table, contract, etc).](image)

Afterwards, all the received information is handed to the sole DM, an anesthesiologist. The DM will read and analyze the available information and then will try to contact anesthesiologists from different subspecialties. Although the general focus of all medical professionals is the safety and wellbeing of the patients, each medical specialty has a different goal and needs to be able to deliver different outcomes, which, in turn, leads to different perspectives and opinions. Therefore, different medical specialties and respective types of surgery tend to prefer a specific anesthesia needle or kit and such input is provided to the DM. Based on the gathered information, the DM solely makes the selection of medical companies which will supply each type of anesthesia device. Finally, the DM redacts a document to justify the selection to the sales department.

Regarding the financial aspect, usually the received proposals, for each type of anesthesia device, do not have a significant difference in price between the anesthesia devices proposed by the medical companies. Even though the already mentioned criterion of adjudication expressed in article 139º of CCP states that the chosen proposal should be the most economical advantageous, if properly justified
that the best proposal is other somewhat more expensive, usually the suggestion is accepted. Therefore, the price is not a crucial criterion for the DM when contemplating the available options.

4.2.3. Identified challenges

According to the collected information from the stakeholders, the challenges faced during the evaluation process were identified. The four main concerns are specified below.

a) The lack of a technological tool as a mean to support and ease the evaluation process;
   i. In this specific case, it could be very useful a tool that could help reinvent the evaluation in a more proficient and well-functioning way, such as, storage and sharing of information, screening for key elements or even a communication tool.

b) Limited exchange of perspectives and values between stakeholders;
   i. The DM contacts directly and individually colleagues from the different anesthesiology departments. Therefore, there is no direct crossover of different medical experiences and, consequently, no possibility of justifying one’s perspective. By enabling discussion among stakeholders, it would promote general understanding and ability to reach a consensus on what are the real priorities and when to compromise.

c) Lack of registered documentation to corroborate DM’s final decision;
   i. Even though the DM takes into consideration all the information given, it doesn’t have a registration document, let alone a technological tool, to keep track and gather all the information, which would ultimately allow the DM to corroborate the final decision in case of being contested or need to be validated. Therefore, to improve the evaluation process is necessary to add a technological tool that allow to structure the evaluation process and, overall, support the attainment of a global score that includes more explicitly the input of all stakeholders.

d) Discontent of some stakeholders with the final decision.
   i. This concern is extremely correlated to all the previous. With that being said, although this concern is extremely difficult to overcome, with the aid of a tool that allows discussion between all the stakeholders and, at the same time, express their final input about the several criteria of the acquisition process, there would be a greater possibility for general comprehension and satisfaction.

4.3. Designing a novel approach

4.3.1. Objectives

The proposed socio-technical approach intends to tackle the previous identified challenges in the ongoing process to improve efficiency, optimize the process and validate the outcome with tangible evidence. More precisely, the main objectives will be:
a) implementing web-based platforms to improve communication, dynamism and easiness to reach other stakeholders. This will enable exchange of perspectives and values as well as automation of some steps;

b) implementing a MCDA approach based on software to aid the selection process by establishing the crucial and exclusion criteria and then cross-check them against the characteristics of each alternative;

c) develop a decision support tool that promotes the collection and registration of evidence during the process using the platforms and software mentioned in a) and b), respectively.

### 4.3.2. Redesigned evaluation process

The foundation of this new process is constituted by two main components: technical and social, which can be distinguished but are intertwined throughout the whole process (Figure 10). This connection is reflected on the platforms chosen to facilitate and support this complex process. Hence, in the case of the selected MCDA approach, the MACBETH, it isn’t that unexpected that it is characterized as a socio-technical approach where each stakeholder’s value judgments (social) are considered to weigh in on each alternative to modulate the evaluation process (technical). To collect the value judgements was used a web-based platform, namely SurveyMonkey. Then, further along each component will be elaborated in more detail, depicting the implemented platforms.

![Figure 10 - The unfolding of the socio-technical approach applied to reshape the process used to evaluate the companies’ proposals of medical devices.](image-url)
To develop this socio-technical approach, the fundamental concepts of BPR and screening criteria were perceived as suggestive guidelines. Hence, based on the principles of reengineering, an assessment of the current situation was already made and, subsequently, the objectives for this socio-technical approach were established in a previous section, 4.3.1. In addition, still compliant with the principles of process reengineering, which imply a redesign of the process considering the previous one (Figure 8), as well as to simplify the perception of the various phases, a flowchart representing the outline of the proposed evaluation process is presented below (Figure 11).

The only proceeding that does not suffer any alterations is the one concerning the receiving of proposals’ information submitted by multiple companies. Then, this evaluation process follows by implementing an online survey tool to be possible to define the criteria and respective descriptors of performance. This implies that each expert will receive the link by e-mail to be able to access the platform. These results will be organized to structure the multicriteria model.

Afterwards, a more complex survey will be applied to support the construction of individual multicriteria models and enable the modelling of individual choices of experts in the MACBETH software. Similarly to the previous survey, this one will also occur on a web-based platform and sent by e-mail. Then the outcome will be introduced in the MACBETH software to build the value scales and determine the criteria weights for the individual multicriteria model, thus starting off the multicriteria evaluation of the anesthesia devices.

Soon after, it comes the time for the compromise multicriteria model for the group, where all the experts involved in this evaluation process will attend a decision conference, facilitating the communication among themselves and exchange of points of view. The intuit of this gathering is to reach a general agreement and, therefore, establish the model used in the evaluate process. To accomplish this, taking into account the major incompatibleness of physicians’ schedules, it is proposed to schedule a day in advance for the decision conference. The discussion will follow a structured protocol previously define by the facilitator. During this interchange of impressions, the facilitator will take notes to further consult as well as supervise the meeting to decide when it is appropriate to move on to the next point in the order of business.

After all, a final proposal’s appraisal and evaluation is made by conducting a profile differences and a sensitivity analysis. Only then, it is possible to reach a final recommendation on what would be the best course of action when buying the anesthesiology medical devices.

Finally, as it also happened in the previous methodology, the DM must communicate the final decision to the sales department and wait for their final approval. However, the difference is that instead of writing a full report to justify the decision-making, it can provide the results of the evaluation process as evidence to justify the decision.
Figure 11 - Flowchart of the proposed evaluation process of proposals.
Throughout the whole process several stakeholders intervene and add-value and expertise to the task at hand (Table 1). Thus, there will be three types of stakeholders involved in this process: the DM, Dra. Helena Roxo, the anesthesiologist that previously was solely responsible to select the anesthesia devices and gives the final approval throughout the several steps of the new process; the facilitator, which develops and streamlines the whole implementation process; and the experts, representing the group of anesthesiologists that belong to different subspecialties and will provide their input. In the future, the facilitator role should also be assumed by the DM to gather the necessary, remaining impartial throughout the whole evaluation process.

Table 1 - Processing function and the respective role of each type of stakeholder involved.

<table>
<thead>
<tr>
<th>Process function</th>
<th>Stakeholder</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collecting all the submitted information</td>
<td>DM</td>
<td>Receives all the data and dossier of documents from the sales department.</td>
</tr>
<tr>
<td>Online survey to define screening rules and criteria</td>
<td>DM</td>
<td>Indicates some crucial criteria to be evaluated and topics to be approached.</td>
</tr>
<tr>
<td></td>
<td>Facilitator</td>
<td>Delineates the structure of the survey and posteriorly analyses the results.</td>
</tr>
<tr>
<td></td>
<td>Experts</td>
<td>Fulfil the survey and especially suggest further evaluating criteria.</td>
</tr>
<tr>
<td>Online Survey to gather individual judgements on the performance of criteria for each alternative</td>
<td>DM</td>
<td>Helps to structure the survey data in criteria and descriptors of performance. Validation of medical terminology.</td>
</tr>
<tr>
<td></td>
<td>Facilitator</td>
<td>Delineates the structure of the survey and posteriorly analyses the results.</td>
</tr>
<tr>
<td></td>
<td>Experts</td>
<td>Value judgements regarding the difference of attractiveness between criteria and ranking of swings.</td>
</tr>
<tr>
<td>Online or face-to-face decision conference for interaction of DM with experts to discuss, adjust and validate the multicriteria model</td>
<td>DM</td>
<td>Final validation of presentation structure.</td>
</tr>
<tr>
<td></td>
<td>Facilitator</td>
<td>Guidance and support throughout the structured group discussion. Registration of the key conclusions.</td>
</tr>
<tr>
<td></td>
<td>Experts</td>
<td>Value judgements regarding the difference of attractiveness between alternatives</td>
</tr>
<tr>
<td>Multicriteria model to evaluate the medical technologies</td>
<td>Facilitator</td>
<td>After inputting all data, obtains the global score for each alternative and analyses the results.</td>
</tr>
<tr>
<td>Final proposal's appraisal and evaluation</td>
<td>Facilitator</td>
<td>Presents the results and the developed decision support tool.</td>
</tr>
</tbody>
</table>
4.3.3. Web-based platforms for collaboration

The most suitable web-based platforms will be presented below, more precisely the survey and group platforms. In addition, to clarify, there is the possibility of conducting the group meeting whether online or in a face-to-face meeting.

4.3.3.1. Survey

This type of web-based platform gathers quantitative data from the healthcare professionals. On one side, enables to uncover the key aspects by which a health system performance should be assessed; on the other side, to obtain individual value judgements regarding the current acquisition framework. Therefore, a self-designed, structured survey was implemented in these two instances as an assessment tool for posterior healthcare framework reform.

The survey tool selected was the one designated as SurveyMonkey due to its many advantages and reputation. It is known for its user-friendly interface, free or low-cost packages and for being the overall most used survey tool. Therefore, this online data collection tool is often considered as a benchmarking tool, frequently applied in health and academic research settings. [69] Moreover, this web-based platform is very versatile and easily integrated with the web-based platforms under the umbrella denomination of collaborative software (groupware). More precisely, the SurveyMonkey platform can function alongside Slack or Samepage where, for instance, would appear an automatic notification of any activity that could occur in the SurveyMonkey platform.

4.3.3.2. Online group meeting

In the literature review chapter, section 3.1.1, it was mentioned that Appendix A contains a list of several web-based platforms as an example of possible platforms to implement to provide support, however, due to several limitations, not all are the most suitable in this medical context or would significantly simplify the proceedings.

For this specific hospital environment, there is always the possibility of unpredictable situations that may delay or alter the availability of the physician from one instant to another. In addition, since the anesthesiologists cannot always have access to a computer, there is a necessity of a web-based platform with a well-rounded and highly functional mobile app. Therefore, in case of an online group meeting, the most adequate platform would be the one that is more versatile and has an intuitive layout
in the mobile app. However, as is the case of Jitsi, the web-conferencing platforms sometimes are too restrictive and focus on developing the video features. This may lead to neglect the usefulness of, for example, a well-developed messaging chat. It may prove to be very convenient since the hospital has several areas with bad wi-fi connection that may lag or even completely block the videoconference whereas with a good messaging chat it may allow to continue it, even if at a slower pace. Hence, the best options would be the ones pertaining the collaborative software (groupware) category, such as Skype and Samepage, since they usually are committed to equally develop all the features across the board.

4.3.4. Multicriteria model approach: MACBETH

The MACBETH, an MCDA approach, has been defined as “an interactive approach that uses semantic judgements about differences of attractiveness of several stimuli to help a decision maker quantify the relative attractiveness of each” (p.324) [70]. As mentioned, it operates according to non-numerical value judgements between two stimuli at a time. Thus, the main upside of this decision support system is to not force the DM to choose a direct numerical representation of their preference but rather express a qualitative judgement in a pairwise comparison in terms of difference of attractiveness [70].

To begin the multicriteria assessment process, there is an elicitation of key aspects to determine the evaluation criteria $E_i$ that will define the value tree in MACBETH. At the same time, it is necessary to define the descriptors of performance $P_i$ for each criterion $i$, where the value scales have anchors, both a “neutral” and “good” level which will be assigned the 0 and 100 scores, respectively. Using explicitly defined “neutral” and “good” reference levels is benefic since provides a consistent frame of comparison to the DM throughout the process, which brings a greater understanding and, in turn, has been demonstrated to reduce inconsistencies. In addition, it also provides the possibility of developing a qualitative swing-weighting process which anchored references do not depend on the existing alternatives.[70] These reference levels are crucial to the validity of the model since not using reference levels is known as the most common critical mistake in decision-making. [71] The elicited qualitative judgments can range between $\frac{n(n-1)}{2}$ with $n$ alternatives, meaning that all pairwise comparison are made, to a minimum of $n - 1$ judgments, meaning only comparing one alternative to all the other $n - 1$, although the latter is not very recommended. [72]

Afterwards, for each criterion, the set of performance levels is ranked on order of attractiveness as well as the previously established good and neutral reference levels. Thus, an interactive question-answer protocol is applied to ask the experts, for each pair of impact levels $L_x$ and $L_y$, with $x > y$, the relative difference of attractiveness between $L_x$ and $L_y$. Then, the experts answer according to the MACBETH scale with a “no”, “very weak”, “weak”, “moderate”, “strong”, “very strong” or “extreme” rating. If not evident the difference of attractiveness, it is possible to choose an interval of qualitative rating, such as “moderate-strong”. These answers are introduced in the MACBETH decision support system and are automatically verified for their consistency. If any inconsistency is detected, a suggestion for
judgement modification pops up. After the value judgment’s matrix is fully validated, a numerical scale is build based on the consolidated experts’ value judgements and then discussed. To a certain extent the score of an alternative can be adjusted according to the revised judgement, i.e., without creating inconsistencies. Therefore, as soon as an alternative is selected, a value interval indicates how the score of an alternative within a criterion can be adjusted in the value scale. This discussion ensures that each value scale adequately represents the relative magnitude of difference of attractiveness between options as perceived by the experts. [70] [73]

Afterwards occurs the elicitation of weights for criteria. Firstly, resorting to the neutral and good reference levels, the experts are led to consider a hypothesis where an alternative was neutral in every criterion. Then, it proceeds with the ranking of swings by asking if only a criterion could be improved from the neutral level to the good level, which criterion would be chosen. This was made successively until all the criteria were ordered from the most attractive to the least attractive (global attractiveness). Secondly, it follows a question regarding how much would a swing from neutral to the good level in a criterion increase its overall attractiveness, which would be classified with a qualitative judgement from the previously referred MACBETH scale. As similar questions are made for the subsequent criteria, the value judgements are being inserted in the neutral column in the weighting matrix. [70] Consequently, by doing this, the last column of the weighting matrix cells is filled and the rest of the matrix can be fulfilled by transitivity. [74] As before, inconsistencies would be automatically detected and suggestions would be adopted. In the end, the DM must validate the weights and, if necessary, make adjustments. Afterwards, it was possible to build the weighting scale with the respective weight of each criterion. [70]

After all, by considering the value scale score of each option in each criterion as well as the weights of criteria it is, thereby, possible to obtain an overall performance score for each alternative, accordingly to the additive aggregation model:

\[
V(A) = \sum_{i=1}^{n} w_i v_i(A)
\]

with \( \sum_{i=1}^{n} w_i = 1 \) and \( w_i > 0 \) and \( v_i(\text{Good}_i) = 100 \) \( v_i(\text{Neutral}_i) = 0 \) for \( i = 1, \ldots, n \)

where \( V(a) \) represents the overall performance of an alternative \( A \), \( n \) the finite set of choice alternatives, \( w_i \) the weight of a criterion \( i \) and \( v_i \) the value of local performance of an alternative in that criterion. Also, by convention, the sum of weights must be equal to 1, the weight of each criterion must be positive and, as mentioned, the neutral and good reference level are assigned 0 and 100 scores, respectively. [75] In this aggregation is assumed that each partial score of an alternative contributes independently to its aggregated value. [73]

To facilitate the weights assessment, a sensitivity analysis can be performed, showing how a modification on a certain weight would affect the overall result of the model. This modification must be done within a specific interval, otherwise can also create the mentioned inconsistencies. Therefore, these simulations allow to obtain a glimpse on to which extent changes can impact the overall result. For instance, if only a large shift would be significant to impact the overall score, it will advised against it, since a swing of large magnitude would lead to inconsistencies within the weighting matrix. [70] Based on the application of MACBETH is obtained a cardinal value measurement. Firstly, by modelling
individual choices, therefore getting each individual multicriteria model, and then modelling group choices, leading to the compromise of group multicriteria model.

4.3.5. Structuring the multicriteria model

The analysis procedure of an MCDA approach starts by defining the criteria and descriptors of performance. Therefore, the web-based survey platform is applied to elicit the key aspects. The data collected will be clustered to then be defined as criteria, by which the attractiveness of the set of alternatives will be appraised and help define the respective descriptors of performance. To that purpose, the DM, Dra. Helena Roxo, the one responsible for the procurement decision, will provide the support to properly structure the data in criteria and descriptors of performance.

4.3.5.1. Web-based survey platform

When facing a decision-making problem, usually the focus is on choosing the best possible choice among the alternatives. This standard problem-solving approach entails firstly uncovering all the possible alternatives and only then articulate the objectives or criteria to evaluate the alternatives. According to Keeney, this ‘alternative focused-thinking’ methodology is a limited and inefficient way to reach the ideal alternative containing the intended values. This thinking approach is backwards since should be the values driving the decision-making process. Therefore, Kenney’s proposition is “articulating and using the fundamentals values to guide and integrate your decision-making activities” (p.537) [76], designated as ‘value-focused thinking’. This means that, from the outset, make values explicit and afterwards apply them to identify desirable decision opportunities and to create better alternatives.[76]

Adopting this concept of ‘value-focused thinking’ for the assessment and evaluation of anesthesiology devices and to, subsequently, enable their acquisition, the objectives and values were sought out among the expert physicians. Thus, the following survey was scripted with the intuit of capturing the perspectives and values that are the most relevant and the ones that usually arise concern or even divergencies among co-workers. The collected responses will allow to define the criteria and descriptors of performance.

Considering all the mentioned factors, a survey was structured. The access to the survey web-based platform was made by a link sent in an email. The content of the survey is presented below as follows:

a) What are the characteristics that would exclude a given anesthesia kit to be selected?

b) Considering your daily practice within your anesthesia department, what are the characteristics or criteria that would lead you to select a certain anesthesia kit?

c) Among the anesthesia kits, which one are you more prone to always rely to achieve the intended outcome when performing a procedure? Why is that?

d) When selecting an anesthesia device, how do you consider that “technique easiness” could be evaluated?
e) When selecting an anesthesia device, do you consider “patient safety” as a criterion that could be assessed by the following dimensions?
   i. Technique quickness (avoid unnecessary discomfort during procedure)
   ii. Technique executed with the maximum asepsis
   iii. Minimization of complications
   iv. Efficiency while undergoing anesthesia

   What other dimensions would make an anesthesia device valuable?

f) From a post-procedure perspective, what are the main concerns directly related to the anesthesia kit applied?

g) Besides the safety of all patients, what do you consider as essential outcome goals to declare the treatment of patients successful in the subspecialties of anesthesiology where neuro-axial anesthesia is applied?

h) In relation to the fixation of the catheter to the skin, which type of fixator is the most advantageous and why?

i) Have you ever detected any flaws in the components of the anesthesia kits? If so, what alterations do you suggest?

4.3.5.2. Defining criteria and descriptors of performance

The results of the previously mentioned survey allow to obtain the decisive evaluating factors for the acquisition of anesthesiology’s medical devices. This survey was answered by 5 anesthesiology physicians from several anesthesia subspecialties, namely orthopedics, plastic surgery, obstetrics, urology, chronic pain and pediatrics. Thus, the fact that so many different subspecialties were covered, allows to access a more diverse poll of perspectives and judgments. The information obtained from the survey is presented below (Table 2) and will be clustered in criteria and descriptors of performance with the assist of the DM, Dra. Helena Roxo.

Table 2 – Results of the first survey answered by the anesthesiologists (experts’ group). The information is presented according with main areas of concern clustered by the medical device’s impact during the hospital’s admission period.

<table>
<thead>
<tr>
<th>Hospital’s admission period</th>
<th>Areas of concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td></td>
</tr>
<tr>
<td>▪ Promptness to assemble the medical device;</td>
<td></td>
</tr>
<tr>
<td>▪ Assure the integrity of the medical device;</td>
<td></td>
</tr>
<tr>
<td>Intraoperative</td>
<td></td>
</tr>
<tr>
<td>▪ Duration of the procedure;</td>
<td></td>
</tr>
<tr>
<td>▪ Possibility of extending the anesthesia period;</td>
<td></td>
</tr>
<tr>
<td>▪ Analgesia;</td>
<td></td>
</tr>
<tr>
<td>▪ Quickness and easiness of technique execution;</td>
<td></td>
</tr>
<tr>
<td>▪ Anesthesia effect onset;</td>
<td></td>
</tr>
<tr>
<td>▪ Technique efficiently applied to obtain the intended outcome;</td>
<td></td>
</tr>
<tr>
<td>▪ Handling of the medical device;</td>
<td></td>
</tr>
</tbody>
</table>
- Fitting and adjustment of the workpieces’ settings;
- Patient comfort;
- Lock system of the medical device;
- Integrity of the medical device in the end of the procedure;
- Leak of cerebrospinal fluid (liquor) between needles’ junction (bad fitting);
- Characteristics of the catheter (composition, rigidness, fixation system to the skin, possibility of obstruction, low rate of displacement);
- Technique with the highest asepsis;

**Postoperative**

- Analgesia;
- Possible complications or adverse effects (hematoma, meningitis, epidural abscess, headaches);
- Material contamination causing hemodynamic instability, such as hypotension.

The information gathered provides a wide variety of potential criteria that must be scanned according to the properties previously detailed in the literature review, section Multi-Criteria Decision Analysis (MCDA) in Healthcare. Recalling those properties, it is crucial for the potential criteria to abide by completeness, non-redundancy, non-overlap and preference independence to actually qualify as a set of criteria in MCDA. [33] Solely if all these properties are fulfilled, the model in construction can be considered valid.

Afterwards, the identified criteria are gathered in a value tree (Figure 12) which will be transposed to the MACBETH software. The cost of acquisition of the medical devices is not included as a criterion for the experts to assess the several companies’ proposals since it is firstly considered as a screening criterion and, according to the CCP previously mentioned, even if the final choice it is not the cheapest, if properly justified, it will be accepted. Moreover, even though initially safety was considered as a potential stand-alone criterion, it was then verified that safety is a crucial factor across all instances. Therefore, it is implicitly assumed that all dimensions of descriptors of performance above the neutral level, inclusively, do not compromise the safety of patient.

---

**Legend:**

- Orange boxes highlight criteria.

**Figure 12** – Criteria highlighted by orange boxes, which were defined after the clustering of the information collected in the surveys’ responses. The other boxes define aspects included in the concept of the respective criterion.
To measure the performance of a given anesthesia device in a certain criterion, it was necessary to establish some performance aspects to evaluate. Thus, the 5 criteria presented above (Figure 12) were defined as follows:

- Medical device’s handling: the extent to which the technical and logistical aspects as well as the material composition of the components of the medical device interfere with the ability of executing the technique;
- Technique efficiency: the extent to which the medical device used in the technique interfere with the efficiency of the nerve blockade regarding to adequate time, type of procedure and necessity of being replaced due to no longer being useful;
- Functional Recovery: the extent and pace to which the patient recovers the sensory and motor sensations to the pre-procedure state as well as the possible limitations to perform activities;
- Patient satisfaction: the extent to which the patient is satisfied with the technical aspects of the medical device regarding the comfort during the intraoperative period and the subsequent pain control during the postoperative period;
- Morbidity: the extent to which the patient may have a medical adverse effect due to the medical device applied during the execution of the technique.

After the clustering, each descriptor of performance is associated to a criterion as an ordered set of plausible impact levels of that specific criterion. [34] As mentioned, each descriptor has two anchors as reference levels, the “good” and “neutral”, that are established as the descriptors of performance are defined (Table 3).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Descriptors of Performance levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical device’s handling</td>
<td>H1. Straightforward assembly and fitting of the medical device with standard cerebrospinal fluid reflux. High perception of syringe loss of low pressure as the injection occurs. Easy usage of the locking system and malleable catheter – GOOD;</td>
</tr>
<tr>
<td></td>
<td>H2. Straightforward assembly and fitting of the medical device with standard cerebrospinal fluid reflux. Good perception of syringe loss of low pressure as the injection occurs. Malleable catheter;</td>
</tr>
<tr>
<td></td>
<td>H3. Tricky assembly and fitting of the medical device but standard cerebrospinal fluid reflux. Good perception of syringe loss of low pressure as the injection occurs. Malleable catheter – NEUTRAL;</td>
</tr>
<tr>
<td></td>
<td>H4. Tricky assembly and fitting of the medical device but standard cerebrospinal fluid reflux. Good perception of syringe loss of low pressure as the injection occurs. Catheter exteriorization due to poor fixation system;</td>
</tr>
<tr>
<td></td>
<td>H5. Tricky assembly and fitting of the medical device but standard cerebrospinal fluid reflux. Good perception of syringe loss of low pressure as the injection occurs. Kinking of the catheter due to its rigidness;</td>
</tr>
</tbody>
</table>
### Technique efficiency

<p>| | |</p>
<table>
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</tr>
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<tbody>
<tr>
<td>H6.</td>
<td>Tricky assembly and fitting of the medical with the possibility of disconnection of components. Possible detachment between needles may cause irregular cerebrospinal fluid reflux. Uneasy perception of syringe loss of low pressure as the injection occurs;</td>
</tr>
</tbody>
</table>

| T1. | Blockade adapted to the duration and degree of surgical aggression with fast effect onset and possibility to use the same medical device to extend the anesthetic and analgesic postoperative blockade; |
| T2. | Blockade adapted to the duration and degree of surgical aggression with fast effect onset – GOOD; |
| T3. | Blockade adapted to the duration and degree of surgical aggression – NEUTRAL; |
| T4. | Incomplete blockade without toxicity by local anesthetics; |
| T5. | Incomplete blockade with necessity of technique reversion (new medical device); |

### Functional Recovery

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F1.</td>
<td>Asymptomatic</td>
</tr>
<tr>
<td>F2.</td>
<td>Standard sensory and motor recovery to the pre-procedure state - GOOD;</td>
</tr>
<tr>
<td>F3.</td>
<td>Prolonged recovery as mild numbness or transient paresthesia with performance of activities with mild limitation comparing to the pre-procedure state - NEUTRAL;</td>
</tr>
<tr>
<td>F4.</td>
<td>Sciatica persistency with incapacitant limitations comparing to the pre-procedure state;</td>
</tr>
<tr>
<td>F5.</td>
<td>Chronic paresthesia due to traumatic nerve damage with brief or persistent severe limitations comparing to the pre-procedure state;</td>
</tr>
<tr>
<td>F6.</td>
<td>Nerve blockade persistency with sensory and motor limitations comparing to the pre-procedure state;</td>
</tr>
</tbody>
</table>

### Patient Satisfaction

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P1.</td>
<td>Patient fully comfortable during intraoperative period and regular pain control in postoperative;</td>
</tr>
<tr>
<td>P2.</td>
<td>Mild patient discomfort due to puncture pressure and spine curvature during intraoperative period and regular pain control in postoperative - GOOD;</td>
</tr>
<tr>
<td>P3.</td>
<td>Patient discomfort due to elevated puncture pressure and nerve shock sensation during intraoperative period and regular pain control in postoperative - NEUTRAL;</td>
</tr>
<tr>
<td>P4.</td>
<td>Patient discomfort intensified by nauseas and vomiting (hypotension), but easily manageable, during intraoperative period and regular pain control in postoperative;</td>
</tr>
<tr>
<td>P5.</td>
<td>Patient discomfort intensified by nausea and vomiting (hypotension) during intraoperative period and low pain control in postoperative;</td>
</tr>
</tbody>
</table>

### Morbidity

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>M1.</td>
<td>No morbidity;</td>
</tr>
</tbody>
</table>
M2. Mild physical trauma to the epidermis due to friction or pressure in the injection site – GOOD;
M3. Postdural puncture headache – NEUTRAL;
M4. Epidural or spinal hematoma, meningitis, arachnoiditis, epidural abscess and allergic reactions;
M5. Life-threatening condition: Septicemia and anaphylactic shock;
M6. Death.

4.3.6. Individual Multicriteria models

To model the value judgements of each participant and avoid any influence or group bias, the web-based survey platform, SurveyMonkey, is once more applied. The purpose is to allow a free expression of each expert and make them familiar with the process. The individual value judgements are collected and, based on them, build the value scales for criteria and, subsequently, obtain the criteria weights. As before, the survey was sent to the experts through e-mail.

Even though for the initial survey there were 5 experts, due to reasons unrelated to this study, from now on the elaboration of this socio-technical approach will only count with the contribution of 3 experts.

4.3.6.1. Implementation process

The process to achieve the modelling of each individual choices is composed by two building blocks, the first building a value scale for each criterion and the second obtaining the criteria weights.

Starting off by defining the cardinal value function for each descriptor, each expert will provide their value judgements on the difference of attractiveness between the finite set of performance levels. Therefore, in the judgment’s matrix of each criterion, the set of alternatives can be ranked on order of performance levels. Then, the approach for the questioning process consists on a pairwise comparison where the expert will be asked to express his judgement according to the semantic categories of MACBETH. Therefore, the expert will be faced with a template question similar to: “Considering the criterion $i$, what is the difference of attractiveness between the $L_x$ performance level and $L_y$ performance level?”, to which a qualitative judgement from the MACBETH categorical scale (“no”, “very weak”, “weak”, “moderate”, “strong”, “very strong” or “extreme”) will be expected. These categorical judgements will be inserted in the judgement’s matrix and, thus, allow the construction of an interval value scale. This numerical scale is auto-proposed by the MACBETH algorithm, however an interactive discussion with the DM will assess if any adjustments are necessary to achieve a more meaningful difference of attractiveness and finally validate the cardinality of the scale.

To obtain the criteria weights, another set of questions must be made to the experts. In a first instance occurs the pairwise comparison between alternatives to obtain the ranking of swings. Thus, the questioning process is based on the following template question: “Considering that an alternative $a$ is neutral in every criterion and only one criterion could be chosen to improve to the “good” reference level, which improvement in criterion would it be?”. This question is successively asked for the still
remaining swings until all the criteria are ordered from the most attractive to the least attractive. After all, then it follows a question regarding how much would a swing from neutral to good in a criterion increase its overall attractiveness, such as: “Considering all the other criteria equal, what is the difference of attractiveness between an alternative with a bigger swing from neutral to good compared to a smaller swing?”. Once again, this question is successively repeated. This last questioning protocol it is really specific, depending on the characteristics of each alternative and its placement on the overall attractiveness. By subsequently doing this, the weighting matrix cells can fill the neutral column and, as before, the DM must validate the weights and, if necessary, make adjustments.

4.3.6.2. Web-based Platform: protocol

As mentioned previously, the individual multicriteria model consists of two building blocks. Ergo, the first building block corresponds to the first part of the web-based survey platform and will help to determine the value scales of criteria, whilst the second building block corresponds the second part of the web-based survey platform and enables the attainment of criteria weights. The protocol and respective obtained results for each of the survey’s sections are presented in the following sections.

4.3.6.2.1. First part: Value scales of criteria

The first part of the web-based survey contains a set of questions that intends to assess difference of attractiveness between performance levels of each criterion that, subsequently, allows to fulfil the matrix of judgments to obtain the value scales. These qualitative judgments are expressed according to the semantic scale of MACBETH.

To accomplish this task, the survey is scripted with a section for each criterion, which includes the respective descriptors of performance (Table 3) as well as the definition of the “good” and “neutral” reference levels. In addition, some comments are added with instructions or to clarify what is expected. Upon reading all this contextual information, the expert can finally provide his qualitative judgement regarding the importance of improvements within a criterion. To that purpose, the expert is faced with a question always with the same structure: “Considering your experience using medical devices in your daily clinical practice, state the importance in improving the impact level of a medical device in terms of [criterion]”. By establishing a standardized question, it fosters the reduction of ambiguity of interpretation that could emerge as an expert was providing the input across the different criteria.

According to good practices and to reduce eventual inconsistencies within the multicriteria decision-making model, the difference of attractiveness between performance levels was made using the two anchors already stipulated, the “good” and “neutral” reference levels. [70] Thus, for each criterion, it was asked how each anesthesiologist classified the improvement necessary for the performance levels below the “neutral” level to achieve that same “neutral” level. Simultaneously, considering the performance levels between the “good” and “neutral” reference level, a likewise procedure was employed to ask the difference the attractiveness regarding the “good” level. To fulfil even more cells of the matrix of judgements and, therefore, capture more accurately the given input, as one of the default
suggestions in the M-MACBETH guide, it was also asked the difference of attractiveness between each consecutive level. [74] This way, it was possible to certainly fulfill the entire diagonal immediately above the main diagonal of the matrix of the judgements.

Each expert indicated only a category of the semantic scale to express the difference of attractiveness between the performance of levels. Then, these judgments were inserted within the matrix of judgements in the M-MACBETH software and the remaining cells were deduced by transitivity. Therefore, for each expert and for each criterion, there is a value scale. Whenever an inconsistency in the matrix of judgements was detected, the suggestions of the software M-MACBETH to solve them were accepted. With respect to possible adjustments and validation of the value scales, these were only made with the DM and not the experts.

The resulting value scales for the whole criteria will be presented for further analysis in the Results chapter and compared with the value scale obtained in group for the compromise group model.

### 4.3.6.2.2. Second part: Obtaining criteria weights

Afterwards, the web-based survey presents a set of questions to evaluate the difference of attractiveness between certain performance levels of a criterion and, subsequently, enables the fulfilment of the weighting matrix of judgments to obtain the criteria weights. Once again, these qualitative judgments are expressed according to the semantic scale of MACBETH.

To simplify the understanding and contextualize the survey, a scheme is displayed with the underlaying idea of a swing between the “good” and “neutral” performance level of each criterion (Figure 13). Also, a letter was assigned to each swing to represent it. Afterwards, the survey proceeds with the ranking of the criteria (overall attractiveness), thus asking a standardized question based on the scheme, as follows: “To improve the impact of the medical device on your daily clinical practice and patients, which “neutral” level would you prioritize to improve (A,B,C,D or E) assuming that all the criteria are on the “neutral” level?”. Then, the expert was also faced with another standardized question as: “Considering the impact of the medical device, indicate the improvement’s importance of the selected swing?”. The expert would express this difference of attractiveness answering according to the MACBETH scale. Thereafter, it was asked to the expert to discard the already chosen improvement and a likewise process was repeated until the criteria was all ranked.
Based on the survey results, for each expert, the ranking of improvements was introduced in the weighting matrix of judgements in the M-MACBETH software. Then, the qualitative judgement for the difference of attractiveness were introduced in the respective cell of the last column and the remaining cells deduced by transitivity. In addition, for possible inconsistencies, the suggestions of the software were accepted with the validation of the DM and not the experts. The obtained criteria weights for each expert are presented in the Results chapter for further analysis with the criteria weights obtained in the group multicriteria model.

4.3.7. Group multicriteria model

After the assessment of each of the individual value judgements, now a compromise between the group of experts will be obtained. To that effect, a decision conference was held in the department of anesthesiology at Hospital Santa Maria, in Lisbon. As before, the objective is to collect the value judgments to insert in the M-MACBETH software and, therefore, build the value scales for criteria as well as obtain the criteria weights.
4.3.7.1. Group decision conference: protocol

The group decision conference was initially thought out to take place using a web-based platform by taking advantage of the video conferencing feature on many of the platforms mentioned in the literature review, section 3.1.1, and Appendix A. However, due to incompatibilities not only on the professional but also personal agenda, a decision was made to change to a face-to-face meeting held during the work time. Therefore, a face-to-face group decision conference took place between the DM and 3 experts, gathering, in this case, an insight on the obstetrics, orthopedics and pediatrics subspecialties of anesthesia. Also, a facilitator is present to guide and moderate the process.

The decision conference has a very similar structure to the individual multicriteria modeling since the same questions made on the web-based survey platform were repeated during the decision conference. This means that the implementation process in section 4.3.6.1. is also underpinning the structure of this decision conference process. The purpose of repeating the questions is to promote a debate of the perspectives and clinical experience from which each person answered a certain question. From there, potential ambiguity on interpretation can be exposed and clarified as well as present different clinical points of view to the group. Only then, the group can reach a general agreement and, subsequently, obtain the compromise group model to build the tool for medical device’s selection.

Similarly to the individual multicriteria model, the decision conference is divided in two main segments: firstly, building of the value scales of criteria and, secondly, ranking of the swings for criteria overall attractiveness. In addition, in each segment and for each criterion, the alignment for the decision conference was first presenting the results obtained in the individual multicriteria, highlighting the results with the biggest discrepancies, and then proceed with the questioning. For a better understanding, the following sections will explain in detail the process for building the value scales and for obtaining the criteria weights.

4.3.7.1.1. Value Scales of criteria

The first segment of the decision conference intended to collect the group qualitative judgements regarding the difference of attractiveness between exactly the same performance levels inquired in the first part of the web-based survey. Therefore, the questions presented had a very similar structure in comparison to the survey.

In the course of the first segment of the decision conference, each time after presenting the individual value scale obtained for each expert in a certain criterion, the ensuing question had the following structure: "Considering the impact of the medical device, the importance of going from $L_y$ (performance level $y$) to $L_x$ is characterized as [category from the semantic MACBETH scale]" (Figure 14). After some debating between the experts, there was the possibility of reaching a consensus on only one category or a range of categories from the semantic MACBETH scale. Then, each time, the qualitative judgements were introduced in the value judgments matrix in the MACBETH software (Figure 14).
After collecting the specific value judgments for a certain criterion, the remaining of the value judgments matrix was completed by transitivity. Afterwards, if inconsistencies were detected, they would be solved by adopting one of the MACBETH suggestions. Only then, the resulting value scale was presented to the experts and DM for possible adjustments. In every criterion, there were a consensus that the resulting value scale was already accordingly to the group judgment, being, therefore, validated without any adjustment made. Hereupon follow the resulting value scales for the criteria (Figure 15 to 19). As it is noticeable, the questioning protocol led to an intentional partial fulfillment of the matrixes to prevent that an excessive amount of pairwise comparisons began to be a cognitive burden. Therefore, the pairwise comparison were only made between consecutive performance levels as well as by comparing performance levels to the fixed reference levels “neutral” and “good”. The use of the reference “neutral” and “good” levels is encouraged since, according to Belton and Stewart, “the use of central rather than extreme reference points may guard against inaccuracies arising because of possible non-linearity in values occurring at extreme points, a factor which is particularly important in the assessment of weights”. [70]
Figure 15 - Resulting value judgements matrix (a) and respective value scale (b) for the Medical device's handling criterion.

![Medical device's handling matrix and scale](image1)

Figure 16 - Resulting value judgements matrix (a) and respective value scale (b) for the Technique Efficiency criterion.

![Technique efficiency matrix and scale](image2)

Figure 17 - Resulting value judgements matrix (a) and respective value scale (b) for the Functional Recovery criterion.

![Functional Recovery matrix and scale](image3)
4.3.7.1.2. Weights of criteria

In the second segment of the decision conference, the intention was to obtain the ranking of the swings and, consequently, obtain the criteria weights. As it happened on the first part of the decision conference, firstly the results regarding the individual multicriteria models were displayed. Thus, to emphasize the variability of the results, it was showcased the ranking chosen by each of the experts. Once again, the question procedure has a very similar structure to the one implemented in the survey to obtain the individual multtcriteria model. Therefore, the experts were presented with the same scheme as the one featured in the survey (Figure 13), which displays the swings between the “good” and “neutral” performance levels for each criterion. Then, to determine which criterion would they improve from the “neutral” to the “good” level, the following question was made to the experts: “Considering a medical device characterized with the 5 neutral criteria (orange), and only one criteria could be chosen...
to improve the medical device impact, which criterion would be (A, B, C, D or E)?” (Figure 20). After, it is asked to exclude from the possibilities the previous selected swing (A, B, C, D or E) and the question was repeated until a ranking of the swings is achieved.

![Ranking of improvements](image)

---

In this scheme, the neutral impact levels (orange) and good impact levels (blue) are displayed in detail for each criterion. Each letter (A, B, C, D, E) represents the improvement from the neutral to the good performance level in the respective criterion.

**Figure 20** - Example of the questioning procedure presented during the decision conference to obtain the ranking of the swings. The slide displays the swings with the criteria respective “good” and “neutral” performance levels and the standardized question.

Afterwards, each improvement must be evaluated with a qualitative judgment from the MACBETH scale. Thus, for each criterion, the following question was made to the experts: “How do you characterize the difference of attractiveness of the selected improvement?” (Figure 21). After discussing it, the ranking of the improvements and the respective value judgements were inserted into the weighting matrix (Figure 21).

---

![Criterion: Medical device’s handling](image)

**Figure 21** – (a) Example of the questioning procedure, in this case for the Medical Device’s Handling criterion, presented during the decision conference to obtain the criteria weights. Each slide presented the MACBETH scale, the swing of a specific criterion, presenting the “good” and “neutral” levels, and the standardized question. (b) Weighting matrix in the MACBETH software with a highlighted yellow cell corresponding to the difference of attractiveness pointed out in the slide in (a).
After all the collected data is inserted into the MACBETH software, the remaining of the weighting matrix was completed by transitivity. Afterwards, if inconsistencies were detected, they would be solved by adopting one of the MACBETH suggestions. Below, it is depicted the final weighting matrix and resulting criteria weights (Figure 22).

![Figure 22 - Resulting weighting matrix (a) and the respective criteria weights (b).](image)

During the decision conference, the criteria weights suffered some adjustments. It was considered that the criteria “Functional Recovery” and “Morbidity” had a more similar weight, therefore the interval difference between both was decreased. At the same time, it was also considered that the criteria “Functional Recovery”, “Morbidity” and “Technique Efficiency” have a higher weight compared to the other two remaining criteria, “Patient Satisfaction” and “Medical Device’s Handling”. Thus, the weight of criterion “Technique Efficiency” was slightly increased. In the end, the criteria weights were validated by the experts and DM.

4.4. Design of a novel DSS

The DSS developed to potentially be used in future acquisition processes composed by a decision-support tool in Excel complementing the M-MACBETH software. The evaluation process involving the M-MACBETH in future acquisitions will basically be a replica of the section 4.3.7. Group multicriteria model. To design the decision-support Excel tool (Figure 23), once again the social and technical components were considered. More precisely, the DM was probed and asked to indicate any useful features. The input received was to create a tool that embraced the process from the very first moment to the last. Therefore, on the technical side, a decision was made to design an Excel tool that starts with worksheets containing the data submitted by the medical companies during the public applications.
process. At the end, graphics, tables and other data types would be available to use as evidence of the decision analysis in the report to deliver to the Sales department.

The main purpose of this tool is to overall support the assessment and decision process in MACBETH. This main objective is composed of several goals, more precisely:

- Promote a structured and inclusive communication process between physicians in different subspecialties;
- Promote clinical critical thinking in group and decrease the tendency to fall back on pre-defined concepts;
- Facilitate the organization and analysis of information that will help to evaluate alternatives in a more interactive way;
- Support the coordination of the process to help the DM reach the multiple goals and, in the end, provide already assembled and structured data to support the report;
- Complement the debate on either the web-based platform or face-to-face meeting.

### Decision support tool to assist the decision-making process in MACBETH

**Objectives**

<table>
<thead>
<tr>
<th>The main purpose of this tool is to overall support the assessment and decision process in MACBETH. This main objective is composed of several goals, more precisely:</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>Promote clinical critical thinking in group and decrease the tendency to fall back on pre-defined concepts;</td>
</tr>
<tr>
<td>Facilitate the organization and analysis of information that will help to evaluate alternatives in a more interactive way;</td>
</tr>
<tr>
<td>Support the coordination of the process to help the DM reach the multiple goals and, in the end, provide already assembled and structured data to support the report;</td>
</tr>
<tr>
<td>Complement the debate on either the web-based platform or face-to-face meeting.</td>
</tr>
</tbody>
</table>

**Outline of tool functionalities**

- Promote a structured and inclusive communication process between physicians in different subspecialties.
- Promote clinical critical thinking in group and decrease the tendency to fall back on pre-defined concepts.
- Facilitate the organization and analysis of information that will help to evaluate alternatives in a more interactive way.
- Support the coordination of the process to help the DM reach the multiple goals and, in the end, provide already assembled and structured data to support the report.
- Complement the debate on either the web-based platform or face-to-face meeting.

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**Figure 23** - Screen of the welcoming page of the Excel tool with the objectives and outline being displayed.
5. Results

The results chapter will present the four main outcomes of the developed socio-technical approach. Firstly, it will be presented a comparison between the individual and group multicriteria models, highlighting the main differences and similarities. Secondly, it will be presented a real application case based on the acquisition process of anesthesiology medical devices, more precisely anesthesia kits, at Hospital Santa Maria. Thirdly, it will be displayed a decision support tool combining the tool built in Excel, which purpose is to aid in the selection of medical devices, alongside the MACBETH software and, therefore, be applied by the DM in future acquisition processes. Finally, the results of the feedback survey will be reported, which focus on the possible validation of this socio-technical approach and collection of any suggestions to improve it.

5.1. Comparison of the modelling of individual and group choices

At this stage, the outcome of the individual and group multicriteria models is showcased making evident that these present variabilities in the results. To clarify and explore these differences and also possible similarities, a comparison is made between the results obtained for the individual (Expert A, B and C) and group modelling choices. However, it is important to emphasize that the individual model allowed each expert to express himself without any group bias and at the same time get acquainted with the criteria and impact levels. Then in group, considering the individual results, a discussion was encouraged to expose the reasoning and the distinct perspectives. Finally, in the end, the process converged allowing to reach a multicriteria model based on the group understanding.

5.1.1. Value scales

Both in the individual and group multicriteria models, the qualitative judgements regarding the difference of attractiveness between performance levels were registered. Then, these value judgments, based on the semantic MACBETH scale, are converted into a numerical value scale. For an adequate and equitable comparison, all the obtained value scales for each criterion are presented and analyzed (Table 4). For the good and neutral levels of performance, the scores are anchored as 100 and 0, respectively, being quite easily identified.

When assessing the difference of attractiveness between performance levels $L_x$ and $L_y$, it is considered that intervals between performance levels can be deduced and then compared to other levels. To determine if an improvement from $L_y$ to $L_x$ is equally, more or less attractive when compared to other improvement, the difference of attractiveness between pairs of levels $z_{xy}$ and $z_{rf}$ is made:

$$v_i(z_{y\rightarrow x}) - v_i(z_{r\rightarrow f}) \Rightarrow \begin{cases} = 0 \\ < 0 \\ > 0 \end{cases}$$
where $v_i$ represents the value corresponding to the performance level in the value scale. If the difference is null the improvements are equally attractive whereas when the improvement is higher than zero the improvement from $L_y$ to $L_x$ is more attractive than from $L_r$ to $L_f$. [77]

Table 4 - Value scales resulting from the individual (Expert A, B and C) and group multicriteria models regarding all the criteria.

<table>
<thead>
<tr>
<th>Medical devices' handling</th>
<th>Expert A</th>
<th>Expert B</th>
<th>Expert C</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>H2</td>
<td>H3</td>
<td>H4</td>
<td>H5</td>
</tr>
<tr>
<td>100</td>
<td>66,67</td>
<td>0</td>
<td>-116,67</td>
<td>-116,67</td>
</tr>
<tr>
<td>100</td>
<td>50</td>
<td>0</td>
<td>-116,67</td>
<td>-116,67</td>
</tr>
<tr>
<td>100</td>
<td>50</td>
<td>0</td>
<td>-150</td>
<td>-300</td>
</tr>
</tbody>
</table>

| Expert A | Expert B | Expert C | Group |
| T1 | T2 | T3 | T4 | T5 | / |
| 225 | 100 | 0 | -150 | -150 | / |
| 226,67 | 100 | 0 | -100 | -133,33 | / |
| 250 | 100 | 0 | -200 | -300 | / |
| 300 | 100 | 0 | -133,33 | -333,33 | / |

| Expert A | Expert B | Expert C | Group |
| F1 | F2 | F3 | F4 | F5 | F6 |
| 100 | 100 | 0 | -200 | -200 | -366,67 |
| 133,33 | 100 | 0 | -66,67 | -133,33 | -233,33 |
| 100 | 100 | 0 | -250 | -400 | -550 |
| 300 | 100 | 0 | -133,33 | -333,33 | / |

| Expert A | Expert B | Expert C | Group |
| P1 | P2 | P3 | P4 | P5 | / |
| 166,67 | 100 | 0 | -133,33 | -300 | / |
| 200 | 100 | 0 | -40 | -100 | / |
| 166,67 | 100 | 0 | -100 | -266,67 | / |
| 200 | 100 | 0 | -150 | -350 | / |

| Expert A | Expert B | Expert C | Group |
| M1 | M2 | M3 | M4 | M5 | M6 |
| 125 | 100 | 0 | -125 | -250 | -400 |
| 400 | 100 | 0 | -100 | -100 | -100 |
| 150 | 100 | 0 | -125 | -275 | -425 |
| 120 | 100 | 0 | -120 | -160 | -280 |

Regarding the “Medical device’s handling” criterion, it was the one that raised inconsistencies in all of the individual’s expert models, being the only time in case of the expert A and C. Although there are more inconsistencies, it was somewhat expected since more comparisons between performance levels were made to the experts. Looking at the value scales it is possible to deduce that the improvement from H3 to H2 as well as from H2 to H1 are in all the cases less attractive than the H3 to H1 (neutral-good levels) improvement. Meaning, for instance, that since expert B in the H3 to H1 (neutral-good levels) improvement has an interval of 100 points whereas in the improvement from H2 to H1 has an interval of 50 points (100-50=50), the H3 to H1 improvement is more attractive. Furthermore, in each of
the improvements from H3 to H2 and from H2 to H1, the difference of attractiveness is similar between
the experts and in the group. Then, in the H5 to H4 and H6 to H5 improvements there is a higher
discrepancy of the individual’s values towards the group value, especially the value of expert C in the
H6 performance level (-650 considering -255.56 by the group). It is worth notice that the expert B has
the same value for the H4, H5 and H6 performance level (-116.67). This happened due to the suggestion
adopted to solve the detected inconsistencies.

The same analysis approach can be followed for the remaining criteria. Concerning the “Technique
efficiency” criterion, no inconsistencies were detected, therefore there is no possibility of extending
inconsistencies to the generated value scales. The improvement with greater prominence is the one
from T2 to T1 which was always considered more attractive than the improvement from T3 to T2 (neutral-
good levels) and where there was more agreement among experts and the group. Considering the
“Functional Recovery” criterion, similarly to the previous criterion, there were also no inconsistencies
detected in the given judgments. Analyzing the improvement from F2 to F1, it was always considered
less attractive than the F3 to F2 improvement (good-neutral levels), although the decreased
attractiveness is not so accentuated as with the individual opinions. In the case of the “Patient
Satisfaction” criterion, once again, there were no inconsistencies detected when the judgements were
inserted in the MACBETH software. In the case of the improvement from P2 to P1, it was considered
less attractive by expert A and C, actually by the chance with the same value (166.67), and equally
attractive by expert B and the group, when comparing to the P3 to P2 (neutral-good levels) improvement.
However, the performance level P1 is the one that presents not only more concordance between experts
but also with the group as well. Finally, the “Morbidity” criterion, where only the expert B had
inconsistencies detected but immediately solved by the suggestion adopted, being again the reason for
the same value in the M4, M5 and M6 performance levels. Regarding the improvement M4 to M3, only
expert B considered it equally attractive when compared to the improvement from M3 to M2 (neutral-
good levels) while the other experts and the group considered more attractive. However, the
performance level M4 has somewhat similar values among the experts as well as with the group
agreement.

5.1.2. Criteria Weights

The individual and group criteria weights obtained by asking the experts to rank the improvements
between the neutral and good performance levels are presented below (Figure 24). It is worth recalling
that while the group criteria suffered some adjustments, the same wasn’t possible to happen for the
individual criteria weights. Looking ate the values, only expert A and the group decision has some
commonalities across all the criteria. Then, there is also some similarities between expert B and C in the following criterion: Functional Recovery, Patient Satisfaction and Morbidity.

Although throughout the comparison between the results of the individual and group multicriteria models plenty of discrepancies were spotted, the key idea to take away is that the decision conference enabled the discussion of concepts and exposition to different interpretations and, in the end, the experts converged their judgements and reached a final group agreement. From now on, the group multicriteria model is the one used to reshape and improve the process of medical devices’ selection.

5.2. Socio-technical approach for selection of medical devices in neuro-axial anesthesia

This socio-technical approach was developed to improve the evaluation and selection process of anesthesiology medical devices in hospital settings, more precisely anesthesia kits. This approach assesses the impact of the several alternatives and compare their impact based on the criteria defined throughout this socio-technical approach. In the end, the M-MACBETH software will suggest the alternative that presents itself as the highest value proposition.

Since anesthesia kits are the anesthesiology medical devices being purchased recurrently, the evaluation process focus is on the anesthesia kits that are crucial to perform the neuraxial anesthesia medical procedures. In this case, the evaluation of anesthesia kits is made in the neuro-axial anesthesia context, however it could also be applied to other anesthesia fields, for instance, the plexus anesthesia.

Since this socio-technical approach was formulated at Hospital Santa Maria, the data source used to implement this tool is based on their last acquisition process of medical devices for anesthesiology. The acquisition process, already mentioned in the section 4.2.2 and showed in Figure 9, contains, among other files, the companies’ catalogues of anesthesia kits and the obligation’s notebook, both
essential to properly implement this tool. The obligation’s notebook defines the guidelines for a company to fulfil to be eligible for the public applications. Meanwhile, the companies’ catalogues of medical devices can help to understand the differences in their characteristics.

Moreover, the medical companies have a deadline to apply for the public applications process and submit the necessary information to Hospital Santa Maria’s sales management department. The application process is organized through differentiated numbered positions (Table 5) and, for each one, only the best possible brand will be selected.

5.2.1. Anesthesiology inclusion requisites

The inclusion requisites correspond to a fundamental concept, established in section 4.1.2, herein designated as the screening criteria. Therefore, appealing to the defined notion of screening criteria, the inclusion requisites determine a list of items necessary to comply, without any exception, otherwise the medical company’s proposal is automatically rejected. These inclusion requisites allow to, first and foremost, exclude the medical company’s proposals that to do not obey to certain standards and, thus, save time evaluating a proposal that will later be proved unfitting by a certain characteristic.

According to the Hospital Santa Maria’s sales management department, when the public applications are open, it is made clear to the interested medical companies that it is necessary that all the proposals must obey the specifications in the obligation’s notebook. The most relevant are presented below:

a) declaration of acceptance of the content of the obligation’s notebook as is stated in Article 57º ‘Documentos da proposta’ of the CCP;

b) code from INFARMED to prove that every single piece of medical equipment is approved and received a certificate from INFARMED;

c) proof of payment of medical equipment commercialization taxes to INFARMED;

d) present the unit price, with and without IVA, in numbers, which cannot surpass the maximum unit price established (Table 5);

e) present the total price, with and without IVA, in numbers and written;

<table>
<thead>
<tr>
<th>Position</th>
<th>Designation</th>
<th>Maximum unit price (€, s/IVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Continue epidural anesthesia kit 17G</td>
<td>12,00</td>
</tr>
<tr>
<td>10</td>
<td>Sequential anesthesia kit pencil-point</td>
<td>16,50</td>
</tr>
<tr>
<td>11</td>
<td>Epidural anesthesia kit 18G</td>
<td>7,90</td>
</tr>
<tr>
<td>12</td>
<td>Epidural anesthesia kit 20G</td>
<td>18,00</td>
</tr>
</tbody>
</table>

Table 5 - Position of each kind of medical device available for companies to compete to supply and their respective maximum unit price established as a threshold by Hospital Santa Maria (G = Gauge, MM = Millimeter). Note: the absent positions correspond to the medical devices not relevant to this case.
f) the company must present all the attributes of the proposed medical equipment for evaluation purposes. The table with the technical specifications required to be fulfilled by the medical companies is presented in Appendix B – Inclusion requisites, Table 10.

g) catalogues where each one of the technical specifications are identified for each position it competes;

h) deliver a realistic full-size sample of each medical device for each position it competes and properly identified to allow a worthwhile quality evaluation;

i) reference corresponding to each asset proposed;

j) the proposal application is done exclusively through an electronic platform for public contracting;

k) variations of proposals are not allowed;

l) the presented proposals are not negotiated.

5.2.2. Assessment of the proposed anesthesia devices

Once the time period for public applications ends, then it is possible to proceed with the assessment of the data sent by the multiple brands of medical devices. As illustrated in Table 10 (Appendix B – Inclusion requisites), the technical features mandatory for each category are explicit in detail. However, these are only some of the physical requirements of the medical devices for them to have a successful impact when performing an anesthesia procedure. For that purpose, the criteria defined during the socio-technical approach will help to evaluate and determine the alternative with the best possible impact.

As mentioned before, the data available in the last acquisition process is used to implement this tool. Thus, the following table (Table 6) displays the application status as is in the last acquisition process. It is worth notice that each medical company can apply to several of the positions and for confidentiality reasons the medical company name will be presented as Brand A, B, C and D.

Table 6 – Matching between the four medical companies (Brand A, Brand B, Brand C and Brand D) and the positions to which they submitted a proposal (G – Gauge). Note: the absent positions correspond to the medical devices not relevant to this case.

<table>
<thead>
<tr>
<th>Position</th>
<th>Designation</th>
<th>Brand A</th>
<th>Brand B</th>
<th>Brand C</th>
<th>Brand D</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Continue epidural anesthesia kit 17G</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Sequential anesthesia kit pencil-point</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Epidural anesthesia kit 18G</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Epidural anesthesia kit 20G</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

In the previous table (Table 6), it is evident which medical companies submitted a proposal for a specific position to supply that type of anesthesia kit. Usually if any inclusion requisites weren’t met by certain medical devices, there is an observation on the table. However, in the case of anesthesia kits,
no observation was made since all the anesthesia kits accomplish the inclusion requisites. In the case of position 7, no medical company submitted a proposal which, fortunately, is very uncommon of happening. Since the position number 12 only had a single proposal and all the inclusion requisites are verified, then the proposal will likely be accepted. For position number 10 and 11, the same two medical companies, Brand B and C, competed for the positions without infringing inclusion requisite. Therefore, position number 10 and 11 are plausible candidates to continue the evaluation process.

5.2.3. MACBETH evaluation

Hereafter, the medical devices that accomplished all the inclusion requisites (position 10 and 11) can now be evaluated according to the group multicriteria model using the MACBETH software. For each medical device, it was defined its impact on the criteria and then its performance was evaluated using the group multicriteria model. In the end, comparisons between the medical devices proposed to a certain position are presented.

The impact level on each criterion for each medical device was determined according to the data in the acquisition process mentioned above, which was then completed and validated by the DM. Even though a research to find studies concerning these medical devices was made on several databases, the data was always scarce, incomplete or from dubious sources.

The figures below (Figure 25 and 26) show the assembled impact levels on the criteria for the medical devices in position 10 and 11, which respectively designate the ‘Sequential anesthesia kit pencil-point’ and ‘Epidural anesthesia kit 18G’.

![Image of Table of performances]

Figure 25 - Impact levels on criteria for the medical devices (Brand B and C) competing for the position 10 (Sequential anesthesia kit pencil-point).

![Image of Table of performances]

Figure 26 - Impact levels on criteria for the medical devices (Brand B and C) competing for the position 11 (Epidural anesthesia kit 18G).

Analyzing the figures, especially Figure 26, it is noticeable that the impact levels on both brands present similarities. To clarify, according to the anesthesiologists when collecting data to complete the performance table, Brand B and Brand C are both prestigious brands which features have very similar capabilities and feasibility, with very small exceptions. Therefore, even though these positions allow to
test the model, best scenario case would be having more options and with more distinct impact levels to explore the full range of the impact levels. Henceforth, the performances of these devices will be presented and analyzed.

### 5.2.3.1. Overall scores

Once the multicriteria model is applied to the options, here Brand B and C, the results can be analyzed in the table of scores (Figure 27 and 28). The global performance score is showed in the yellow column whereas the partial performance score, regarding each criterion, is showed in the remaining columns. Looking at Figure 27, for position 10, the medical device option with the higher global performance score is the Brand C, equal to the ‘Good’ reference level. In the case of Figure 28, for position 11, the medical device option with the higher global performance score is the Brand B, equal to the ‘Good’ reference level. In both cases, the criterion that was decisive was the ‘Medical Device’s Handling’.

Comparing the results obtained with the medical devices that were actually selected in the acquisition process used as a data source, the anesthesia devices coincide. In addition, when validating the model with the DM, it was confirmed that the intervals between the options’ scores really reflect the perception of the DM of how much the anesthesia devices differ in the case of each one of the positions.

### 5.2.3.2. Differences profiles

The feature ‘Differences profiles’ is applied to explore the weighted differences between the scores of two options, indicating to which extent the differences between the two options being compared compensate or not. By default, the values displayed correspond to the difference between the global performance scores according to the subtraction indicated in the header of the figures, for instance, ‘Brand B – Brand C = …’.

Observing the Figure 29, it shows that the option ‘Brand B’ has negative contributions (orange bar) in position 10, meaning that option ‘Brand B’ is outperformed by the second option, ‘Brand C’, in the following criteria: ‘Medical Device’s Handling’, ‘Technique Efficiency’ and ‘Morbidity’. Meanwhile, a null difference is registered for criteria ‘Functional Recovery’ and ‘Patient Satisfaction’, thus indicating that the two options are considered indifferent in these criteria.
In the case of Figure 30, it displays that the option ‘Brand B’ has only one positive contribution (green bar) in position 11, which means that option ‘Brand B’ is outperforming the second option, ‘Brand C’, in the ‘Medical Device’s Handling’ criterion. For the remaining criteria, a null difference is registered, therefore indicating that the two options are considered indifferent in the criteria, with the exception of the ‘Medical Device’s Handling’ criterion.

5.2.3.3. Sensitivity Analysis

A sensitivity analysis was performed to try to perceive to which extent the model’s final recommendation would be altered if the weight of a criterion was changed, considering that, at the same time, the proportionality between the remaining weights is kept. To present these results a graphic displays each option’s line as well as the good and neutral reference levels to show the changes in the option’s global score (vertical axis) when the criterion weight varies from 0 to 100% (horizontal axis). Besides, a red line will symbolize the current weight of the criterion selected at the moment.

Looking at Figure 31 (a), it is evident that for ‘Medical Device’s Handling’ criterion the lines representing each of the options do not cross each other, meaning that the option ‘Brand C’ is always more attractive regardless of the weight. The same happens for the ‘Technique Efficiency’ and ‘Morbidity’ criteria (not represented here). Now considering the Figure 31 (b), it is noticeable that the two options’ lines intersect, which usually represents the point of global indifference between the two options as well as the exact weight necessary to provoke a swap in the rank of overall attractiveness. Therefore, usually this would be the situation where, from now on, the option previously considered more attractive (superior line before the intersection) would become less attractive than the other option from the intersecting line, as soon as the weight increased beyond the point of indifference, also known as point of intersection. However, in this specific case the intersection occurs exactly when the weight varies
100%, meaning that in reality a rank swap never occurs. The same situation happens with the ‘Patient Satisfaction’ criterion.

Analyzing the Figure 3-2 (a), it displays an intersection right in the beginning where the variation of weight is 0%, meaning that initially both options were indifferent in the overall attractiveness but as the weight increased, option ‘Brand B’ was always the most attractive. For Figure 3-2 (b), in this case for ‘Technique Efficiency’ criterion, the options have always the same overall score regardless of the criterion weight. The same happens with the remaining criteria.

5.3. Decision-support tool

The development of this socio-technical approach had always a key outcome: formulate a decision-support tool for the evaluation and, subsequently, selection of anesthesiology medical devices. More precisely, a tool combining the MACBETH software and a clinical decision-support Excel tool. The MACBETH software purpose would be exactly the same as the role played throughout the formulation of this socio-technical approach, meaning to build a quantitative model based on the pairwise
comparison of judgments. Meanwhile, the tool in Excel will not only complement the MACBETH proceedings but also assist the onset and the aftermath of the whole decision-making process at the hospital.

Furthermore, the main focuses of this tool are to bring innovation and improve the evaluation process of anesthesia devices currently applied. Hence, the Excel tool was formulated as an interface complementing the MACBETH process, which will require the exchange of information. On one hand, the decision-conference can be guided using the Excel tool, either in face-to-face or online meetings, which in turn, can facilitate reaching an informed agreement to introduce in the MACBETH software. On the other hand, the Excel tool can be fulfilled with data from MACBETH and, for example, help to delineate the final report. As a last resort, the clinical decision-support excel tool can also be used as a simplified analysis of the performance scores in case of not being able to handle MACBETH. However, for more detailed and customized graphics, MACBETH already defined features can be explored.

The implementation of this tool will allow to structure the decision-making process in a way that assures the many adversities that could jeopardize its credibility and reliability are tackled. For instance, this tool establishes a structure where certain evaluation steps promote clinical critical thinking in group. In addition, since the physicians have distinct clinical experiences or even different academic backgrounds, all of this will influence the rationale behind the thinking and decision-process. Therefore, in an attempt to overcome it, this tool promotes communication and tries to reduce the tendency to automatically fall back on pre-defined concepts without giving it a second thought.

The framework of the Excel tool is presented below through the outline (Figure 33) and, then, the evaluation steps are explained in more detail specifying the potential of the features in each section of the tool (Table 7).
Table 7 – The sections in the Excel tool with the respective evaluation steps necessary to go through during the decision-making process.

<table>
<thead>
<tr>
<th>Sections</th>
<th>Evaluation steps in each section</th>
</tr>
</thead>
</table>
| General Guidelines | ▪ Perceive the objectives and potentialities of this tool;  
▪ Obtain a general overview of the tool and its content through the outline; |
| Tool Instructions | ▪ For each section, detailed instructions on how to take advantage of the functionalities of this tool are presented;  
▪ Suggestions on how to apply the features to the evaluation process; |
| Price & Technical Specifications | ▪ For each medical device, its position, designation, maximum unit price acceptable by the hospital and the technical specifications are available here to consult;  
▪ The total number of positions opened is displayed; |
| Inclusion Requisites | ▪ Verify if a medical device proposed by a medical company accomplishes the full list of inclusion requisites to be able to continue the assessment process; otherwise, it is automatically rejected; |
| Medical devices for evaluation | ▪ A notice regarding the status of the inclusion requisites’ assessments is displayed, warning, with the exact number of assessments, if it is not complete;  
▪ Displays the total number of positions opened;  
▪ Total number of positions without any proposal as well as a table with the respective position and designations of those medical devices;  
▪ Table showing for each type of medical device, specified by its position and designation, which medical devices proposed by the medical companies are suitable to continue the assessment process. Besides, it also shows the total number of proposals for each specific position; |
| Discussion | ▪ Presents the value tree built in the MACBETH software;  
▪ Discussion topics are suggested and registered in a table, functioning as guidelines during the discussion in the decision conference;  
▪ For each medical device, the discussion topics can be argued between stakeholders and a table is available to register, for each discussion topic, the group agreement as well as remarks of individual perspectives; |
| Performance levels | ▪ The assessment of medical devices on criteria according to the value scales obtained from MACBETH are displayed here in a table available for consult; |
| Medical devices’ evaluation > P | ▪ Table showing the criteria weights obtained using the MACBETH software;  
▪ Comparison of partial performance scores for each medical device in a table;  
▪ Graphic comparing the partial performance scores for each medical companies’ device; |
| Medical devices’ evaluation > G | ▪ Comparison of global performance scores for each medical device in a table;  
▪ Graphic comparing the global performance scores for each medical companies’ device; |
A warning is displayed saying either all the evaluation steps have been checked or, on the counterpart, that all the steps have been completed and the proceed to the final section.

Numerical general overview concerning the whole evaluation process: number of positions opened, number of positions without any proposal, number of proposals that accomplished the requisites, number of medical devices initially rejected (requisites not accomplished) and total number of proposals;

Circular graphic showing the percentage of medical devices that accomplish the requisites and the ones that are initially rejected;

Graphic regarding the number of proposals for each type of medical device segmented by medical companies’ name and total number of proposals for that type of medical device;

Table as a final comparative map of all the medical devices proposals for each position (Approved versus Rejected) with the possibility of making observations.

To better showcase the features on each section of this Excel tool, print screens with highlighted descriptions of the purpose of the features and how to use them will be presented below (Figure 34 to 44). Starting off by the two solely informative sections of this tool (Figure 34 and 35).
Afterwards, the anesthesia devices open for public application and, therefore, made available for medical companies to apply, can be listed in a table in this section (Figure 36), according to its application position, designation, maximum unit price acceptable for the hospital to afford and, finally, the technical specifications required for the company’s application to be accepted. This list may be useful to consultation during the group discussion as well as to assist the DM to verify the inclusion requisites.
The next section (Figure 37) allows to verify if each anesthesia kit complies fully with the inclusion requisites imposed by the Public Contract Code as well as by the Hospital Santa Maria. Otherwise, the anesthesia kit will be automatically rejected, thus not even being completely evaluated.

Each anesthesia kit will be associated to one of the tables listed along the worksheet. To identify the anesthesia device being evaluated in each table, the yellow shaded cells will contain the data referring to each type of anesthesia kit. More precisely, in front of the yellow cell saying “Medical Device” and bellow the labels “Position” and “Designation” by choosing from the drop-down lists, already configured according to the data in the columns with the same name from.
the table in the section "Price & Technical Specifications". This way, it gives the liberty to choose what anesthesia kit the evaluation will start as well as avoid the existence of empty table because no medical company submitted a proposal to a certain medical device. Then, in the actual table, fulfill each column header with the brand name of the medical companies who submitted a proposal to the anesthesia kit at stake.

In the table, each line corresponds to an inclusion requisite. Only if all the requisites are checked, the field denominated as 'Current State of the medical device assessment according to the accomplished requisites:', below the column correspondent to a certain medical company's anesthesia kit, will automatically turn to 'Approved' (green letters). Otherwise, if any of the requisites is deemed as 'Error', the field will automatically turn to 'Rejected' (red letters), excluding the anesthesia kit from the respective medical company. Meanwhile, if the requisites are being checked (meaning no 'Error' was found), the state on the field will say 'Incomplete', warning that the assessment is not complete until a state of 'Approved' or 'Rejected' is reached.

**Figure 37 - Inclusion requisites section with side instructions and explanations in the rose textboxes.**
In the following section (Figure 38), a safeguard was implemented, warning if any inclusion requisites' assessment was left 'Incomplete'. Thus, in front of the cell labelled 'Status', an automatic message can be displayed either saying 'Number of assessments of inclusion requisites incomplete:' in red or 'The assessment of the inclusion requisites is complete. The medical evaluation can proceed.' in green.

The purpose of this section is to allow to register the number of positions that didn't receive any proposal from any medical company as well as a table to fulfill with the position and designation of the type of anesthesia kit. To complement and allow a direct comparison, it is automatically displayed the total number of positions opened.

At last, the anesthesia kits proposed by the medical companies which accomplished all the inclusion requisites are listed. A table is presented where the positions and respective designations have to be inserted as well as the names of the medical companies in the header of each column. Then, in each cell of the table, choose from a drop-down list the option 'Yes' or 'No' indicating that if the medical device from the correspondent medical company if it is eligible to continue the assessment. The last column of the table will automatically present the total number of proposals, for each position, that are valid to continue the evaluation process.

![Figure 38 - Medical devices for evaluation section with side instructions and explanations in the rose textboxes.](image-url)
The next section (Figure 39) suggests structural guidelines to employ during the discussion to foster inclusion of multiple perspectives and, at the same time, record them to recall in the future, if necessary.

The value tree built in the MCABETH software is pasted in this section to be available and support the discussion during the decision conference. Alongside, there is a table for each type of anesthesia kit, that once more, can be fulfilled by choosing from a drop-down list the ‘Position’ and ‘Designation’.

Then, each table has a column with possible discussion topics and for each of them, a column to register any individual remark that may be worthwhile to remember posteriorly and yet another column to register the reached group agreement.

A table is presented in the upcoming section (Figure 40) where, for each criterion, it is presented the distinct performance levels of the anesthesia devices according to the value scales obtained from the MACBETH software.

This table is available that section to consultation. In addition, if the performance levels as well as the value scales are altered they have to be inserted in this table, which will automatically updated the performance levels available in the drop-down list of the following sections designated as 'Medical device's evaluation > P' and 'Medical device's evaluation > G'. Besides, the points of the value scales used in the calculation of the partial and global performance scores will also be automatically updated.
The following section (Figure 41) exhibits the partial performance scores of each anesthesia kit in a table that when fulfilled will automatically generate a graphic with the same information.

On the right corner, a small table displays the weights of criteria. In case they are altered in future acquisition processes, there is a safeguard if the total sum is not 1, where a warning is displayed in red saying ‘Error: Sum not equal to 1’. Otherwise, it presents in green ‘Sum=1’.

Firstly, for each anesthesia kit, the first column of the table has to be fulfilled with the name of the brand of the medical companies that accomplished the inclusion requisites. Then, the performance level of the anesthesia kit on the specific criteria indicated on the header of the column can be chosen from the drop-down list in each cell. Afterwards, the partial performance scores will be automatically calculated. In addition, a graphic will also be automatically generated with the information introduced in the table.
The upcoming section (Figure 42) exhibits the global performance scores of each anesthesia kit in a table that when fulfilled will automatically generate a graphic with the same information.

Firstly, for each medical device, the first column has to be filled with the name of the medical companies that accomplished the inclusion requisites and only then the performance level of the anesthesia kit on the specific criteria indicated on the header of the column can be chosen. Afterwards, the global performance scores will be automatically calculated. In addition, a graphic will also be automatically generated with the information introduced in the table.
The next and final section (Figure 43) presents the general overview in numbers of this process, a table as a comparative map and graphics to be presented in the report to be delivered to the Sales Department. A safeguard was also implemented here to warn if all the previous sections were not checked, meaning that one or several sections could be not completed or in need of reviewing (Figure 44). In the beginning, on the tool instructions section, is stated that as each section is completed, the checkbox besides the header should be ticked. Otherwise, in this last section a warning will be displayed: "Attention! Not all the steps have been checked.", in red. If everything is executed, it will present a message saying "All the steps have been completed. Fill the comparative map." in green.

The general overview presents automatically numerical values regarding 'Number of positions opened', 'Number of positions without any proposal', 'Number of proposals that accomplished the requisites', 'Number of proposals initially rejected (requisites not accomplished)' and "Total number of proposals". In turn, a donut graphic is automatically generated regarding the total number of proposals, divided by the number of proposals that accomplished the requisites and the ones which didn't, meaning that were initially rejected.
Moreover, a graphic displays the proposals for each type of anesthesia kit, segmented by medical companies’ name and total number of proposals for that type of anesthesia kit. Furthermore, a table will function as a comparative map of the final assessment. The columns of 'Position' and 'Designation' will be already automatically filled. Then, for each position, it will be indicated which medical company’s anesthesia kit was selected for a certain position by choosing the option 'Approved' from the drop-down list. For the remaining alternatives, the option 'Rejected' will be selected. In addition, there is a column for final observations besides each final decision (Rejected or Approved).

Figure 43 - Report section with side instructions and explanations in the rose textboxes.

Figure 44 – The action of ticking or not the checkbox will determine the warning message in the Report section.
5.4. Feedback regarding MD-Evaluation tool

To wrap up and bring a closure to the socio-technical approach process, a survey was sent with the intention of receiving feedback to possibly keep enhancing this socio-technical approach as well as validate it. Therefore, the survey was elaborated using several statements and a Likert scale, with 5 scale points, to rate them. This Likert scale, well-known for its scoring schemes in an attempt to quantify the people’s perceptions, interests and opinions [78], is implemented as ordinal data, which response item has choices varying from “Completely Agree” to “Completely Disagree”. In this case, each statement starts with the expression "This socio-technical approach…” and, in total, there are 9 statements to evaluate.

This survey was answered by the participants in the decision conference, more precisely the 3 experts and the DM. The results obtained from the Likert-scale assessment are presented in a stacked bar graphic below (Figure 45).

In figure 45, as a general overview, it is immediately possible to notice that under no circumstance anyone has answered with a ranking lower than “Indifferent”, meaning that no one has disagreed with any of the statements. Overall, all the statements are oriented in a sense of assessing the validity of the developed decision-support tool and since all the feedback tends to similar degrees of agreement, one can considered that this tool received the stakeholder's validation. This is especially evident in statements such as “…represents an improvement considering the currently implement method.” and
“...allowed to obtain a satisfactory tool to select the medical devices.” that only received the category ‘Completely Agree’ and ‘Partially Agree’. Regarding the statement “… facilitated a bigger incorporation of anesthesiologists’ points of view.”, there was an answer of 75% ‘Completely Agree’ and 25% ‘Partially Agree’ which overall means that the experts felt like this socio-technical approach enabled them to actually contribute to this process of evaluation and selection of anesthesia kits.

Furthermore, the survey also had a facultative open-written question asking for suggestions concerning future studies or comparisons to be made with the current study. The only response obtained claimed in the future it would be interesting to evaluate how the medical device characteristics dictate their performance with the guided echography probe.

This survey allowed to consolidate the perception of usefulness, innovation and added-value that this socio-technical approach brings to the selection process of anesthesia kits in hospital settings.
6. Discussion

Underpinning this socio-technical approach, there was a MCDA approach coupled with hospital-based HTA. Throughout the development process, HTA was tailored to the anesthesiology context at Hospital Santa Maria. The continuous hospital-based HTA was present during the assessment, evaluation and decision-making concerning the anesthesia kits. The HTA strong suit is obtaining relevant knowledge on the repercussions of medical devices through a research-based and practice-oriented evaluation. Since multiple criteria require a systematic and reproducible approach to determine their impact in decisions regarding medical devices, the HTA allowed to collect evidence and information that explored the integration of value judgements alongside the cost-effectiveness. For instance, the experts and DM contributed to the HTA process, for example, by their representativeness in the decision conference and through the given input in the exploratory interviews. In addition, this hospital-based HTA involved an assessment of evidence concerning the safety, quality, efficacy and application of the anesthesia kits. Therefore, gathering both the most scientific evidence and the social value evidence, it is not only crucial as well as necessary to a proper HTA. Regarding, the cost-effectiveness, in this particular case, it did not demand a full-on assessment since from the beginning the hospital had a detailed policy on their willingness to pay for an anesthesia device, meaning the maximum unit price. If the proposal did not comply with this inclusion requisite it would be automatically rejected. Other than that, according to the DM and the criterion of adjudication, any proposal could be accepted as longs as it was considered the most economical advantageous. Therefore, the hospital-based HTA results enabled the DM to get the perception on the likely value of anesthesia kits before deciding to select them to be purchased. All in all, the hospital-based HTA functioned as an evidence-based and priority health setting process which final output was a recommendation on the selection of anesthesia kits.

Developing a socio-technical approach to improve decision-making processes in hospital settings culminated in a decision-support tool. In this chapter, the advantages of implementing this socio-technical approach are explored as well as the limitations found. Besides, it is crucial to keep in mind that the socio-technical approach was achieved without neglecting the multiple objectives.

6.1. Advantages of the proposed socio-technical approach

Implementing a sociotechnical approach meant taking advantage of a MCDA approach, where the social component enabled the objective of promoting communication and inclusion of more stakeholder’s value judgments in the decision-making process whereas the technical component enabled to implement a robust method based on the additive model.

During the elaboration of the socio-technical approach there were always some concerns, as is the case with the potential risk of bias and the quality of evidence. Thereby, by initially carrying out an individual multicriteria model where all value judgements were collected individually, it was a stand against possible group bias, such as dominance of assertive individuals and avoid conformity of more passive or tolerant individuals. Hence, even though the survey does not promote social interaction and
communication, it was a useful web-based platform to allow a freely expression and collection of each one of the experts’ perspectives. In addition, the individual multicriteria model also introduces the stakeholders to the typical evaluation process of an MCDA approach, in this case, more precisely the MACBETH. Regarding the group multicriteria model, naturally the possibility of bias was not forgotten. Therefore, to begin, all the input and resulting data obtained in the individual multicriteria model were displayed and considered in the decision conference. Besides, the decision conference framework was designed to promote equitable communication and critical thinking, which, for instance, can help to rethink heuristics whose application have been known to lead to cognitive bias. In addition, the role of the present facilitator was to dynamize and mediate the decision conference, for instance, by guarantying everyone’s participation in the discussion.

Another initial concern was the elicitation through numeric methods since individuals cannot adequately express points of view, value judgements and beliefs with numerical accuracy. Hence, to avoid this difficulty, the MACBETH approach was a legitimate choice. Therefore, it was possible to collect the qualitative judgements of the stakeholders, according to the semantic MACBETH scale, and, in moments of hesitation to reach a unanimous decision on a single category, there was a chance to choose a range of categories from MACBETH scale.

Furthermore, the possibility of structuring a generic value tree allows to succinctly capture the DM’s input to assess the value of medical devices. This framework also enables a visually intuitive mindset validated by the group and that can be viewed or consulted anytime.

The resulting decision-support tool allowed overall to build a more reliable and credible decision-making process and, thus, reduce the accountability of the DM, who previously had all the weight of the decision. One of the takeaways of the group multicriteria model was revealing that discussing and sharing clinical perspectives in group led to broadening their perception. By promoting inclusion of more anesthesia subspecialties and, subsequently, a more active role during the decision process, it enriches the evidence available to make a more informed final decision. Since all the collected evidence is registered in this tool, more precisely in the Excel tool, which is configurated to formulate an ongoing report with the data available which, ultimately, can be used on the final report to deliver to the Sales Department. Moreover, the developed decision-support tool eliminates the gap regarding the reproducibility and replicability of consecutive acquisition processes.

By applying the MCDA concepts and guidelines, a valid and robust socio-technical approach for process improvement in hospital settings was achieved. Although this decision-support tool is implemented and ready to use in the evaluation process of anesthesia kits for neuraxial anesthesia, it can be adapted. Not only it can be adapted to other anesthesia domains, as is the case of plexus anesthesia, but also for other medical specialties. This socio-technical approach could assess the impact of several medical devices as long as this approach is redefined with criteria properly tailored for the specific type of medical device in question as well as adjusted with reliable qualitative judgments. Therefore, even though anesthesiology was the main focus and the test context, the validation of this socio-technical approach indicates that it can be implemented to originate an adapted decision-support tool for other evaluation processes of medical devices in hospital settings.
Despite improving the process of acquisition of medical devices in hospital settings being a challenge, relying on informal processes could result in suboptimal decisions. All in all, it is necessary a structured process to evaluate alternatives and priorities so one can overcome possible inconsistencies, variabilities or suboptimal decision-making.

6.2. Limitations

During the implementation of this socio-technical approach several challenges were encountered. For instance, some experts lacked familiarity with the available and proposed technologies, which led to some hesitation regarding their use. Therefore, the initial intention to introduce more dynamism to the process using several integrated web-based platforms was not fully achieved. However, in future acquisition processes they may fully embrace them.

Moreover, another limitation that could have made this study more thorough would have been the inclusion of not only more than one anesthesiologist from the several anesthesia subspecialties but also with a wide range of ages, since recent practicing anesthesiologists to senior professionals. Although this would probably lead to even more conflicting perspectives and judgements, it would had provided a wider and more diverse testing data. Due to several reasons, going from schedule incompatibilities or unavailability due to professional and personal reasons to even the dimensionality of a hospital, as it is the case of Hospital Santa Maria, this was not possible to do in this study. Regardless, the positive outcomes throughout this study and the validation obtained from the anesthesiologists’ feedback can be used as evidence to implement this socio-technical approach at a broader scale in the hospital.
7. Conclusion

Decision-making in any healthcare and hospital settings matter have always been known to be complex, intricate and even conflicting. The context of the anesthesiology medical specialty is no exception, especially because it is present in almost every single medical intervention or procedure, regardless of which medical specialty is handling the complication. In the specific case of anesthesiology medical devices, the continuous evolution and emergence of newer possibilities demands an ever-lasting evaluation to be able to do an evidence-based decision-making. Naturally, one would have thought that somewhere a socio-technical approach, including a MCDA method, would have been developed to support this process. However, according to the up-to-date literature review, that's not a reality.

In a nutshell, it was acknowledged that the current decision-making process concerning the acquisition of anesthesia kits in place at Hospital Santa Maria had room for improvement. Therefore, after reviewing the process another approach was proposed and tested according to the hospital settings. During the implementation of the MD-Evaluation tool, the clinical inter-practitioner variability in clinical decision-making, reported to be a factor in the contextualization, was verified mainly in the individual multicriteria model. Even though the ultimate purpose of every physician is the safety and wellbeing of the patients, each anesthesia subspecialty can have different goals and needs to be able to deliver different outcomes, which, in turn, leads to different perspectives and judgments. Nevertheless, by promoting inclusiveness and structured discussions among anesthesiologists from several subspecialties, a general agreement was reached in the group multicriteria model.

The new decision support approach proposed several adjustments to allow to expedite the process and introduce a technologically innovative, inclusive and new organizational structure. Thereby, this was achieved by developing a socio-technical approach, the MD-Evaluation tool, that, ultimately, led to the resulting decision-support tool combining the MACBETH software and an Excel tool.

As a general overview, all the challenges identified were addressed and all the intended objectives were achieved. Since introducing a proficient technological tool to expedite the decision-making process as well as register data to elaborate an evidence-based report to even achieving more inclusiveness and promote communication, reducing possible discontentment with the final decision. The main takeaway of this study is, even though process improvement in hospital settings maybe challenging, it is welcomed. In this case, the result is a validated process improvement which tool is ready to be used in future acquisition of anesthesia kits applied in the neuraxial anesthesia medical procedures.

The elaboration of the MD-Evaluation tool has the potential to contribute to anesthesiology scope and MCDA methodologies. The implementation of MCDA principles and methodologies resulted in an evidence-based, transparent and technological support tool to aid in decision analysis of medical devices in a medical specialty so crucial but, somewhat, neglected in terms of research when compared to other medical specialties. More precisely, it stands out for addressing decision-support when evaluating medical devices in neuraxial anesthesia whereas, up-to-date, the focus of the studies is on anesthesia treatment options. In fact, the proposed tool increases the span of validated implementations
of MCDA and its ability to answer to much needed topics of investigation. In addition, it also corroborates that the way forward in decision-making is through implementation of approaches with communication as the key to broaden shared knowledge and reach consensus, all fundamental principles of socio-technical approaches as MCDA. In Hospital Santa Maria, this sounded approach allowed to improve the evaluation process of anesthesia kits and make them aware of the possibility of adapting it for other medical specialties’ evaluation processes in hospital settings.

7.1. Future investigation

To conclude, future investigations concerning the process improvement in hospital settings, more precisely in the anesthesiology context, should be performed and compared with the results of this socio-technical approach. For instance, using this socio-technical approach, comparisons could be done between the results obtained in Hospital Santa Maria, considered a central hospital, and a district hospital, which designates a hospital with a smaller geographical coverage and less medical specialties and, subsequently, less anesthesia subspecialties. Therefore, it could be assessed if a wider versus narrower scope of anesthesia practice could influence the priorities defined for certain hospital settings. Another possibility could also be comparing the results of applying this socio-technical approach in the Hospital Santa Maria, a university hospital, and in a non-university hospital. Thus, it could be assessed if the decision-making would be significantly influenced by treatment protocols designed considering a learning approach versus non-learning hospital settings. Performing this type of external benchmarking (comparison with other hospitals) would allow to explore if different hospital settings would have very disparate necessities or priorities.

Furthermore, as stated, the last survey sent to obtain feedback, collected also possible suggestions and also had a facultative open-written question asking for suggestions concerning future studies or comparisons to be made with the current study. The only response obtained claimed in the future it would be interesting to evaluate how the anesthesia kits characteristics dictate their performance with the guided echography probe.
References


92. Tuenter, H., *Using multi-criteria decision analysis to evaluate the potential of biosimilars to lower costs in oncology*. 2015, University of Twente.


## Appendix A – MCDA and the social component

**Table 8 - Specifications, advantages and disadvantages of some of the methods currently used to elicit preferences and perspectives from the DM.**

<table>
<thead>
<tr>
<th>Method</th>
<th>Specifications</th>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>Focus Group Discussion (FGD)</td>
<td>Assembly of a group of individuals that discuss and share experiences as the researcher tries to draw beliefs and perceptions from their interaction. Widely used to consult and obtain the stakeholder’s notions on a subject before a decision is made. [41] Group discussions can either occur in face-to-face meetings or in a virtual space, such as using webinar. [79]</td>
<td>▪ High face validity due to the possibility of establish an accurate understanding and perception. [41]</td>
<td>▪ Data obtained usually is context specific and may be subject to biases. [41]</td>
</tr>
<tr>
<td>Interviews</td>
<td>The researcher enquires each individual, aiming to elicit the views and different perspectives of each stakeholder rather than defining the decision itself. [41]</td>
<td>▪ High face validity; ▪ Easy to implement; [41]</td>
<td>▪ Might require an extended period to conduct the interviews of all participants, specially if necessary to dislocate. [41]</td>
</tr>
<tr>
<td>Q Methodology</td>
<td>This technique aims to obtain the key perspectives and beliefs within a group by asking individuals to rank subjectively the set of items (eg. most agree to most disagree). Afterwards, multivariate data reduction techniques are used to aggregate the rankings into a typology of perspectives. It is more properly employed if the intent is to understand the linkages in opinions between the different topics. [41]</td>
<td>▪ Systematic and structured; ▪ Presence of qualitative depth as well as semi-quantitative evidence; [41]</td>
<td>▪ Risk of bias when raking the items; ▪ Possibly time-consuming and complex interpretation; ▪ Cognitively demanding. [41]</td>
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<tr>
<td>Nominal Group Technique (NGT)</td>
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| Sequential process where the first step of this technique is to gather individual data (hence nominal) from the participants in a confidential manner. Then, the moderator merges and organizes the collected information in a list of unique topics to further be ranked by consensus priority through a group discussion. [41] [80] | ▪ Can be executed with limited resources and time; [41]  
▪ Encourages the generation of individual ideas (creativity);  
▪ Sharing the ideas in group stimulates the cognitive association of individual ideas and further brainstorming;  
▪ Equalizes participation;  
▪ Toleration of conflicting ideas;  
▪ Very successful consensus building technique; [80] | ▪ Risk of bias, specially facilitator bias; [41] |

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<tr>
<th>Surveys</th>
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| Tool usually applied to obtain individual preferences. [79] Surveys are composed by a set of questions to collect the input data and, posteriorly, aggregate and perform analysis on the data. [81] can either be applied in the more traditional ways or using web-based platforms. [82] | ▪ Online surveys allow access to individuals in distant locations and difficult to reach. Besides, automated data collection saves time and effort. [82]  
▪ Usually, faster and cheaper. [83] | ▪ Online surveys deal with uncertainty regarding the validity of data and sampling issues (questionable knowledge over online communities). [82] |
Delphi

This is a technique to promote consensus within a group of experts since not only resorts to anonymous but also iterative methodologies. This means that participants will be asked individually to answer multiple “rounds” of structured questionnaires, by rating their answers in a scale, such as the Likert scale. Then, following each round, the group receives controlled feedback pertaining to the whole panel’s answered items. The initial round is usually depicted as the divergent thinking stage, since captures each individual initial judgement knowledge, and the posterior rounds as the convergent thinking stage due to the revising of the judgements based on the received controlled feedback. [41] [84] [85] [45]

- Advantage over face-to-face meetings, since it eliminates the eventual influence of stronger personalities and higher status dominance. Thus, this anonymous and iterative process improves group communication since preserves independency of thought, not giving in to group pressure, and avoids interpersonal conflicts and miscommunication problems between elements. [41] [84] [85] [45]
- Suitable for high conflict situations. [41]
- Requires considerable planning and preparation time;
- Possibility of poor response rate. [41]
<table>
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<tr>
<th>Questionnaires</th>
<th>Online web-questionnaires:</th>
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<tbody>
<tr>
<td>These can be implemented either in more traditional ways or through web-based platforms. [45] The questionnaire method is highly applied in data collection, for example, in research. [86]</td>
<td>allows participants to conclude the questionnaire without time constraints or need to dislocate;</td>
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<td>higher engagement if these include audio or video files; [45]</td>
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<td></td>
<td>low cost of data collection;</td>
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<td>can reach a large amount of target subjects; [86]</td>
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<tr>
<th>Decision Conferencing</th>
<th>Online web-questionnaires:</th>
</tr>
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<tbody>
<tr>
<td>Meetings of stakeholders overseen by a neutral facilitator that gathers data and participant’s judgements. Then, using the collected information, the facilitator will provide structuring to the group’s tasks and can introduce a computer-based model that incorporates all the viewpoints from the group. This ‘tool of thinking’ enables participants to be aware of the logic behind other viewpoints and, therefore, reach a shared understanding of the issues, create a sense of common purpose and commitment to move forward. [40] [87] In addition, decision conferencing can also be performed through web-based tools which are able to support long-distance group communication and knowledge exchange activities. [88]</td>
<td>possibility of low response rates and associated bias, since responses may not come from the target subject group.</td>
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<td></td>
<td>response rates may be affected due to no contact between researcher and participants; [86]</td>
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<th>Online web-questionnaires:</th>
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<tr>
<td>▪ Web-conferencing is the appropriate choice in case of limited budget, geographic dispersion or when in need of a significant level of collaboration. [88]</td>
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| Only one person at the time can manifest their perspective, waiting to take turns, which can prolong the meeting. [88] |
Table 9 - Techniques implemented through web-based platforms.

<table>
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<tr>
<th>Typology</th>
<th>Technique/Tool</th>
<th>Specifications</th>
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<tbody>
<tr>
<td>Online Focus Group Decision</td>
<td>itracks</td>
<td>Platform for online focus groups combining various software tools, with emphasis on the chat, board, community and video chat tools. The framework for the message and video chat fosters real-time focus group debates between the participants in a general shared screen, overseen by a moderator. Simultaneously, there is an adjacent and private screen where shareholders observing the debate exchange ideas with the moderator to help steer the conversation and get a deeper insight. The board and community tools operate as an asynchronous threaded discussion. In addition, there is also a simplistic embedded survey option to collect data. To facilitate the assessment of the outcome results it is possible to obtain reports, for instance transcripts of chats or video format, which can be downloaded. This tool is available on a web-based and mobile app format, however, it is necessary to book a demo or buy it. [89]</td>
</tr>
<tr>
<td>Survey</td>
<td>LimeSurvey</td>
<td>Open source tool of free online surveys, equipped with multiple useful features, ranging from diversified and flexible question types (eg. multiple choice questions, file upload…) to quota management or even inbuilt score system visible to the participant or not. [90] The obtained data will be recorded and stored and then totally accessible to the researchers, as raw data, statistics or even graphs. Not only the statistics’ results but also responses can be exported to files for further analysis. [91] This tool guarantees anonymity and confidentiality of participants, since assures that the obtained data cannot be traced to the individual in order to protect his integrity. [90] [92]</td>
</tr>
<tr>
<td>Opinions-Online</td>
<td></td>
<td>Group collaboration tool for global participation, voting, surveys and group decisions in a private and customized site. This platform allows the creation and edition of multiple types of questionnaires with unlimited number of questions, providing different ways of collecting data since multiple choice questions, approval voting, raking alternatives to even multiattribute scoring. Besides, there are interactive ways of viewing the results, such as group settings, with the possibility of making them only available to the enquirer or for all the participants, which can be accessed immediately or when every group participant has answered. Other features include collecting written comments, an opinion barometer that is updated each time a new revised opinion is submitted and supporting other types of groups processes, as is the case of the Delphi method. [93, 94]</td>
</tr>
<tr>
<td>Tool</td>
<td>Description</td>
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<tr>
<td>SurveyMonkey</td>
<td>Free web-based tool to design and implement structured surveys, allowing to collect data and identify the main aspects to be considered for assessment. [95] It also supports the possibility of the survey being anonymous, although it still provides several options for the facilitator to contact participants. This tool exhibits several useful features as a multitude of question types (eg. yes/no responses, drop down menu responses...), a survey completion progress indicator as well as export results in an Excel file for analysis. [96] [91]</td>
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<tr>
<td>TypeForm</td>
<td>Online data collection tool using conversational forms and surveys, which are accessible through a free limited plan as well as full paid plans. It is available on several technological devices (computers, tablets and mobile phones) and it can be connected or integrated with other useful apps, such as export data for Google Sheets. [97]</td>
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<tr>
<td>Welphi</td>
<td>An example of a standalone implementation of the Delphi technique, allowing to create questionnaires to drive consensus online. [98] This computer-based group DSS efficiently elicits and analyses each DM’s perspective and value judgement in an asynchronous way. Moreover, it is notorious for facilitators smoothly interacting with the technological tools to properly design and execute the study, since enables managing the participants activity, automatic incorporation of decision rules as well as monitor and access the data obtained in each round of questionnaires. [45]</td>
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</tr>
<tr>
<td>(Cisco) Webex</td>
<td>Collaborative web-based conferencing tool used for group discussion through videoconferencing and other interactive features such as real-time screen sharing, slideshow and the ability to share and annotate documents. This approach also allows writing on a virtual whiteboard, recording meetings and the possibility of participating on the webconference from a computer, smartphone or tablet. [99]</td>
<td></td>
</tr>
<tr>
<td>Jitsi</td>
<td>Jitsi-meet is a free open-source and multiparty videoconferencing application providing a real-time group communication platform. Among the multiple functionalities, the emphasis stands on the ability for multimedia streaming, screen sharing, chatroom and even recording the meeting. In addition, there is the possibility to create an open shared document with synchronized collaborative editing, that may be download. There is also an interesting virtual hand-rising feature, signaling the participant intention to be the next person to speak, as well as the possibility to upload files and for encryption by defining a password for the web meeting session. [100, 101]</td>
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<tr>
<td>Collaborative software (groupware)</td>
<td>Free web-based videoconferencing tool with real-time chatroom and content sharing, accessible through computers, mobile phones and tablets. This online media application has a screen sharing display feature and the participants have the ability to do co-annotations, share files, access the general shared board and record the meetings with posterior access to the transcripts. In addition, each meeting is encrypted, including password protection, and enable polling and allow a virtual hand-rising. [102] [103] It also provides a ‘breakout room’ functionality allowing to divide the participants into smaller groups, all monitored by the same process facilitator, and, in the end, reunite in the ‘main room’. Very similar to Skype, except instead of the 25 participants limit, it has the possibility of interaction up to 200 participants and 3000 passive viewers. [102]</td>
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<tr>
<td>Zoom</td>
<td>Free application that allows web-conference meetings, providing services such as audio-visual transmission, instant messaging and screen sharing. Some useful features are the live streaming across multiple platform, file sharing and the possibility of recording the web-conference session to subsequent review or reflection, being available for 30 days and possible to download. [104] The user can log on either using a computer, mobile phone or even tablets. [102] It is also possible to create a poll making one question at the time with a maximum of 5 response options but each participant can only respond by choosing one. Each question has a time window to be answered and when the deadline is almost finishing, the participants are automatically notified. Then, the results of the polling are available for consult for all the participants in the web-conference meeting.</td>
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<tr>
<td>Skype</td>
<td>Tool combining features such as team chat, video conferencing, screen sharing, task management, notes, shared calendarization, file sharing and real-time document co-editing. In addition, there are several built-in integrations with other apps allowing chat bots to pop up and tell what’s happening in those other apps, such as Dropbox, Typeform, and automatically add it to the workflow. The entire communication tool set is free and accessible through web browser or mobile apps.[105]</td>
<td></td>
</tr>
<tr>
<td>Samepage</td>
<td>Cloud-based communications and collaboration solutions based on the team messaging and online meetings options, which enable video conferencing with screen sharing, sharing of video and other files, and tasks management. It also incorporates a cloud phone system to improve communications and allow multiple extensions. This tool can operate on a web browser or mobile app by free trial or buying an upgrade version.[106]</td>
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</tr>
<tr>
<td><strong>Slack</strong></td>
<td>This web-based platform offers many features, mainly related to direct messaging, group threads (also known as channels) and file sharing. The workspace, which can be administrated by a single person or a team, works as a community platform that can be segregated into private or public channels. This tool also integrates with several third-party applications, such as SurveyMonkey and Google Drive, and provides an API (application programming interface) to enable the possibility of creating apps and automated processes that also can be linked to the integrated apps. Even though Slack it is known for its compatibility with many apps, the downside it is not all the chat functionalities are free, such as videoconferencing. It can be accessed through mobile apps and web browser. [107]</td>
<td></td>
</tr>
<tr>
<td><strong>Flock</strong></td>
<td>This group collaboration software provides a messaging platform, for teams or direct messaging, audio calls, screen sharing, polls, note sharing, video conferencing and file sharing. There is also the option to integrate external apps, such as OneDrive, to avoid switch between collaboration tools. In addition, it also provides an API to enable the build-in of apps and customs integrations by developers. However, even though it is available for free, some of the mentioned features are limited or only accessible by paying an upgraded version. [108]</td>
<td></td>
</tr>
</tbody>
</table>
## Appendix B – Inclusion requisites

Table 10 - Mandatory technical specifications for each medical device proposed by the medical companies when competing to fulfill the available position (G – Gauge, MM – Millimeter, cc – cubic centimeter).

<table>
<thead>
<tr>
<th>Position</th>
<th>Designation</th>
<th>Technical specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Continue epidural anesthesia kit 17G</td>
<td>Epidural needle - Tuohy Weiss point / 17Gx80MM / Depth markers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nylon and tungsten catheter - 19Gx914MM /</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lateral orifices, Romba point and depth markers /</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and introducer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plastic syringe 10 cc – LOR type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plan filter – 0.2 µ and thread connector</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apyrogenic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sterile</td>
</tr>
<tr>
<td>10</td>
<td>Sequential anesthesia kit pencil-point</td>
<td>Epidural needle - Tuohy Weiss point / 18Gx80MM / Depth markers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raquianesthesia needle – Whitacre pincel-point / 27Gx143MM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nylon and tungsten catheter - 20Gx914MM /</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lateral orifices, Romba point and depth markers /</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and introducer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plastic syringe 10 cc – LOR type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plan filter – 0.2 µ and thread connector</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apyrogenic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sterile</td>
</tr>
<tr>
<td>11</td>
<td>Epidural anesthesia kit 18G</td>
<td>Epidural needle - Tuohy point / 18Gx80MM / Depth markers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transparent polyamide catheter of 3 orifices and closed point</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plastic syringe 10 cc – LOR type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plan filter – 0.2 µ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sterile</td>
</tr>
<tr>
<td>12</td>
<td>Epidural anesthesia kit 20G</td>
<td>Epidural needle - Tuohy point / 20Gx50MM / Polyamide catheter with a central orifice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6x0.35x750 MM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sterile</td>
</tr>
</tbody>
</table>