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Hospitalization time reduction in Internal Medicine wards with BPM

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Master's Computer Science and Business Management

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Para a Aida, o Hugo e a Alice

Acknowledgments

Thanking my family is not commonplace, it is the demonstration that I know what sacrifices and dedication mean, how I value the strength and energy they gave me. Without them, it wouldn't make sense.

To my friends, I thank you for being the first stone, the impetus for the Master's degree, for always being that voice that points out wisdom with the simplicity of those who see from afar.

Professor Rúben Pereira was an advisor who, allowing one to fly freely, ensured that I'd never drift apart, that the path led to the desired destination. Thanks also to co-advisor Rafael Almeida, available whenever I require.

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I thank also all the participants in the research, for their patience and willingness to help achieve the best possible result.

Resumo

A redução do tempo de internamento hospitalar é um fator chave para a otimização de recursos em saúde e para a garantia dos melhores cuidados aos pacientes. O tempo de internamento, além dos custos financeiros e logísticos para a organização hospitalar, tem uma influência direta na qualidade de vida dos pacientes.

BPM permite a otimização e melhoria contínua de processos tendo um histórico de sucesso na aplicação a diversos setores de atividade. Na área da saúde, contudo, esta metodologia tem uma aplicação limitada, havendo escassa investigação à sua aplicação holística a processos clínicos e, em particular, à gestão de internamentos.

O presente estudo propõe um processo, redesenhado e otimizado, para o internamento de pacientes nas unidades de Medicina Interna, reduzindo o tempo de internamento ao mínimo possível com os consequentes benefícios organizacionais, financeiros e de saúde. Para alcançar este objetivo foi realizada a modelação dos processos de internamento nas unidades de Medicina Interna nos hospitais da área metropolitana de Lisboa, Portugal, identificando práticas comuns e as diferenças existentes, e, desse modelo existente aplicada a metodologia BPM para o redesenho e otimização de processo.

Foi usada a metodologia de investigação DSR tendo como artefacto resultante o processo otimizado. A realização de entrevistas a quinze profissionais permitiu a modelação dos processos existentes e as iterações para a validação das escolhas que nortearam a construção do artefacto.

BPM permitiu reduzir o tempo de hospitalização com benefícios para a organização hospitalar e para os pacientes.

Palavras-chave: Business Process Management, BPM, Design Science Research, DSR, otimização de processos, internamento hospitalar.

Abstract

Reducing hospital stays is a key factor in optimizing healthcare resources and ensuring the best care for patients. The length of stay, in addition to the financial and logistical costs for the hospital organization, has a direct influence on the quality of life of patients.

Using BPM methodology allows the optimization and continuous improvement of processes, having a history of success in application to different sectors of activity. In the health area, however, this methodology has a limited application, with little research into its holistic application to clinical processes and to the management of hospitalizations. On the other hand, the BPM methodology is obliged to respond to technological and behavioral changes to prove its relevance, something to which this research also aims to contribute.

The present study proposes a redesigned and optimized process for admitting patients to Internal Medicine wards, reducing hospitalization time with the consequent organizational, financial and health benefits. To achieve this objective, the hospitalization processes in Internal Medicine units were modeled in hospitals in the Lisbon metropolitan area, Portugal, identifying common practices and existing differences, and from this existing model the BPM methodology was applied for process redesign and optimization.

The DSR methodology was used with the resulting artifact being the optimized process. Conducting interviews with fifteen professionals allowed the modeling of existing processes and iterations to validate the choices that guided the construction of the artifact.

BPM use to redesign and optimize the hospitalization process in Internal Medicine wards reduced hospital length of stay.

Keywords: Business Process Management, BPM, Design Science Research, DSR, process redesign, hospital length of stay.

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List of Abbreviations

AI	-	Artificial Intelligence
AEP	-	Appropriateness Evaluation Protocol
BPM	-	Business Process Management
BPMN	-	Business Process Management Notation
BPMS	-	Business Process Management System
DSR	-	Design Science Research
DSR	-	Design Science Research Methodology
KPI	-	Key Performance Indicators
LOS	-	Length of Stay
ML	-	Machine Learning
OVA	-	Organizational Value Added
PDCA	-	Plan, Do, Check, Act
RPA	-	Robotic Process Automation
VA	-	Value Added
VUCA	-	Volatile, Uncertain, Complex, and Ambiguous

Chapter 1 - Introduction

Public administrations (which in an organic sense is understood as the system of bodies, services, and agents of each State and in a material sense is the very activity developed by these bodies, services and agents) are often portrayed as inefficient [1]. While part of this reputation stems from competition between the private and public sectors for the investment capacity available in each country [2], it is true that the inefficiency of public administrations can jeopardize the productivity of economies [3]. In State budgets and in the weight of the economy, the health sector has a considerable and growing weight [4].

The healthcare sector, which has public services as a fundamental pillar in much of the world and in particular in Europe, faces growing challenges [5]. The Organization for Economic Co-operation and Development has warned that pressure on health systems has increased on a global scale due to expanding costs and that this may jeopardize the sustainability of health services [6]. Given this context, organizations in the health sector have been faced with the constant challenge of increasing their efficiency, in particular hospitals, where the main investments and costs take place [7]. Hospitals are the most relevant individual entity in the cost structure of the health sector and the one that has weighed the most on the evolution of costs [8], making it necessary to assess the efficiency and reasonableness with which hospital resources are used.

Some consider a hospital as the most complex human organization ever devised [9]. This famous quote of Peter Drucker shows how hospital management is a great challenge. In the health sector, hospitals are, by far, the most relevant individual entity in the cost structure of the health sector [7], and the one that has weighed the most on the evolution of costs [8]. But the pressure for greater productivity and efficiency exists for the entire healthcare sector.

The challenge for greater efficiency has meant that various strategies, methodologies, principles, or tools, which have already proven to be useful in various spheres of the economy for this purpose (industrial or services sector), begin to be implemented in the health sector [10]. From research to redesign or process optimization that has been carried out, it is in the operating rooms that attention and research is more focused - which justifies most of the research carried out and can be explained by the costs inherent in this type of services [11]. As for the techniques used, simulation combined with linear programming or with heuristics and meta-heuristics has occupied the attention of researchers [11].

However, the healthcare context is still driven by traditional function-oriented structures and with siloed information shortly shared by different stakeholders [12]. Additionally, there is often a lack of a holistic and integrated view of the relationships between processes and the entire activity of the organization – these limitations can be overcome with the Business Process Management (BPM) application to the healthcare sector [13].

In addition to these limitations, there is often a lack of a holistic and integrated view of the relationships between processes and the entire activity of the organization – these limitations can be overcome by resorting to Business Process Management (BPM) and applying it to the health area [14]. If BPM is probably the most promising management practice in improving operational efficiency [15], these advantages seem to be a hypothesis to be explored. The flexibility recognized by the BPM strategy allows its widespread use in health services, particularly in a hospital environment [14].

Hospitalization does not come without risks, especially for elderly population. Due to associated comorbidities and prolonged bed rest, hospitalization can enhance complications secondary to the cause of hospitalization, potentially causing motor and cognitive problems, reducing autonomy and the quality of life [16]. [17] have concluded that after 10 days of bed, there is a substantial loss of skeletal muscle mass, size, and function. Hospital length of stay (LOS) must be the minimum possible to reduce the negative impacts on patients and, as so, is a quality metric health systems use to compare hospital efficiency [18].

Hospital LOS can be influenced by clinical factors and non-clinical factors. Adverse medical events, delays on complementary diagnostic tests, clinical decisions and discharge planning are the main clinical factors that influence hospital length of stay [19], [20]. Short bed capacity in secondary care, transfer between services and short provision of care for the elderly are the non-clinical factors more relevant [21]–[23]. This delayed discharge is associated with mortality, infections, depression, reductions in patients' mobility and their daily activities. But, also, has great significance in hospital costs because extra bed-days could account for up to 30.7% of total costs [24].

Internal Medicine wards are specialized in complexity, serving severe long-term illnesses, and helping patients with multiple conditions, many time resulting in long hospitalizations [25]. These wards have significant cost weight in the hospital spendings, and due aging population is where hospital length of stay is increasing [26].

As hospital length of stay has significant financial, logistical e health implications, the reduction of the hospitalization time can help make healthcare more financially sustainable, to make a better usage of the available resources and have significant impact on patients' quality of life. The main motivation of this research is to create the best possible hospitalization process to internal medicine ward to achieve greater hospital process efficiency.

Another motivation is to prove the adequacy of BPM application in healthcare processes directly related with hospital patients, improving the knowledge in this research field. This research can be valuable to further stimulate the creation of more scientific knowledge and real application of BPM.

A practical and a theoretical motivation, an answer to a real-world question and a contribution to the body of knowledge, the optimization of the hospitalization process in Internal Medicine wards and the evaluation of BPM usage to that purpose, these are the motivations for this research.

Our research focus on the application of BPM to redesign a optimize the internal medicine admission process with the purpose to reduce the hospital length of stay. We will use the DSR to develop the improved admission process as the resulting artifact using the BPM framework. We address the processes of the Internal Medicine wards of the hospitals in the metropolitan area of Lisbon, Portugal. Using that knowledge, we model the "as-is" hospitalization process in the Internal Medicine wards and redesign it to achieve greater efficiency. And that leads us to the research question we intend to answer is: Can BPM be used to model the hospitalization process in Internal Medicine Wards and to make it more efficient?

The remaining parts are organized as follows. The literature review of the application of BPM to the health sector will be presented in the Chapter 2 (State of the Art), beginning with a brief description of BPM and the methodology followed in the review. The Chapter 3 (Research Methodology) describes the methodology DSR and how it is used in this research. In Chapter 4 there is the Artifact Description and its Evaluation. The Discussion of the results is made in Chapter 5 and Conclusions are presented in Chapter 6.

We largely followed the publication schema for a DSR presented by [27]. The one adaption made is to gather in the same chapter the Artifact Description and Evaluation. Our choice is due to relate easily DSR and BPM, because the final artifact is resultant of the BPM "to-be" process and, therefore, makes it more comprehensive. Nevertheless, the different sections in the Chapter respect the suggested publication schema.

Chapter 2 - State of the Art

2.1. Background

This literature review addresses the application of BPM in the healthcare sector. As healthcare organizations need to improve their processes, become more productive and efficient, it's necessary to assess how BPM was used in the sector and, from that analysis, review in which healthcare areas, organizations, or departments it is more mature. On the other hand, this research is also important to solve the problems identified by [12], as some of them are reported to exist in healthcare and their resolution can have a big impact not only in healthcare but also in the future of BPM.

BPM and digital innovation are two sides of the same coin that must be worked together: from the evolution in the discovery of processes that the new possibilities of process mining allow, to the redesign and local optimization of processes for global reuse, opportunities are countless [28]. In the health sector, advances in software and hardware, the incorporation of the cloud and the source of Internet of Things (IoT) sensors, allow expanding the spectrum of technologies and techniques applicable and available to BPM [28] and for possible integration in a BPM System (BPMS).

2.1.1. Business Process Management - BPM

A process oriented organizational structure, a culture based on the process approach and compliance with continuous process improvement methods drives corporate success [29]. Business Process Management (BPM) is a discipline that intends to identify, analyze, design, implement, monitor, and manage the work processes within and across organizations, many times using Information Technology for that purpose [12]. It is characterized by its life cycle, which provides for constant process improvement (Fig. 1) and aims to ensure that business processes are efficient, effective, and in line with the organization's strategic objectives, and is focused on continuous improvement. It was inspired in the known PDCA cycle (Plan, Do, Check, Act).

The BPM phases begin with the identification of the process, which leads to the discovery of how it materializes, who are the actors, participants, and stakeholders, in an attempt to make explicit the organization's tacit knowledge about how the process exists. Based on this modeling, a set of tools and methods is then applied to analyze the process and verify its weaknesses, from which the bases for its redesign are laid. The process redesign is carried out using optimization and redesign techniques, of which heuristics are one of the best examples. Once the redesign and improvement scenarios are defined, the one to implement is chosen, with the subsequent monitoring and follow-up necessary for

its reassessment and restart of the process [30]. Interest in BPM has grown as process improvement challenges have amplified in today's global competition [31].

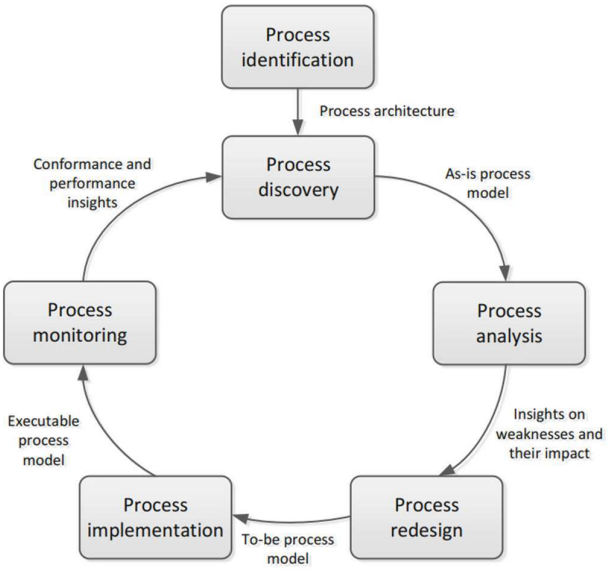

Fig. 1 - BPM cycle, image from [30].

To explain the processes, although is not the only solution, BPM uses its own notation, the Business Process Model and Notation (BPMN), which is a notation based on a series of standard icons for the design of processes, which facilitates its interpretation and dissemination.

Although old school BPM had some drawbacks due to three main problems (challenges to capture human behavior, to deal with real life systems complexity and to deliver actual improvements) and some bad implementations in big companies (Shane Co., American LaFrance, and FoxMeyer Corp., for example), the last decade revived the interest in BPM due to the success of Robotic Process Automation (RPA) and process mining implementations [32]. Also, the results of the artificial neural networks applications mainly after 2010 and the new Artificial Intelligence and Machine Learning hype have reinforced BPM possibilities.

BPM is based on a lifecycle that promotes process innovation to obtain more efficiency in the organization and does it in an iterative way [30]. With the recent dynamism due to digital innovation, increasing customer needs and severe competition, the traditional BPM exploitative process of incremental improvements is also being completed with an explorative approach that aims to benefit of key technology adoption [33]. This tension between exploitation and exploration is called ambidexterity and is a vital capability for surviving in dynamic business environments [34].

Technological developments are forcing a VUCA organizational environment (volatile, uncertain, complex, and ambiguous) [35]. This poses pressures on public and private organizations to stay successful, having to answer rising customer needs and expectations, and fulfill with innovation needs [36]. BPM must evolve.

The principles of good BPM include technology appropriation, context-awareness and holism, among others [37], demonstrating great openness to this fast-paced digital evolution. But digitization first, and now digitalization, are forcing evolution in BPM capabilities to go along with this socio-technical changes [38]. Which new BPM capabilities areas to address and how to update capability frameworks is an ongoing debate that needs to be developed and addresses the challenge to incorporate knowledge from other disciplines as innovation management, entrepreneurship, customer relationship management, data science, and agile software development [39]. But it is certain that BPM is beneficiating from digitalization efforts [40]. Also, an ongoing debate is how to develop BPM scientific field and to address the strong fragmentation into self-fueling sub-areas that lead BPM to a crossroads [41].

Recently, the biggest problems faced in BPM research were identified: BPM-driven value creation from data, expansive BPM, automated process redesign, constructing digital twins, lack of objectivity in process descriptions, fixed granularity levels for process analysis, augmenting process mining with common sense and domain knowledge, worker-centric process management and mining processes using stochastic data [12]. This was an investigation of a group of the major BPM researchers worldwide. As is identified, BPM application in healthcare is a potential starting point for developing solutions for the mentioned problems [12]. As healthcare is a knowledge-intensive business processes sector, it is an area where the value creation from data can be of great advantage, as from augmenting processes mining with common sense and domain knowledge. This can make healthcare processes more efficient, and BPM more prepare for these new challenges. BPM is mature, but it can still grow stronger.

2.1.2. Process Identification and discovery

Business processes are everywhere, but few organizations have the resources to model all their processes in detail. Nevertheless, process identification is necessary for the ones of strategic importance for an organization in order to meet business goals [30].

Business processes play a central role for integrating different views and perspectives of an organization. There are several process categories: core, support, or management. In an architectural point of view, there are three types of relationships between processes: sequence, decomposition, and specialization. [30] suggest that there should be a selection criterion for applying BPM to a business process to reduce risk of failure and to prioritize attention: strategic importance, health, and feasibility.

In BPM life cycle, process identification is the first phase. It is very important because it sets the context of the business process in the organization, defines them (within the organization of or the scope of a specific project), and prioritize their management, deciding which to deal in the rest of BPM cycle. This phase main goals are to understand the organization and to maximize the value of BPM projects.

The second BPM phase is process discovery that, after process identification prioritization, starts to gather information on the project with the purpose of documenting the process. As referred, there is a preferred notation used in BPM to graphically display the modeled process: BPMN. With over 100 symbols, BPMN can be quite complex. Nevertheless, is a powerful tool to display process information and assure that process intervenient are aware of all the complexity of a process.

Process discovery is the act of gathering information about an existing process and organizing that information as an "as-is" process model [30]. Information gathering has two main roles that assure modeling languages usage and real existent process knowledge: process analyst and the domain expert. There are commonly three process discovery challenges: fragmented process knowledge, think of processes on a case level, and unfamiliarity with business process modeling languages.

The process discovery methods that can be used are: evidence-based discovery (as document analysis, observation, or automated process discovery - Fig. 2), interview-based discovery (interviewing multiple process domain experts, also for the same role), and workshop-based discovery (has the advantage of resolving inconsistent views between domain experts).

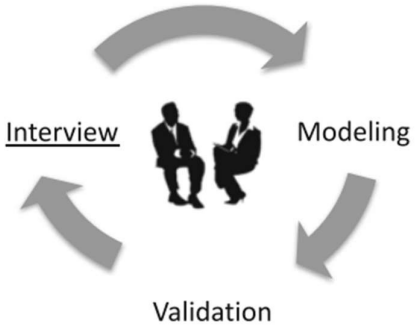

Fig. 2 - Phases of the interview method. Taken from [30].

For the process modeling method, [30] advise the usage the following five steps: identify the process boundaries, identify activities and events, identify resources and their handoffs, identify the control flow, and identify additional elements.

The information retrieval can come from descriptive methods, surveys, documentation or standards, or others, and has the goal to describe with maximum detail the process. After this information is collected, it is made a model of the process in order to better understand the process but also to share our understanding of the process.

2.1.3. Process analysis and redesign

Process analysis is the following BPM phase of the cycle. Starts from the objective of understanding reality to identify opportunities for improvement, validating the vision and scope of the process. To carry out this journey, we begin by carrying out an assessment of the current performance of the process, which in the future will be used as a baseline in comparison with future performances resulting from changes and improvements to the process. After evaluating current performance, a set of qualitative and/or quantitative analysis techniques can be applied to the process: qualitative - value-added, waste stakeholder (Pareto analysis and PICK Chart), root cause (cause-effect and why-why diagrams); and quantitative - flow analysis (cycle time, critical path, little's law, capacity and bottlenecks), queues, and simulation.

After a process analysis, there is the redesign phase. The process analysis can identify a set of issues that must be overcome. Suggest the usage of the Devil's Quadrangle framework to help in process redesign and optimization. This framework has four performance dimensions: time, cost, quality, and flexibility Fig. 3.

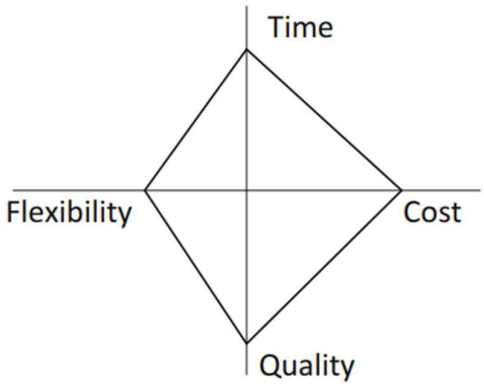

Fig. 3 - The Devil's quadrangle. From [30].

There are several choices for a process redesign method, as showed in Fig. 4. The redesign orbit proposed by [30], presents the process redesign methods between transactional (that redesign a process in a incremental way) and transformational methods (that make a grand scale process change), and intersects them with their nature: analytical (use of quantitative techniques) or creative (use of group dynamics). These for characteristics are, also, related with a inward-looking (viewpoint of the organization) or an outward-looking (viewpoint of an outsider's perspective of the process).

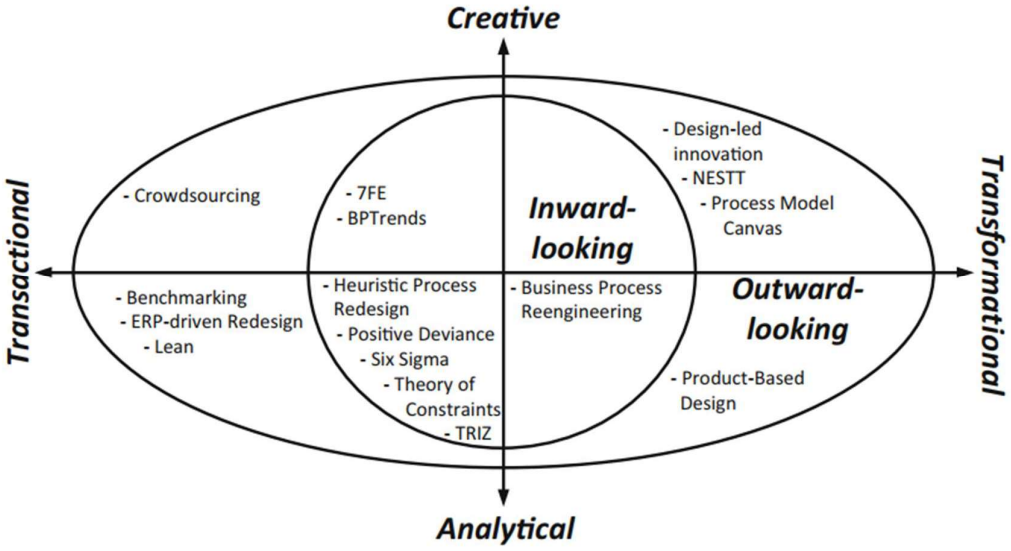

Fig. 4 - The redesign orbit with the possible process redesign methods. From [30].

The usage of heuristic process redesign, a transactional, analytical, and inward-looking method, has showed great success [30]. [42] gathered the best practices on process redesign and concluded for the usage of the devil's quadrangle dimensions applied to a set of redesign heuristics. These redesign heuristics can be seen as a set of rules of thumb that have been successful applied to generate redesign scenarios. From this study, there is a set of 29 heuristics organized in order of their orientation (customer, business process operation, business process behavior, organization, information, technology, external environment).

The outcome of a process redesign is a set of scenarios, presented with a strengths and weaknesses analysis, to be presented to the ones in charge of making the strategic decisions of the organization. The decision made is then passed to the following BPM life cycle stage (Process implementation), and afterwards passes to the stage of process monitoring. BPM cycle then restarts in a new pursuit for the most efficient process.

2.2. Literature review methodology

A systematic literature review (SLR) evaluates, summarizes, or interprets existing and available research essential to answer a specific question, a particular topic, an individual area of study, or a phenomenon of interest [43]. An SLR is much more than an elaborate annotated bibliography [44] and must be systematic, explicit, and reproducible [45]. With these presuppositions, a methodological approach must be guaranteed, as well as the transparency of the steps developed and the decisions that guided their implementation, allowing for duplication and supervision by others who follow the same protocol. A relevant aspect that the SLR must achieve is to be based on a rigorous review process, guaranteeing the trust of readers, and ensuring its usefulness [45]. The specific contribution of the research carried out to the existing scientific knowledge must also be explained [46].

This SLR is part of the literature review of a specific topic, without the collection or analysis of primary data by the author [45]. The protocol used for its elaboration follows the methodology indicated by Kitchenham [43], which suggests three main stages (Fig. 5): planning, conducting, and reporting the review.

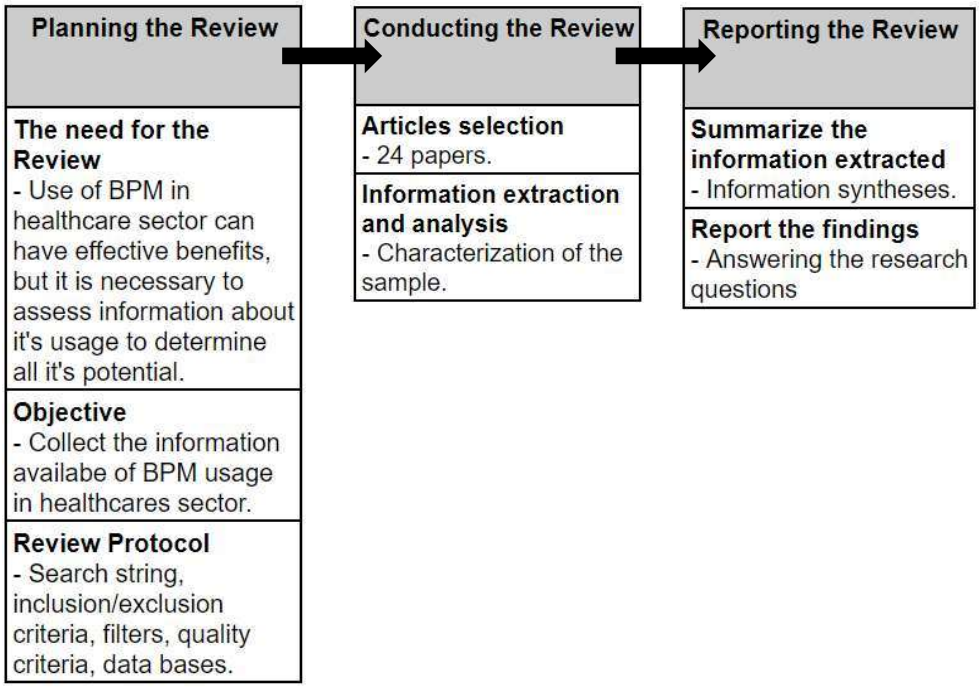

Fig. 5 - The stages of a Systematic Literature Review.

2.2.1. Planning the literature review

This subsection represents the first phase of the methodology used in the SLR, describing the need to carry out the literature review, specifying the research objective synthesizing it in the research questions and determining the definition of the review protocol.

The need for the Review

The rising costs in healthcare can jeopardize the sustainability of the sector and the access of people to those services. This reality opens the possibility for an area of research that is in accelerated development and intends to apply strategies, methodologies, processes, and tools, that have already proven themselves in other sector like industry or services, to the health sector [10]. BPM has numerous advantages in improving processes, making them more efficient, but its use in healthcare is still at an early stage [14]. It is necessary to assess whether BPM can be a useful tool to improve the quality and effectiveness of healthcare processes.

To the best of authors' knowledge, the previous research related to this topic is the one that follows. Research was made to assess the usage of BPM for optimizing clinical processes [14]. However, despite the SLR having been delivered for publication in October 2019 (almost three years ago), it is not just a temporal issue that justifies this new research: it does not clearly indicate the methodology followed and the search words do not include "process redesign" or "process optimization" which reduces the effectiveness of the results we intend. (Ranaweera et al., 2021) reviewed the application of BPM in healthcare but discarded studies of interventions that were not implemented or without a digital intervention, resulting in reduced analysis of 14 articles. [11] mainly focused on the management of operating rooms. The promotion of BPM in healthcare was also reviewed till September of 2016 [10], nearly seven years ago, and with a search string that didn't include specific healthcare organizations as 'hospital', just for example. Our study differs from the previous reviews in that it does the review of the usage of BPM in healthcare in recent years adopting more broader approach, which gives a larger coverage of experiences, and assess how BPM has been applied in the redesign and optimization of processes in the health sector.

Objective

To produce a literature review that assesses for what purposes BPM is used for process redesign and optimization in the healthcare sector, in which health institutions was BPM adopted in the redesign and optimization of processes in the health sector and how fully is the implementation of BPM in the redesign and optimization of processes in the healthcare sector.

Review Protocol

The review protocol begins with the definition of the research words to be used later in the scientific databases and which derive from the research questions formulated. The construction of the search string is described in Table 1. The scientific databases used in the research were: IEEE Xplore Digital Library1, ACM Digital Library2, Scopus3, Web of Science4 e PubMed5.

The initial search was performed using the search string in all article's fields. Then, a filter was applied so that the search was limited to the abstracts of articles in scientific databases. The second filter was applied to eliminate duplicated articles. The third filter applied the inclusion and exclusion criteria indicated in Table 1 and quality criteria indicated in Table 2. Finally, a fourth manual filter validated the studies relevant to our investigation by reading the abstracts.

Table 1 - Inclusion and exclusion criteria.

Inclusion Criteria	Scientific publications in journals or conferences. Written in English. Full text available online. Indication in *Abstract* of relevance for analyzing BPM process redesign or optimization in healthcare. Published between 2010 and 2022.
Exclusion Criteria	Nonscientific papers, white papers or thesis. Not in English. Only partial available online. No identification in Abstract of relevance to a BPM implementation in healthcare for process redesign or optimization. Published before 2010.

It should be noted that, on purpose, the search string was relatively open, which led to a relevant set of articles only being rejected after applying the manual filter. This choice stems from having identified, in exploratory research, that the exclusion of the acronym BPM could eliminate relevant articles and repeat a limitation identified in related works [14] – the inclusion of the acronym BPM sometimes leads to confusion with "beats per minute" which is used from medical research to musical research.

Table 2 - Quality criteria description.

Quality inclusion criteria	Papers on journals of quality Q1 or Q2[6]. Papers on conferences of quality A or B[7]. Papers on conferences of quality A1, A2, B1 or B2[8].

In addition to the application of filters, there must be an opening for a complementary search for references (backward snowballing) present in the universe of articles identified in the search to incorporate any valuable information. Once again, the inclusion/exclusion criteria must be applied to scientific articles that result from this complementary research. The review protocol is in Fig. 6.

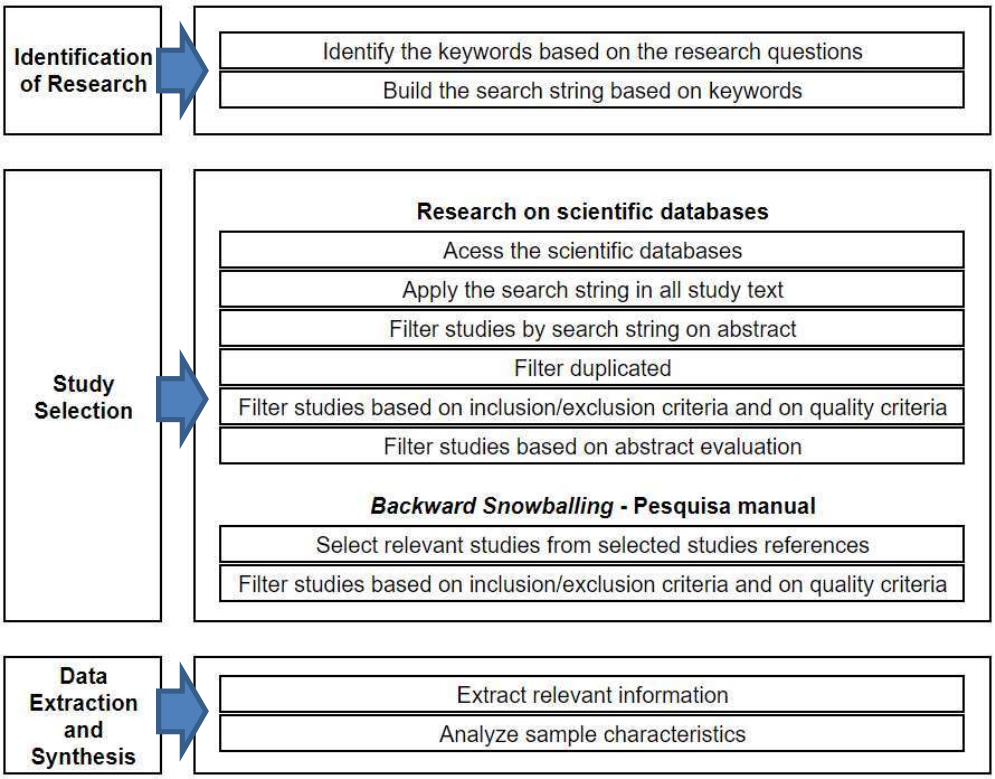

Fig. 6 - Review Protocol.

2.2.2. Conducting the Review

This subsection represents the second phase of the methodology used in the SLR, describing the application of the review protocol and the analysis of the extracted information.

Identification of Research

Several keywords were identified and combined to build the search string (Table 3).

Table 3 - Research string and keywords description.

Keywords	Hospital; Medicine; Healthcare; Medical; Clinical; Redesign; Optimization; BPM; "Business Process Management"; "Process Redesign"
Search String	(Hospital OR medicine OR healthcare OR medical OR clinical) AND (redesign OR optimization) AND (BPM OR "Business Process Management" OR "Process Redesign")

Study Selection

The initial search was carried out without restrictions on the databases, applying the search string adapted to the specifics of each database. The result of the initial search was a universe of 10170 articles. The second filter was applied searching the string only in the abstract and reduced the universe of eligible article entries to 717. The third filter was applied to eliminate repetitions and reduced the universe of eligible articles to 393. The third filter applied the inclusion and exclusion criteria and the indicated quality criteria and reduced the universe of eligible articles to 123. All articles in this universe were validated by manual analysis carried out by reading the abstract, and those that were not related to the research questions were removed from the universe. At the end of the application of the last filter, a universe of 18 articles results. Additionally, the universe of articles was completed by a backward snowballing process, which allowed the addition of 6 more articles, resulting in a universe of 24 relevant articles for analysis.

A greater detail of the steps of the filtering process can be analyzed in Table 4.

Table 4 - Filtering process.

Database	Initial	1.º Filter	2.º Filter	3.º Filter	4.º Filter
IEEE	295	94	93	20	1
ACM	3 119	21	15	3	1
Scopus	5 619	255	223	83	11
Web of Science	411	158	15	5	2
PubMed	726	189	47	11	3
Total	**10 170**	**717**	**393**	**123**	**18**

Database Search	18
Backward Snowballing Search	6
Total	**24**

Data extraction and analysis

Having carried out the selection process of articles, we found that the universe for analysis is built with 5 articles from Conferences and 19 published in newspapers, as can be analyzed in Fig. 7.

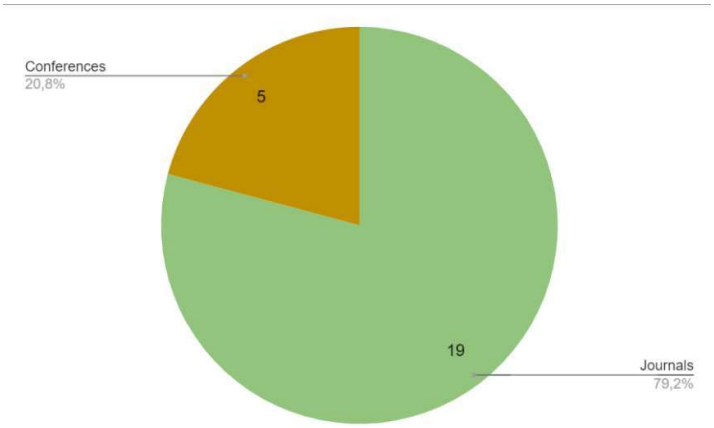

Fig. 7 – Distribution of studies between Conferences and Journals.

The temporal distribution of the publication of articles accounts for a year of greater research production (2020), probably due to the need imposed by the pandemic to an internal optimization, but mainly shows a growing interest over time in the use of BPM for the redesign and optimization of processes in the health area. The temporal distribution of the studies by the publication year can be seen in Fig. 8. The complete list of articles, with the identification of the title, authors, year of publication, type of article and the identification of the Conference or Journal in which it was published, can be found in Appendix 5.

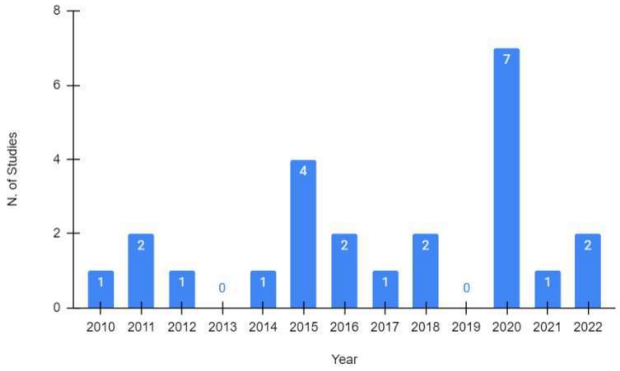

Fig. 8 - Studies published by year.

2.2.3. Reporting the Review

This subsection refers to the last phase of the SLR methodology, summarizing the information extracted and answering the research questions.

Summarizing the extracted information

The analysis of the universe of selected articles makes it possible to identify the objectives for which BPM is used for the redesign and optimization of processes in the health sector. Table 5 summarizes this information, having found the objectives Process Modeling, Process Redesign, Improve Key Performance Indicators (KPI), Implement BPMS, Standardization, Decision Support System, Weaknesses Detection and Process Automation.

Table 5 - BPM usage purposes within redesign and optimization of processes in healthcare.

Objectives	Studies	Total
Process Modeling	[47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61]	**15**
Process Redesign	[48], [62], [63], [50], [51], [53], [64], [65], [56], [58], [60], [59]	**12**
Improve KPI	[48], [49], [51], [53], [65], [58], [66], [59], [67], [60], [61]	**11**
Implement a BPMS	[47], [48], [63], [54], [64], [66], [60], [61]	**8**
Standardization	[62], [63], [54], [66], [67], [60]	**6**
Decision Support System	[63], [54], [55], [64], [66]	**5**
Weakness Detection	[52], [63], [55], [66]	**4**
Process Automation	[48], [61]	**2**

The level of completeness of the implementation of BPM in the universe of articles analyzed is summarized in Table 6, with an indication of the BPM phases implemented.

Table 6 - BPM stages implementation.

	BPM Stage				
Studies	**Discov.**	**Anal.**	**Rede.**	**Impl.**	**Monitor.**
[52]	■	■			
[47]	■				
[48]	■	■	■	■	
[49]	■				
[62]			■	■	■
[63]		■	■	■	
[50]	■	■	■		
[51]	■	■	■		
[13]	■	■	■	■	■
[53]	■	■	■	■	
[68]					
[54]	■	■			
[65]			■		
[55]	■	■	■		
[64]	■	■	■	■	■
[56]			■		
[57]	■	■			
[58]	■	■	■		
[69]	■	■	■	■	
[66]	■	■	■	■	■
[59]	■	■	■	■	■
[67]	■	■	■	■	■
[60]	■	■	■	■	■
[61]	■	■	■	■	■

The typology of institutions in which BPM in the redesign and optimization of processes in the health sector is summarized in Table 7. Articles referring to several units of Hospitals, Clinics and a Telemedicine investigation were found.

Table 7 - Health institutions typology where BPM was used for process redesign or optimization.

Health Institution	Articles	Total
Hospital	[47], [48], [49], [63], [50], [51], [54], [65], [55], [59], [67], [60], [64], [57]	**14**
Clinics	[62], [53], [55], [56]	**4**
Telemedicin	[48]	**1**

Report the findings

For what purposes is BPM used for process redesign and optimization in the healthcare sector?

According to the information summarized in the Table 5 the following objectives were found for the use of BPM in the redesign and optimization of processes in the health sector: Process Modeling, Process Redesign, Improve Key Performance Indicators (KPI), Implement a BPMS, Standardization, Decision Support System, Weaknesses Detection and Process Automation.

Process Modeling is the most repeated objective in the analyzed BPM implementations. It is one of the pillars of BPM [30] and belongs to one of the initial phases on which the others are based. Process modeling allows process traceability and can make visible aspects of the process that were unknown to the entire community or stakeholders [63]. The visual identification of the process, as with the use of BPMN, also makes tacit knowledge more easily transferable, making it explicit knowledge [66]. In cases where the use of a BPMS is used, it is also relevant to provide additional information about the tasks and performance of the participants [63]. Process modeling is also one of the objectives for performing Data Mining, being a challenge to interpret the data and its correct use [47].

Process Redesign is one of the predictable goals for the use of BPM in the healthcare sector. Being one of the phases of BPM [30], the motivations for this objective are varied in the universe of articles under analysis. For example, [62] introduced the redesign of processes to implement a study with clinical tests in which it tried to standardize the process after having redesigned it and materialized reality in a checklist. There is an example of the redesign of a clinical pathway for eye surgery to eliminate cataracts [53]. Still in the application of process redesign applied to the redefinition of clinical pathways, its use for the introduction of telemedicine should be highlighted [48]. The application of optimization techniques in the process redesign phase is referred, for example, using heuristics to reduce the waiting time in Emergency Services [51]. Process redesign for Surgery Services is also mentioned, particularly in response to the traditional problem of planning and scheduling surgeries [59]. An innovative study should be mentioned, from the application of BPM to the redesign of a clinical process, in which a diagnostic process was redesigned, its optimization and the inclusion of BPMS information to aid diagnosis [63].

The use of BPM for the purpose of Improving Key Performance Indicators (KPI) is recurrent with particular emphasis on two indicators: cost and time. The time indicator is the most mentioned, in its Length of Stay (LoS) aspect, applicable to various possibilities such as Emergency Services [51] or Operating Room Services [59]. The reference to the cost indicator can be analyzed in the use of telemedicine services [48]. The versatility of BPM implementations is also distinguished by the numerous possibilities of usable indicators [30].

The purpose of Implementing a BPMS is assumed when a greater maturity of the knowledge of BPM exists, but also with a greater desire to make the choice more effective. This happens when one already assumes the analysis of a health organization by its processes, as happens when one intends to manage clinical paths [54]. One of the most advantageous situations is when information is incorporated into the BPMS to aid in the decision [63] or clinical patient information to centralize the information and make it available to professionals [60]. Equally important is the use of BPMS to turn hospital operational data into management information [64].

Standardization is one of the goals to be highlighted when trying to standardize testing or disease identification processes in which the processes are dispersed across several units [67].

The purpose of using BPM to implement a Decision Support System is clear when incorporated into the clinical process in which it assists the decision [63]. But it is also used to improve perioperative efficiency and ensure optimal use of an Operating Room [64].

The use of BPM with the objective of Weakness Detection is also indicated, which is understood in the connection to the Data Mining process [52].

A different suggestion is the incorporation of performance metrics in the characterization of processes [66].

The Process Automation objective is not as referenced as one would expect when compared to the application of BPM to the industry. This may derive from the health sector being dependent on processes with large human participation, which, for the time being, is indispensable. The uses of BPM with the objective of Process Automation were in the introduction of telemedicine and the collection of information from patients at home by censors [48], and in an attempt to improve the efficiency of a hospital [61].

In which health institutions was BPM adopted in the redesign and optimization of processes in the health sector?

The use of BPM in hospitals in the redesign and optimization of processes is more recurrent than in other spaces, as seen in Table 7. This general statement, however, has derivations in the various units where this happens, such as the Emergency Department [51], Operating Room [59] or Medicine services [48].

There is not enough variety to correctly assess the use of BPM in Clinics or in Telemedicine.

How fully is the implementation of BPM in the redesign and optimization of processes in the healthcare sector?

The implementation of BPM is scarcely carried out in its entirety, as can be seen from the analysis of Table 6. Of the 24 articles analyzed, only 7 indicated the completion of the fullness of the phases. This information accounts for some need to deepen the use of BPM in its maximum capabilities and greatest benefits. However, even more worrying is the fact that none of the articles (in particular those that referred to using the fullness of BPM) indicate the continued use over time of BPM – BPM being a philosophy of a continuous cycle of improvement, the conclusion is the there is a need to deepen its application to the health sector.

2.3. Conclusions of the literature review

The use of BPM for process redesign and optimization in the healthcare sector is still at an early stage of scientific research. We identified 24 articles published between 2010 and 2022 on this topic, mainly focused on the hospital environment. The use of BPM was carried out with the objectives of Process Modeling, Process Redesign, Improving Key Performance Indicators (KPI), Implementing a BPMS, Standardization, Decision Support System, Weaknesses Detection and Process Automation.

The fullness of the BPM life cycle was only indicated to have been carried out in 7 of the 24 articles analyzed, but in none of them there is a reference to the use of BPM as a permanent cycle of process improvement.

Since BPM is a promising methodology in the continuous improvement of processes, having already given solid evidence in industrial or service sectors, more research is needed to evaluate its application to the redesign and optimization of processes in the health sector, which is an area of future work that could lead to unavoidable improvements in the challenges facing the health sector now and in the future.

Chapter 3 - Research Methodology

3.1. Design Science Research

The research methodology adopted in this study is DSR. This methodology was developed to be primarily employed in information systems, computer science, or engineering, due to the need to address research in applied disciplines [70]. DSR is oriented to the creation of artifacts as a problem-solving paradigm, seeking to achieve innovative solutions to real-world problems [71]. This research paradigm had a hype in recent decades mainly to it's potential to foster innovation in organizations [72].

The referred artifacts can be represented by constructs, models, methods, and processes, and are the result of the DSR as the sum of the knowledge generated in the research [71]. The knowledge and full understanding of the problem domain and the solution for it are achieved when building and implementing the artifact. DSR have proved to present good results creating significant economic and societal impact [72].

As stated by [73], scientific research needs to be characterized by abstraction, originality, justification, and publication. This is necessary to be distinguished of the way that solutions are developed by commercial providers or practitioners' communities.

A DSR must include three characteristics as a methodology: conceptual principles, practical rules for its conduction, and procedures to perform the research [70]. The DSR methodology and procedures, as proposed by [70], must include Problem Identification and Motivation, Definition of Solution and Objective, Design and Development, Demonstration, Evaluation, and Communication.

3.2. When and how to evaluate the DSR

The main distinction on when to evaluate a DSR is *ex ante* versus *ex post* evaluation [74]. *Ex ante* evaluation is the predictive assessment of the impacts of a future situation or implementation, as *ex post* is the assessment of an implemented system or solution [75]. Therefore, the evaluation is not only conducted at the conclusion of a design-construct-evaluate cycle, but there can also be a design-evaluation as an *ex ante* one [76].

As stated by [76], a *ex ante* evaluation is well suited for deciding whether to acquire, develop or invest in a technology, or for deciding between several competing technologies. This is a good choice in situations in which implementations are costly and can be applied as a cost benefit analysis. In these cases, the artifact is evaluated based on its design specifications alone. Consequently, the moment when the evaluation is made shows how design research is a part of design science as can be seen in Fig. 9.

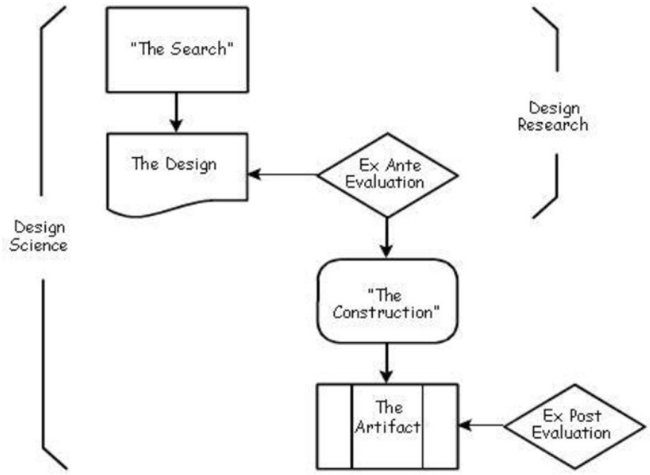

Fig. 9 - Ex ante versus ex post, taken from [76].

Another relevant aspect in the DSR choice of strategy for evaluation is which primary form will be approached: artificial or naturalistic evaluation [77]. An artificial evaluation does the analysis of a solution technology in a contrived and non-realistic way, whereas naturalistic evaluation does the analysis in a real environment i.e., within the organization, involving real users using real systems to solve real problems [74]. Natural evaluation embraces the complexity of real life and, as such, it can be difficult and costly to apply. There are several methods that can be included in a naturalistic evaluation as case studies, field studies, surveys, ethnography, phenomenology, hermeneutic methods, and action research [76].

One-on-one interviews can be very useful for evaluation, typically with a duration from half an hour to more hours as needed [78]. These interactions with stakeholders are fundamental to improve the artifact. Also, descriptive evaluation methods can be employed, as the informed argument uses information from knowledge base to prove artifact's utility [79].

3.3. Relating DSR with BPM cycle

As expressed in previous chapters, BPM methodology is a set of concepts, methods, and techniques to support process identification, discovery, analysis, redesign, implementation, and monitoring. And has

a life cycle that repeat itself for an always more performant process. BPM is applied to identify and solve organizational problems.

As shown in [80], BPM processes can be the outcome of a DSR as we intend in our research. Also, a DSR project can receive feedback since the early stages, questioning and updating their scope as they progress in the project [72], which is very interesting for the BPM life stages and process.

As stated by [71], also Design science has the purpose to create artifacts and evaluate artifacts that are intended to solve organizational problems, varying the artifacts from the form of software, formal logic, mathematics to informal language descriptions. As so, the outcome of different BPM life cycle stages, can be considered an artifact (a process, identified and documented, for example).

The connection between the DSR guidelines proposed by [71] and BPM life cycle can be consulted in Table 8 - DSR guidelines applied to BPM life cycle. As expected, BPM life cycle has several interconnection possibilities with DSR guidelines.

Table 8 - DSR guidelines applied to BPM life cycle.

Guideline	**Description applied to BPM life cycle**
Guideline 1: Design as an artifact	Several BPM cycle stages can have as output an artifact as a process and its documentation (identification, discovery, analysis, redesign, or implementation)
Guideline 2: Problem relevance	Not specific to BPM life cycle, but applicable to the usage of BPM: solve identified organizational problems
Guideline 3: Design evaluation	The same stages identified in Guideline 1
Guideline 4: Research contributions	Depending on the research purpose, can be the process model "as-is", the "to-be" model, as documenting redesign scenarios or monitorization procedures.
Guideline 5: Research rigor	Use of BPM framework
Guideline 6: Design as a search process	Usage of BPM life cycle and its methods
Guideline 7: Communication of research	Not specific to the BPM life cycle, but an outcome of several stages depending on the need to document the results

3.4. The research

This research focuses on optimizing the hospitalization process in internal medicine wards, identifying and modeling the "as-is" process, and propose several redesign scenarios.

As stated by [73], scientific research needs to be characterized by abstraction, originality, justification, and publication. This is necessary to be distinguished of the way that solutions are developed by commercial providers or practitioners' communities. In Table 9 we describe the principles of our research.

Table 9 - This DSR principles.

DSR Principle	Explanation
Abstraction	The research consists of proposing a redesigned and optimized process for reducing the length of hospital stay in Internal Medicine wards. Also, can be used to address the application of BPM in healthcare processes that, as seen in the literature review, is needed research.
Originality	The usage of BPM to reduce length of stay in hospital Internal Medicine wards is not in the known body of knowledge.
Justification	BPM was used to optimize processes in very different areas, so it is expected to have impact also on hospital processes. Nevertheless, there is a lack of research in applying the BPM framework to processes that involve patients. Experts were interviewed and addressed the proposed improvements and process modification along the BPM implementation.
Benefit	The reduction of hospital length of stay is much needed in Internal Medicine wards due to the hospital costs and the patient health. Also the BPM research field can be developed by this research.

In this study we follow the DSR guidelines proposed by [71] as described in Table 10. These practice rules, when followed, assure that the DSR achieves its purpose: the creation of an artifact that expand the limits of human capabilities and organizations.

Table 10 - DSR guidelines.

Guideline	Description
Guideline 1: Design as an artifact	The artifact to be presented is a BPM redesign of a hospital internal medicine ward process that reduces the length of stay

Guideline	Description
Guideline 2: Problem relevance	Hospital length of stay is a major problem when addressing hospital costs and patients health and recovery prospects
Guideline 3: Design evaluation	Utility, quality, and efficacy are evaluated by interviews to professionals and the application of BPM life cycle
Guideline 4: Research contributions	BPM application in the health sector and process optimization
Guideline 5: Research rigor	Use of BPM framework
Guideline 6: Design as a search process	Iteration with professionals' feedback
Guideline 7: Communication of research	Publication of the research

A DSR must include three characteristics as a methodology: conceptual principles, practical rules for its conduction, and procedures to perform the research [70]. The DSR methodology and procedures, as proposed by [70], is presented in Fig. 10.

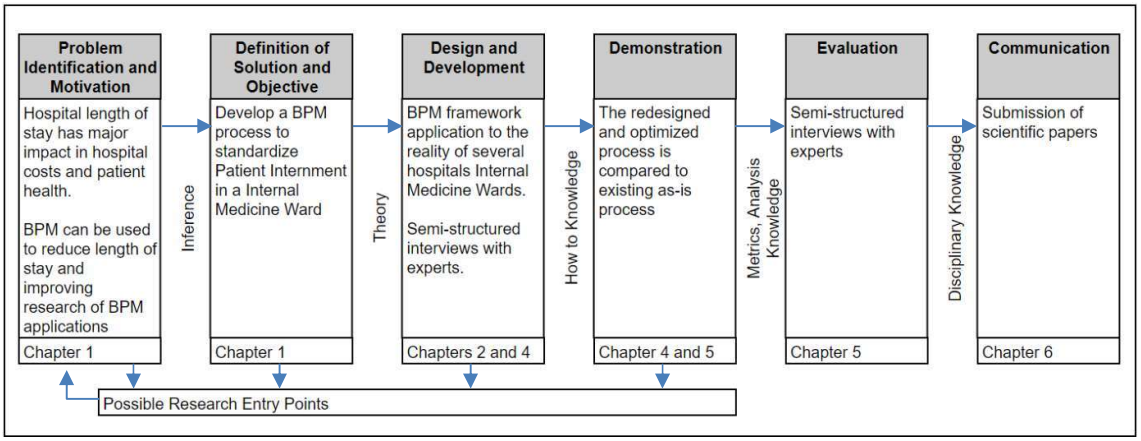

Fig. 10 - DSRM Process Model Followed.

3.5. Data collection

This research focuses on optimizing the hospitalization process in internal medicine wards. It is based on state managed hospitals and hospital centers in the metropolitan area of Lisbon, Portugal. The hospitals and hospital centers in which the investigation is carried out serve a population of more than one million and eight hundred thousand people.

There is no standard internal medicine ward hospitalization process, a guideline, or a protocol, defined for application across different hospitals and hospital centers. Thus, the modeling of the "as-is" process resulted from the collection of information on existing processes in the various hospitals and hospital centers, identification of similar points and differences, allowing the construction of the common model and isolating different practices in the different locations. To properly analyze a process, it is necessary to start by understanding its current state, developing models of the "as-is" process [30].

The "as-is" model must be a faithful reproduction of the process as it is recognized in the organization and as it is currently implemented. To gather the information to model de process many different methods can be used, as direct observation, one-on-one interviews, written feedback, structured workshops [30]. In our research we addressed doctors in several hospitals of the reported region of Lisbon, Portugal, to gather the information and validate the process model and redesign.

As stated by [81], there are different potential methods that designers can use to work with, several of them also used in BPM methodology, such as focus groups, expert interviews, surveys, ethnographic techniques, field research, storyboarding and use of prototypes. Also, designers can the simple asking, observing, and performing cycle [82].

As it is not necessary for design researchers to construct an artefact in order to evaluate a design theory [76], the confrontation of domain experts with possible process redesign solutions can serve as an evaluation method in connection with BPM framework.

To collect information and look for areas for improvement, interviews were carried out with doctors and experts. Field monitoring was also carried out, with a visit to the hospital and direct observation of the process and the work of professionals.

Twelve interviews were carried out with internists doctors, one interview with a hospital manager, one interview with a clinical director and one interview with a hospital IT systems administrator. In total, fifteen interviews were carried out, lasting between 45 minutes and 2 hours. Three interviews were carried out in person and twelve were carried out via video conference. There was audio recording of all interviews.

There was also a field observation was carried out in the largest hospital in the universe in question. This direct observation happened on the 20th of April of 2023 and, in addition to contacts with other medical professionals besides those who carried out the interviews, allowed interaction with nursing professionals and social workers, enriching the information collected. It was also provided an insight to the software used in by medical teams in the daily basis.

3.6. Descriptive method organization - interviews

The interviews were conducted by the same researcher and involved twelve Internal Medicine physicians, one hospital manager, one clinical director and one hospital IT manager. The information on the interviews is in Table 11. There were two interviews of the Hospital IT Manager due to need to clarify some of the IT problems and perspective that were referred by process participants and in the original interview weren't questioned.

Table 11 - Interviews information.

Interview Date (2023)	Stakeholder	Function	Experience (Years)	Gender	Age	Dur.
13/03	Domain Expert	Hospital IT Manager	25-30	M	55-60	1h15m
27/03	Domain Expert	Hospital manager	25-30	M	55-60	1h37m
03/04	Process Participant	Senior Internist Doctor	15-20	M	40-45	1h47m
04/04	Domain Expert	Department Director and Assistant Professor of Medical School	40-45	M	65-70	1h37m
23/05	Process Participant	Internist Doctor	10-15	W	35-40	37m
23/05	Process Participant	Internist Doctor	5-10	M	30-35	52m
26/05	Process Participant	Internist Doctor	5-10	M	30-35	1h29m
26/05	Process Participant	Senior Internist Doctor	15-20	M	40-45	43m
29/05	Process Participant	Service Director Internist Doctor	30-35	W	60-65	1h05m
29/05	Process Participant	Internist Doctor	5-10	W	30-35	43m
30/05	Process Participant	Internist Doctor	10-15	W	30-35	36m
05/06	Domain Expert	Hospital IT Manager	25-30	M	55-60	42m

Interview Date (2023)	Stakeholder	Function	Experience (Years)	Gender	Age	Dur.
27/06	Process Participant	Internist Doctor	15-20	W	40-45	44m
28/06	Process Participant	Internist Doctor	10-15	W	35-40	35m
05/07	Process Participant	Internist Doctor	10-15	M	35-40	54m

The interviews consisted of three parts: 1- Identification of the existing "As-is" process; 2- Collection of improvement proposals; 3- Validation of improvement suggestions made by researchers. The first two parts of the interviews were triggered by asking open questions, to guarantee greater freedom for the interviewee. Despite the use of open questions, when identifying the "as-is" process, it was guaranteed that the answers addressed the following topics: description of the process, communication between teams, management of pathologies, access to exams and complementary means of diagnosis, relationship between hospital services, relationship with services outside the hospital and communication with patients' families.

In the first part of the interviews, as the "as-is" process was being defined, interviewees were asked whether they validated the information collected. The second part of the interviews consisted of the question: "In your opinion, how can the hospitalization process be improved and the length of stay in hospital optimized?" The third part of the interview served to question the interviewee with possibilities for improvement suggested by the literature, by the experts interviewed or suggested by previous interviewees. As referred in [79], a descriptive evaluation method that can be used in a DSR is the informed argument and, as suggested, was used to build an argument for artifact's utility.

The first four interviews (Hospital IT manager, Hospital manager, Senior Internist Doctor, and Department Director and Assistant Professor of Medical School) served as the basis for the "as-is" process and for the universe of process redesign possibilities. The direct observation, carried out in the hospital and accompanying healthcare teams in action, allowed the validation of the information collected in the first four interviews and refine the knowledge acquired.

The additional information (to the “as-is” model, suggestion for redesign and optimization, and judgment of other redesign possibilities) of the remaining interviewees was iteratively added in the end of each interview and used in the following. From the nineth interview on, there was no more new information to improve the “as-is” model, no new idea for possible redesign possibilities and neither a new opinion or perspective on the propose redesign possibilities. Despite the internists interviewed from the nineth interview on were from different hospitals, only confirmatory information was valuable, admitting that we have had reached a saturation point.

Chapter 4 - Reporting the findings

4.1. The “as-is” process

The organization of internal medicine wards may differ between hospitals. From the composition of the medical team, the distribution of nursing teams, the distribution of social workers, the number of people in the secretariat, the routines within the different teams, there are several points of difference. However, it was possible to outline a common trunk that will be presented as our base process.

There are differences between the resources available in different hospitals. Therefore, the composition of the teams, the number of patients assigned to each team, and the distribution of responsibilities within each team may differ. Even the software, whether used to document the patient's journey, whether used to schedule exams or other means of diagnosis or used for communication between teams or within the hospital organization, can be different. The modeling of the “as-is” process was carried out with abstraction relative to that of the software or the composition of the teams.

4.1.1. Process Identification and discovery

The process of hospitalization to internal medicine wards begins, in more than 90% of situations, with an indication for the patient to be admitted emitted by the emergency department. The remaining situations arise from internal referrals, from patients coming from other services or hospitals, or from patients admitted through external consultation.

The hospitalization process follows the following phases:

- admission to the internal medicine ward;
- assignment of the patient to a medical team;
- definition of the diagnosis;
- definition of therapy;
- patient assessment;
- hospital discharge;

Admission to the internal medicine ward is carried out subject to prior medical evaluation and the existence of vacancies for hospitalization. The admission of a patient to the internal medicine ward does not mean that the diagnosis has been defined, only that the patient is stabilized. If a patient is admitted during the weekdays (9am-5pm), they are immediately handed over to the medical team who will accompany them until medical discharge. If the patient's admission takes place outside the aforementioned hours, it is handed over to the responsibility of the medical team that is in charge of the internal emergency department and only on the following day is it handed over to the medical team that will accompany the patient until discharge. The responsibility of the internal emergency medical team is to ensure that patients are stabilized, it does not have the purpose of diagnosing patients.

The patient's assignment to a medical team depends on the bed assigned to the patient, given that the distribution of responsibilities between medical teams is carried out by the beds they have assigned. Within the medical team that takes care of the patient, there is a professional who is directly responsible for their follow-up.

The definition of the diagnosis is carried out, ideally, within the first two working days after the patient arrives at the ward. However, this period is not always observed because, due to difficulties external to the ward, there is not always availability to carry out exams, to carry out other complementary means of diagnosis or to use consultancy from other medical specialties. The definition of therapy is carried out after the diagnosis is reached and transmitted to the nursing team.

Patient assessment is carried out in the morning of each working day, only exceptionally there is patient assessment on weekends and holidays. Patient assessment is an element of discussion among the medical team on the morning of each working day. There is a moment in which several medical teams, chief nurse, and social worker responsible, discuss clinical cases among themselves to share knowledge and advise on the steps to follow and to discuss the near future of the patient.

Clinical discharge is decided only by the specialist doctor. In situations where the team has internship students, even if they directly monitor the patients, the responsibility lies with the specialist doctor. Only exceptionally are there medical discharges on the weekend. On the other hand, often the same professionals who are in the wards also make shifts in internal emergency teams. When this happens, having worked during the night, it is unlikely that a clinical discharge will be given the day after this work because they have the day off.

Hospital discharge does not always coincide with clinical discharge, meaning that, despite health conditions make discharge possible, the patient remains hospitalized. There are several situations in which patients remain in hospital despite being clinically discharged: waiting to be transferred to back-up services, delays in transfers to intermediate care or continued care services, lack of places in nursing homes, or lack of family support. Around 15% of patients admitted to the various hospitals where we interviewed professionals were hospitalized despite having already been discharged and not needing hospital care.

In the differences identified between different hospitals, the following should be highlighted:

- There are hospitals where, in addition to the emergency service, there is an observation service. In reality, this observation service works like an internal medicine ward but where the beds have been replaced by stretchers and there is no pre-defined maximum number of patients. In moments of greater demand they are more chaotic, in moments of lower demand they can provide a better service. Nevertheless, during periods of overload on internal medicine wards, there are patients who are discharged from observations services without having been admitted to the wards, despite having been waiting for several days for this vacancy;

- The multidisciplinary meeting in which the various medical teams, those responsible for nursing and social services participate, does not have the same frequency in all hospitals. There are hospitals where it is performed once a week, there are other hospitals where it is performed fortnightly;

- There are hospitals that have outpatient consultations where doctors also perform this task and there are hospitals where this service is not available;

- There are hospitals where there is a day hospital that shares resources with internal medicine wards and there are hospitals that do not have this function;

- Only some hospitals have teams for home hospitalization.

From the information collected, in particular from the interviews carried out, we can list some aspects that characterize the process and which were emphatically stated:

- Lack of professionals;
- Work overload and exhaustion of existing professionals;
- Using external service providers that do not guarantee the expected quality of service;
- Delays in carrying out exams and complementary diagnostic means;
- Difficulties in communication between hospital teams and services;
- Difficulties in communication between hospital services and primary health care;
- Difficulties in accessing medical advice;
- Obsolete or barely functional software;
- Process not patient centered.

To model the hospitalization in Internal Medicine ward process, as mentioned, we will use the notation BPMN. For the best application of BPMN in healthcare situations, we used the best practices suggested by [83]. The “as-is” model is displayed in Fig. 11 and Appendix 1.

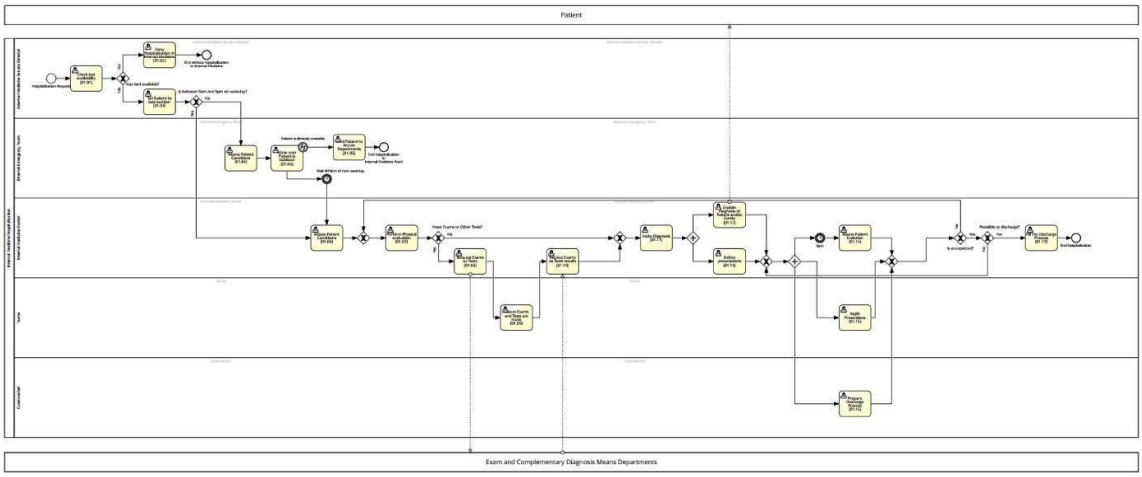

Fig. 11 - The "as-is" model of the existing process.

4.1.2. Process Analysis

The assessment of current performance results from the application of several types of metrics: time, capacity, quality and cost. To carry out this assessment, we used currently existing information and the knowledge of the various stakeholders. For the current investigation, the time metric is the most relevant reference and is the one that will be considered. The average length of stay is the main metric that aims to be reduced.

The application of analysis techniques to the process makes it possible to identify possible problems in the process, possible weaknesses or points that can be improved. This diagnosis then makes it possible to improve process performance. The following techniques were carried out:

- Value analysis: qualitative technique to identify unnecessary actions in the process and qualify the various actions in relation to value creation (Table 12);

- Stakeholder analysis: qualitative technique that analyzes the process from the perspective of each of the process’s stakeholders (Table 13);

- Waste analysis: qualitative technique to identify waste throughout the process, which can be explicit or implicit in each activity;

- Pareto analysis: qualitative technique that hierarchizes and aggregates weaknesses in the process, also known as the 80-20 principle;

- Cause analysis: qualitative technique that organizes weaknesses into categories and relates them as effects of certain causes that must be corrected or eliminated.

Table 12 - Value analysis.

Task	Role	Value analysis
Patient Admission	Head director of internal medicine	OVA
Patient diagnosis	Doctor	OVA
Patient therapy definition	Doctor	OVA
Patient assessment	Doctor	OVA
Patient exam and complementary diagnostic mean schedule	Doctor	OVA
Patient movement	Auxiliary	VA
Patient therapy application	Nurse	VA
Patient discharge	Doctor	VA
Family social preparation	Social worker	VA
Family clinical preparation	Nurse	VA
Transfer to other services	Social worker	VA

By analyzing the process and contacting the people who participate or are involved in it, several stakeholders were identified. It is possible to group the stakeholders of the process according to the following categories: client, direct participant, external entity, owner, and promoter. Therefore, following this cataloguing, the stakeholders found are:

- The customer of the process is the patient;

- The direct participants are the doctor, the nurse, the social worker and the members of the administrative staff;

- The external entities identified are the suppliers of software, of exams and complementary diagnostic means and consultants from other medical specialties;

- The process owner is the service manager;

- The promoter of the process is the hospital administrator.

It was not possible to interview all stakeholders in the process due to administrative issues and lack of authorizations. Therefore, to overcome this difficulty, interviews were carried out with 12 doctors, a hospital administrator, a service director, and a director of hospital IT systems.

Table 13 - Stakeholder analysis.

Stakeholder	**Main problems identified**
Doctor	- Lack of professionals; - Work overload and exhaustion of existing professionals; - Using external service providers that do not guarantee the expected quality of service; - Delays in carrying out exams and complementary diagnostic means; - Difficulties in communication between hospital teams and services;

Stakeholder	**Main problems identified**
	- Difficulties in communication between hospital services and primary health care; - Difficulties in accessing medical advice; - Obsolete or barely functional software; - Process not patient centered.
Hospital administrator	- Lack of professionals; - Budget limitations; - Challenge to align medical and budgetary goals; - Distrustful relation between health professionals and managers; - Workers resistance to change; - Cultural and organizational barriers.
Service Director	- Lack of professionals; - Work overload and exhaustion of existing professionals; - Impossibility to address KPI and prizes. - Delays in carrying out exams and complementary diagnostic means; - Difficulties in communication between hospital teams and services; - Difficulties in communication between hospital services and primary health care;
IT Manager	- Shadow IT; - Budget limitations; - Workers resistance to change; - Cultural and organizational barriers.

Waste analysis makes it possible to expose some inefficiencies in the process. These inefficiencies are identified as Move (which can be movement or transportation), Hold (which can be inventory or waiting time) and Overdo (which can be defects, excess processing, or excess production). In our research, the main inefficiency is related to Waiting, as there are some tasks that can have great impact in the length of stay.

For the Pareto analysis, we identified the five major causes of delays, in order of importance: delays in carrying out exams and complementary diagnostic means, delays in patient transfer to intermediate care or continued care services, delays in patient transfer to nursing homes, delay in family reception, delays in discharging due to weekends. The PICK chart for visualizing the payoff and the difficulty of addressing each issue is in Fig. 12.

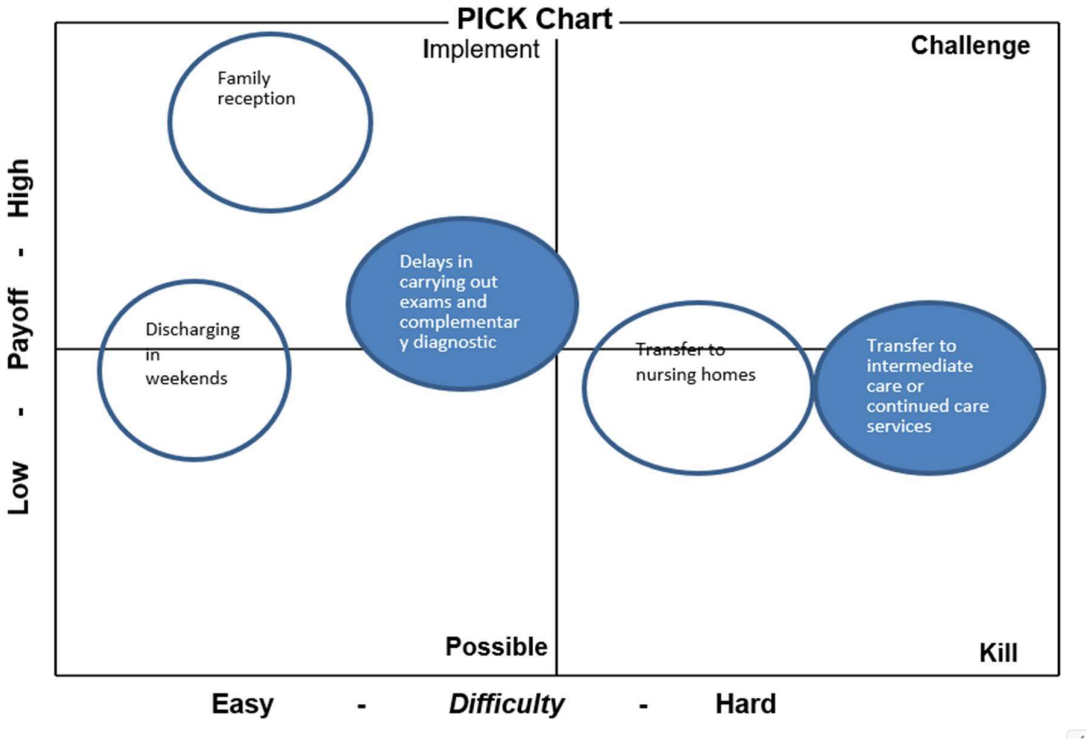

Fig. 12 - PICK Chart with payoff for each identified issue.

The root cause analysis concluded that the main process weaknesses or problems are categorized as Millie (delays due to suppliers), Method (the way process is defined, and communication performed) and Machine (technology issues). The Fig. 13 shows the application of cause effect diagram to the issue "Delays in carrying out exams and complementary diagnostic means".

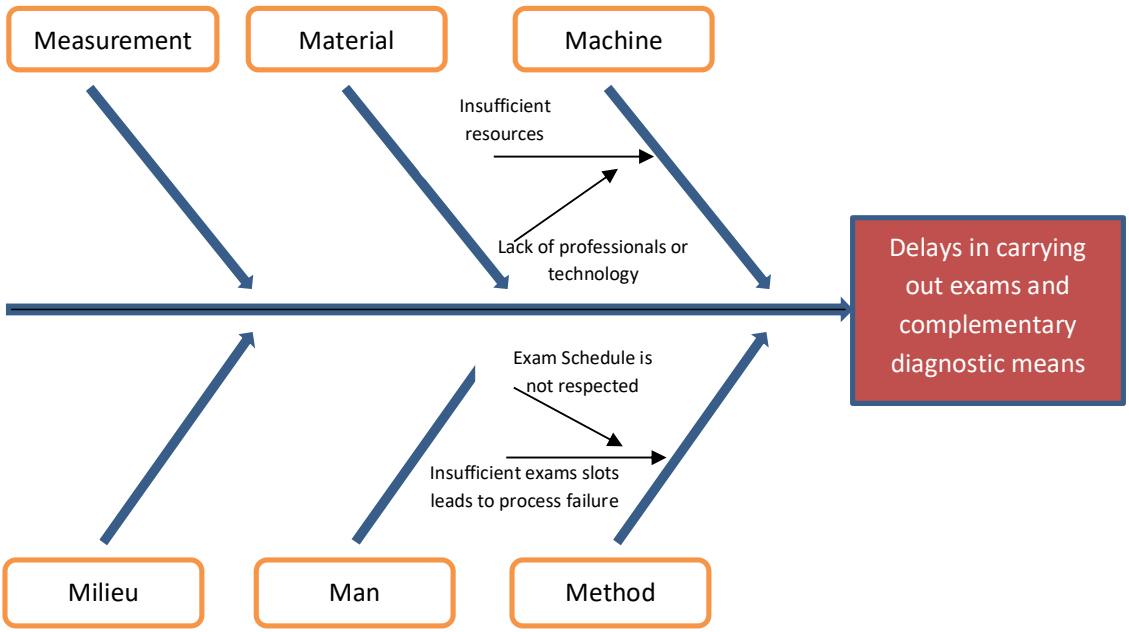

Fig. 13 - Cause-effect for issue: Delays in carrying out exams and complementary diagnostic means.

In Fig. 14 we have the application of cause effect diagram to the issue “Delays in patient transfer to intermediate care or continued care services”.

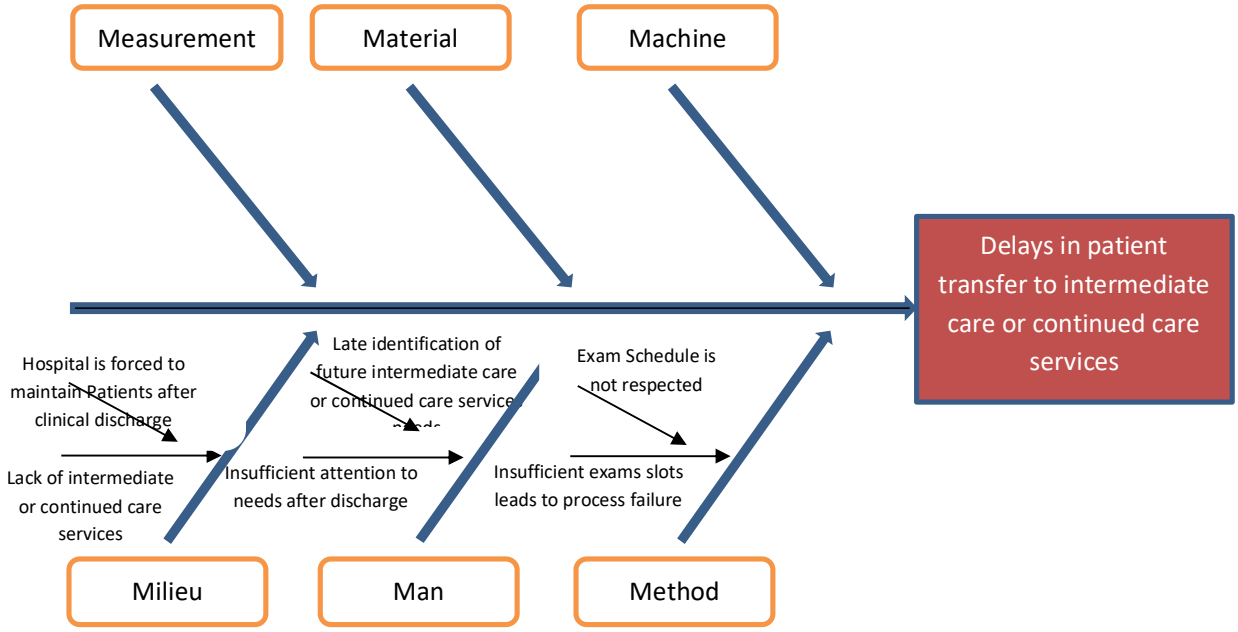

Fig. 14 - Cause-effect for issue: delays in patient transfer to intermediate care or continued care services.

4.2. Process Redesign and iterations

The process analysis phase provides clues for process improvements. However, success in process redesign comes from a structured and systematic approach with the aim of achieving the best solutions and improving performance. Therefore, for a more robust and elaborate approach, several methods for process redesign were developed, which are normally divided between transactional methods and transformational methods [30].

Transactional methods support the identification of problems or waste in the process and help to resolve them iteratively. Transformational methods challenge the assumptions and principles on which the existing process is based and seek to make a change that radically breaks with them. In our work case, the choice of the redesign method fell on heuristics, a transactional, analytical method implemented from the point of view of the organization in which the process takes place.

The method of applying redesign heuristics is divided into three phases: initiation, design and evaluation. The initiation draws on the results of the process analysis and the identified points for improvement. The design allows the choice of heuristics to be applied to achieve performance objectives, reflecting on their use or not through the relationship with other heuristics and weighing the different alternatives and defining scenarios. Assessment is the phase in which the different scenarios are compared in terms of benefits and costs and ranked according to their possible implementation [42]. The division into three phases of this method is something that, in practice, tends to be diluted because, being an iterative method, the phases can overlap. In our case, the iteration that is expected in the DSR reinforces this dilution. In Table 14 is the presentation of the heuristics to our process redesign.

Table 14 - Heuristics application to process redesign.

Category	**Heuristic**	**Application to our process**
Customer	Control Relocation	• Creation of an app that can have direct access to patient's data, monitoring health and a centralized communication to the hospital • Direct telephone contact to doctors
	Contact reduction	• Creation of an app that can have direct access to patient's data, monitoring health and a centralized communication to the hospital • Day hospital
	Integration	• Creation of an app that can have direct access exam scheduling
Business Process Operation	Case Type	• Exam scheduling and patient assessment or medication
	Activity elimination	• Not used
	Case-based work	• Optimize software solutions used by health professionals
	Triage	• Day hospital
	Activity composition	• Exam scheduling by administrative office
Business Process Behavior	Resequencing	• Discharge must be prepared since day 1 of hospitalization
	Parallelism	• Creation of a discharge team
	Knock-out	• Assessment of intermediate care or continued care service's needs, nursing homes vacancies • Preparation of family reception

Category	Heuristic	Application to our process
	Exception	• Creation of protocol with intermediate care or continued care services needs and nursing homes vacancies
Organization	Case assignment	• Not used
	Flexible assignment	• Using administrative staff to deal with exam scheduling. • Using administrative staff to deal with intermediate care or continued care services needs and nursing homes vacancies
	Centralization	• Reinforce communication with different medical specialties
	Split responsibilities	• Not used
	Customer teams	• Not used
	Numerical involvement	• Not used
	Case manager	• Adress a nurse to be responsible for the patient
	Extra resources	• Very important due to lack of medical staff
	Specialize	• Reinforce administrative staff capabilities. • Reinforce nurses responsibilities
	Empower	• Administrative staff exam scheduling
Information	Control addition	• Introduction of a BPMS that can manage exam scheduling
	Buffering	• Introduction of a BPMS that can manage exam scheduling
Technology	Activity automation	• Discharge process • Information for administrative staff to deal with intermediate care or continued care services needs and nursing homes vacancies • Information for patient family
	Integral technology	• Creation of a BPMS
External Environment	Trusted party	• Improve communication and protocols with primary care services
	Outsourcing	• Create deal with intermediate care or continued care services needs and nursing homes vacancies
	Interfacing	• Create an app for patient record and interaction with doctors

4.3. "To-be" scenarios

By evaluating the main problems using Pareto analysis, opportunities for improvement depending on their impact/effort and the application of heuristics, three possible scenarios were identified, and their advantages and disadvantages were considered:

- Scenario 1: Application of improvement opportunities and all heuristics (Table 15 and Appendix 2);

- Scenario 2: Application of improvement opportunities and heuristics with the exception of those that require the creation of a BPMS (Table 16 and Appendix 3);

- Scenario 3: Application of improvement opportunities and heuristics that do not involve investment in IS, in protocols with external entities and in exams capacities, and do not involve the creation of a day hospital (Table 17 and Appendix 4).

Table 15 - Scenario 1 description.

<table>
<tr><td colspan="2">Scenario 1: Application of improvement opportunities and all heuristics</td></tr>
<tr><td colspan="2">Description:
The process has been redesigned with the following changes:
Creation of a computer platform that allows: managing the hospitalization process; be a single point in the management of the patient process; collect patient data and apply machine learning mechanisms to aid medical decision-making and predict problems; have a dedicated app that can serve as a contact between patient, hospital and doctor; centralize the process of scheduling exams and complementary diagnostic means; facilitate communication with doctors from other specialties; facilitate the exchange of information with primary health services.
Strengthen the capacity to carry out exams and complementary diagnostic means.
Reinforce protocols with intermediate and long-term care services.
Reinforce protocols with nursing homes.
Reinforce the number of professionals.
Separate the service provided by doctors in internal medicine wards from internal emergency work.
Ensure a discharge management team that works every day of the week.
Creation of a day hospital.
Hold a meeting with a multidisciplinary team in the first 48 hours of hospitalization and a follow-up to this meeting in the following 72 hours.
Start preparing for hospital discharge from the moment the diagnosis is defined.
Assessment of patients' social conditions, existing family support and needs after hospital discharge within the first 72 hours of hospitalization.
Empower members of the nursing team to take over patient management.
Hold members of the administrative team responsible for managing the patient's calendar.</td></tr>
<tr><td>Advantages</td><td>Elimination of the main bottlenecks.
Reduction in hospital stay.
Equating hospital discharge with clinical discharge.
Data collection for data mining and machine learning.</td></tr>
</table>

Scenario 1: Application of improvement opportunities and all heuristics	
Disadvantages	• Very high budgetary costs. • Confrontation with professional classes. • Not all hospitals have the size to handle all these answers.

Table 16 - Scenario 2 description.

Scenario 2: Application of improvement opportunities and heuristics with the exception of those that require the creation of a BPMS	
Description: The process has been redesigned with the following changes: • Strengthen the capacity to carry out exams and complementary diagnostic means. • Create a bed management team. • Reinforce protocols with intermediate and long-term care services. • Reinforce protocols with nursing homes. • Reinforce the number of professionals. • Separate the service provided by doctors in internal medicine wards from internal emergency work. • Ensure a discharge management team that works every day of the week. • Creation of a day hospital. • Hold a meeting with a multidisciplinary team in the first 48 hours of hospitalization and a follow-up to this meeting in the following 72 hours. • Start preparing for hospital discharge from the moment the diagnosis is defined. • Assessment of patients' social conditions, existing family support and needs after hospital discharge within the first 72 hours of hospitalization. • Empower members of the nursing team to take over patient management.	
Advantages	• Elimination of some the main bottlenecks. • Reduction in hospital stay. • Approximation hospital discharge with clinical discharge.
Disadvantages	• High budgetary costs. • Confrontation with professional classes. • Not all hospitals have the size to handle all these answers. • Communication with patient is not as good as in scenario 1 leading to more unnecessary patient trips to the hospital and resource allocation to these requests.

Table 17 - Scenario 3 description.

Scenario 3: Application of improvement opportunities and heuristics that do not involve investment in IS, in protocols with external entities and in exams capacities, and do not involve the creation of a day hospital	
Description: The process has been redesigned with the following changes: • Reinforce the number of professionals. • Create a bed management team. • Separate the service provided by doctors in internal medicine wards from internal emergency work. • Ensure a discharge management team that works every day of the week. • Hold a meeting with a multidisciplinary team in the first 48 hours of hospitalization and a follow-up to this meeting in the following 72 hours. • Start preparing for hospital discharge from the moment the diagnosis is defined. • Assessment of patients' social conditions, existing family support and needs after hospital discharge within the first 72 hours of hospitalization. • Empower members of the nursing team to take over patient management.	
Advantages	• Reduction in hospital stay. • Better organized process. • Anticipation of some of the problems to earlier stage of the process. • Low budgetary costs.
Disadvantages	• Confrontation with professional classes. • Communication with patient is not as good as in scenario 1 leading to more unnecessary patient trips to the hospital and resource allocation to these requests. • Some of the main bottlenecks remain.

The result of the different scenario application is presented in Table 18. The assumptions made for the assumptions for the calculations made resulted from the information gathered in the interviews. For instance, ensuring a discharge management team that works every day of the week and the multidisciplinary team meeting are determinants for 1 day reduction in the average hospital length of stay. The creation of a day hospital can have a follow up that reduces length of stay, also as strengthening the capacity to carry out exams and complementary diagnostic means, which counts for another reduction of 1 day in average length of stay. The investment on a computer platform as suggested in Scenario 1 is possible to reduce the hospital length of stay in another 2 days, allowing discharge of patients that are also connected to the physicians, centralizing examsand communication with outer services.

Table 18 - Reduction of the length of stay in the different scenario applications.

Scenarios	**Results in length of stay reduction (days)**
Scenario 1	4
Scenario 2	2
Scenario 3	1

Chapter 5 - Results and Discussion

5.1. Demonstration and evaluation

The artifact was validated through the third part of the interviews carried out with health professionals. Throughout the interviews it was demonstrated that the proposed solutions were accepted, and that the investigation path was valid. The incorporation of suggestions from various health professionals allowed us to expand the use of heuristics in process redesign and optimization. The increase in knowledge that came from the interviews with experts was also very important for optimizing the result.

The presentation of several implementation scenarios follows from good BPM practices to ensure that when implementing the scenarios, decision-makers have several options by analyzing the advantages and disadvantages of each of them. The possibility of implementing different scenarios also guarantees flexibility in the proposed solutions, enabling them to adapt to different hospital realities. All the proposed scenarios achieve a reduction in the hospital length of stay.

The utility of the investigation is unequivocal. The possibility of reducing hospital stays has enormous advantages for the healthcare system and patients. In a context in which the cost of healthcare has increased, the aging population has put even more pressure on healthcare systems, the lack of professionals is felt everywhere, the ability to do more and better with resources and optimized processes are immensely useful. By improving hospitalization in internal medicine wards, wards present in most hospitals, this research guarantees even greater usefulness in responding to the need to make hospital resources more efficient. The suggestion of solutions that incorporate technological evolution, allowing the usage of AI or ML, point out the evolution needed to better predict hospital length of stay and to implement accurate decision making.

By following the DSR methodology, the quality of research required for a scientific study is guaranteed. By monitoring compliance with this scientific methodology and the application of the BPM methodology, the necessary robustness of the research is ensured, ensuring its quality.

5.2. Discussion

The present investigation effectively fulfills its objectives. It responds to the need to present an artifact as a result of the application of DSR that fulfills the purpose of presenting a “as-is” model of hospitalization in Internal Medicine wards and propose validated scenarios for future implementation that can reduce hospital stay in internal medicine wards. It also responds to the need to validate the current nature of the BPM methodology for optimizing processes in the healthcare sector, proving that is capable of present solutions for more efficient processes.

Regarding the challenges that the BPM methodology faces today, this investigation proves to be another resource on the way to overcoming these challenges. In a context as demanding as hospital management and in an area as relevant as healthcare, the BPM methodology proves to be very useful and effective. By using a holistic view to model and redesign the process, analyzing its true beginning and end, this investigation adds knowledge to the challenge of expansive BPM. Also, on the proposed "to-be" scenarios there is the possible usage of AI and ML to improve decision making and produce data that can be used in the BPM life cycle for future improvements.

A third major contribution is the demonstration that BPM can be use in a DSR, improving the research options and reinforcing the scientific contribution of BPM field of study.

The reduction in hospitalization time, in any of the proposed scenarios, illustrates the usefulness of the present investigation. It also shows, for the benefit of the future use of hospital resources, that there are possibilities for improving processes that can and should be taken advantage of. The theoretical suggestions presented, regarding the application of the BPM methodology to optimize hospitalization in internal medicine wards, is an important contribution whose implementation is the challenge that follows. Future research can be made by evaluating the real implementation of the proposed "to-be" scenarios.

As previously mentioned, conducting interviews only with physicians may cause a deviation in the analysis and scenarios presented. The difficulties arose from the impossibility of accessing other professionals, such as nurses, social workers, administrative workers, etc. Although the request was made, it was not possible to obtain authorization for such contacts and interviews.

Difficulties in accessing information also marked this investigation. For example, at no time were data provided that could enhance the analysis, such as the average daily cost of hospitalization per patient. This makes it difficult to analyze different scenarios because it makes it difficult to compare the costs of the proposed solutions and fit these costs into the possibility of reducing the length of stay.

It was not possible to access data on hospital processes, in particular those relating to the hospitalization process that would allow data mining. The possibility of accessing hospitalization data, waiting times between exam requests and their completion, period between medical discharge and hospital discharge, waiting times for in-house consultancy, or waiting times for admission in intermediate care units or nursing homes, would be very important because it would give greater quality to the prediction of the outcome of each scenario.

Due to the lack of detailed information, it was difficult to calculate the reduction in the average length of stay. As hospital discharge is currently carried out once a day, after medical evaluation, the unit for reducing the average length of stay we used was the day. This explains the units in predicting the reduction in hospitalization in each of the proposed scenarios.

One of the fundamental points in implementing the proposed scenarios is the culture of hospitals and their professionals. The management of process optimization processes must foresee this dimension, such is the importance it assumes in the organization and in professions and professionals. For example, assigning a nurse to manage a patient implies a structural change in the current process and in the division of tasks between professions. Therefore, it is essential to involve professionals in these changes, demonstrating the collective benefit, to guarantee their success.

The investigation was carried out during a period of enormous labor disputes in the health sector, particularly in public service hospitals. This reality had an impact on the availability of professionals to participate in the research, creating more difficulties that had to be overcome. Wage issues, but also issues of overwork, are the basis of this labor dispute. Work overload is an unavoidable aspect, which affects the performance of professionals and the results of the organizations' activities. This context gives even more strength to the research carried out and the need to take it to future implementation.

The lack of guidelines for the hospitalization of patients in internal medicine wards was identified, giving even more strength to the need for this investigation. The publication of a new management structure for Portugal's public health service, an executive committee, was also justified by the need to create health guidelines and good practice manuals. In this way, the contribution of this research also gains the relevance of being framed within these legislative changes and the possibility of being implemented in the future.

Chapter 6 - Conclusion

The increase in healthcare costs, the demographic aging, a higher average life expectancy and the possibility of living longer with a better quality of life are challenges that require the optimization of healthcare resources. One of the biggest consumers of resources in the healthcare sector are hospitals, so better management of resources in the healthcare sector requires better hospital management. Reducing hospital stay is also a safeguard for patients because hospitalization does not come without risks, especially for elderly population. Comorbidities and prolonged bed rest can enhance complications secondary to the cause of hospitalization, potentially causing motor and cognitive problems, reducing autonomy and the quality of life. Also, hospital-acquired infections are a menace related to prolonged hospital stay that can be minimized.

Our research implemented a DSR to achieve an artifact of a optimized process for hospitalization to internal medicine wards and the reduction of the hospitalization time. We used the BPM methodology to model and redesign the internal medicine ward process, from admission to discharge. We followed BPM life cycle steps of Process Discovery, Process Analysis and Process Redesign to model the “as-is” process and propose three possible scenarios for the “to-be” process.

To model the “as-is” process were made twelve interviews of doctors, specialists in internal medicine, that work on hospitals and hospital centers of the Lisbon region, Portugal. To redesign and optimize the process were also used the inputs of the referred interviews and three experts were also interviews (a hospital manager, a internal medicine service director and a hospital IT manager). The three possible scenarios for process implementation, all assure that the hospital length of stay is reduced.

BPM methodology assured the process modeling and redesign for improved efficiency. The BPM lifecycle was applied to the DSR scientific methodology and proved to be capable of accomplish the goal of the research: the reduction of the hospital length of stay in internal medicine wards.

6.1. Contributions to the scientific and business community

The literature review performed suggests that the application of BPM to healthcare is a field of knowledge that needs updated contributions. Our research proves valid the usage of BPM for process optimization of a internal medicine ward process, demonstrating that in a challenging context as an hospital, BPM is of value to achieve best performance and efficiency.

The research followed the scientific methodology DSR, combining it to the application of BPM to the process modeling and redesign. It proves to be possible to use BPM in a DSR.

As a contribution to the body of knowledge of BPM, the research uses expansive BPM to collect the best information on the "as-is" process and to collect information to the best redesign proposal. This is an important contribution because it helps to answer the biggest problems BPM faces today.

In the "to-be" proposed scenarios, there is the usage of AI and ML. These possibilities are also valuable for BPM cycle as can improve automation and decision making in the future.

6.2. Research Limitations

Our research data was collected in the realization of fifteen interviews. [84] have studied the concept of "data saturation" and the number of interviews made in our research is at the bottom limit of their proposed interval (15-40). However, the data collection in a direct observation initiative helps to reduce limitations. Nevertheless, we must point this as a research limitation that must be regarded.

The data was collected in hospitals and hospital centers of Lisbon region, Portugal. Despite these health infrastructures serve a population of over one million and eight thousand persons, there can be some deviation of internal medicine ward processes of other regions/countries.

6.3. Future research proposal

The implementation of the proposed artifact in a hospital is the foremost future research proposal that we expect can be achieve in a near future. Another research proposal is the validation that the model (and consequently the redesigned process) is applicable outside the region of Lisboa, Portugal.

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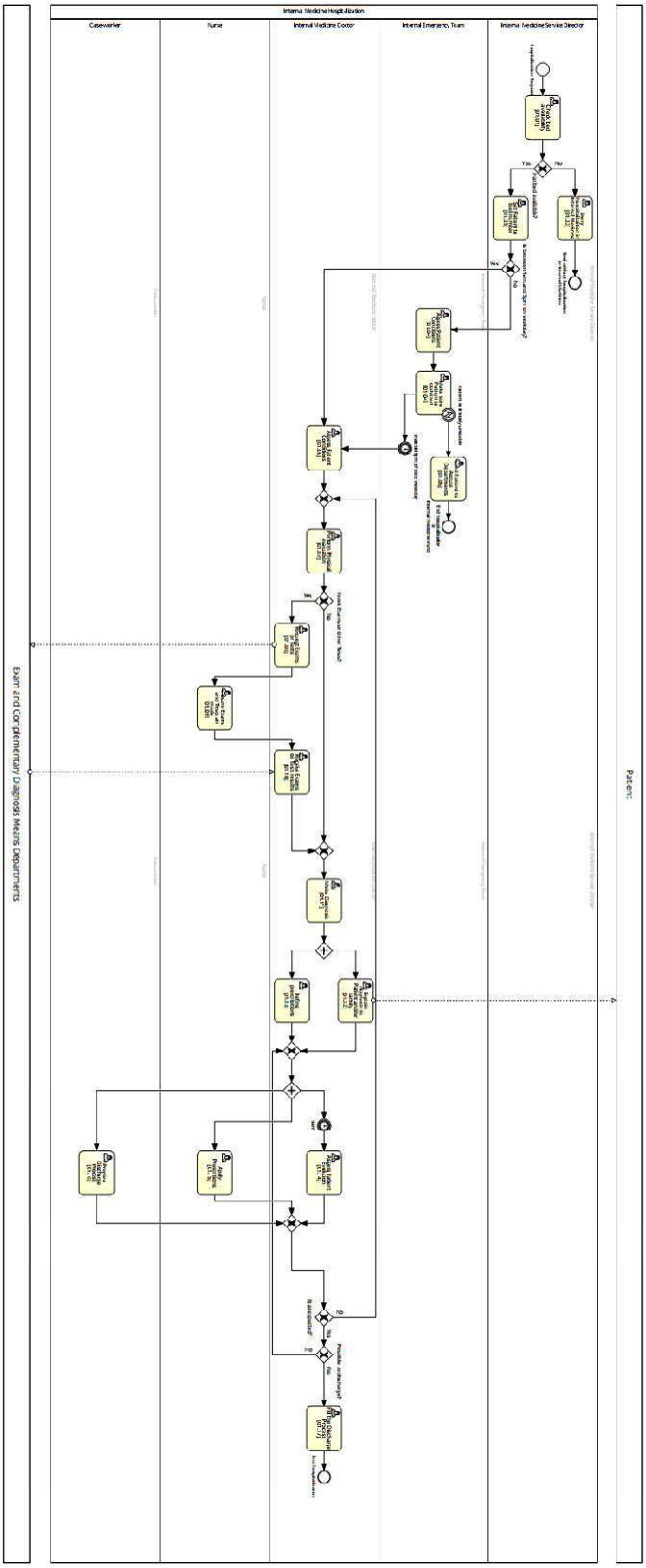
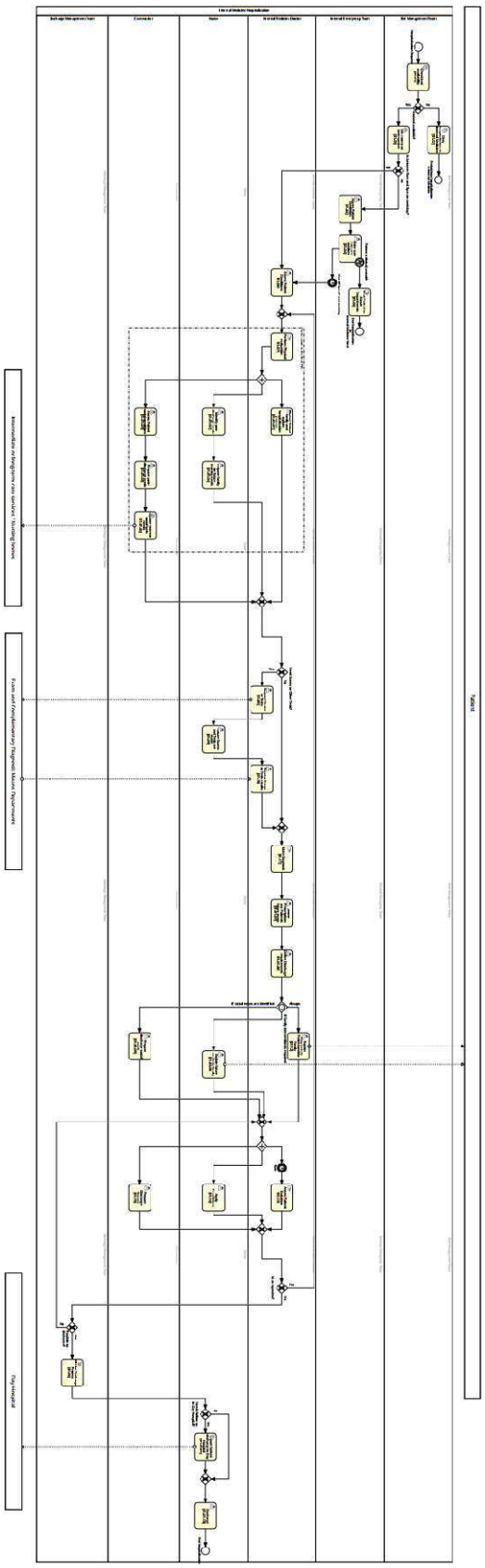
Appendixes

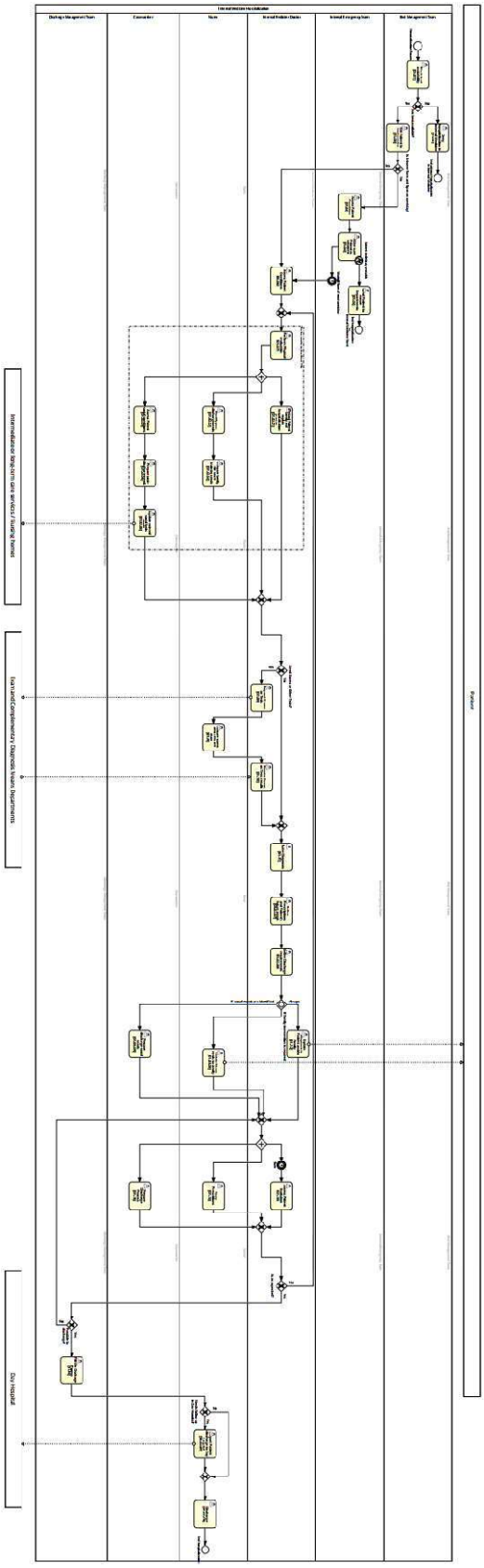
Appendix 1 - The "As-is" process of hospitalization in a Internal Medicine Ward.



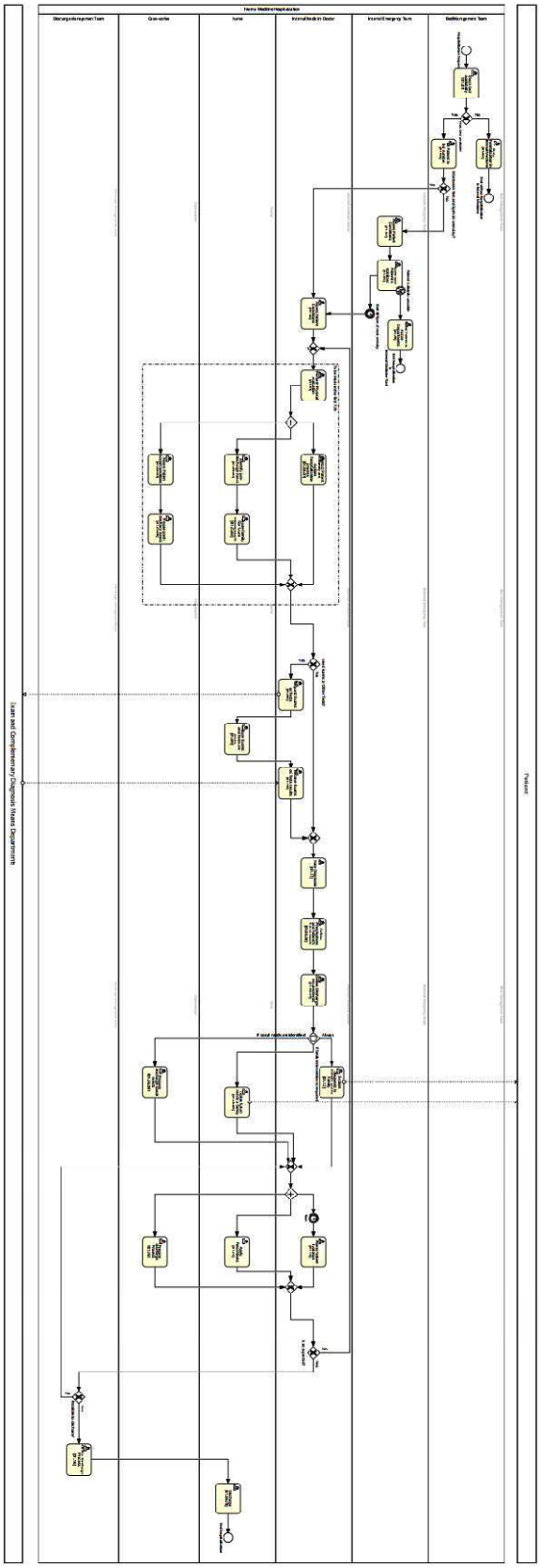
Appendix 2 - The "To-be" scenario 1 process of hospitalization in a Internal Medicine Ward.



Appendix 3 - The "To-be" scenario 2 process of hospitalization in a Internal Medicine Ward.



Appendix 4 - The "To-be" scenario 3 process of hospitalization in a Internal Medicine Ward.



Appendix 5 - Selected studies for literature review analysis.

ID	Título	Autores/Ano	Tipo	Fonte	Qualidade
01	Process mining in healthcare-An updated perspective on the state of the art	[52]	Jornal	Journal of Biomedical Informatics	Q1
02	How Can Interactive Process Discovery Address Data Quality Issues in Real Business Settings? Evidence from a Case Study in Healthcare	[47]	Jornal	Journal of Biomedical Informatics	Q1
03	Bpm support for patient-centred clinical pathways in chronic diseases	[48]	Jornal	Sensors	Q2
04	Succinct contrast sets via false positive controlling with an application in clinical process redesign	[49]	Jornal	Expert Systems with Applications	Q1
05	Study protocol: A cluster randomized trial to evaluate the effectiveness and implementation of onsite GeneXpert testing at community health centers in Uganda (XPEL-TB)	[62]	Jornal	Implementation Science	Q1
06	Support system for early diagnosis of chronic obstructive pulmonary disease based on the service-oriented architecture paradigm and business process management strategy: Development and usability survey among patients and health care providers	[63]	Jornal	Journal of Medical Internet Research	Q1
07	Agent-oriented Decision Support System for Business Processes Management with Genetic Algorithm Optimization: an Application in Healthcare	[50]	Jornal	Journal of Medical Systems	Q1
08	Improving Emergency Department Through Business Process Redesign: An empirical study	[51]	Jornal	Australasian Journal of Information Systems	Q2
09	Business Process Management for optimizing clinical processes: A systematic literature review	[13]	Jornal	Health Informatics Journal	Q2
10	Process redesign of a surgical pathway improves access to cataract surgery for Aboriginal and Torres Strait Islander people in South East Queensland	[53]	Jornal	Australian Journal of Primary Health	Q2
11	ValuedCare program: A population health model for the delivery of evidence-based care across care continuum for hip fracture patients in Eastern Singapore	[68]	Jornal	Journal of Orthopaedic Surgery and Research	Q2
12	Experimental application of Business Process Management technology to manage clinical pathways: A pediatric kidney transplantation follow up case	[54]	Jornal	BMC Medical Informatics and Decision Making	Q2

13	Have process redesign methods, such as Lean, been successful in changing care delivery in hospitals? A systematic review	[65]	Jornal	Public Money & Management	Q2
14	Absorptive capacity as a precondition for business process improvement	[55]	Jornal	Journal of Computer Information Systems	Q2
15	Evaluating and Improving the Perioperative Process: Benchmarking and Redesign of Preoperative Patient Evaluations	[64]	Conferência	2012 45th Hawaii International Conference on System Sciences	Qualis A1
16	Impact of hospital-wide process redesign on clinical outcomes: A comparative study of internally versus externally led intervention	[56]	Jornal	BMJ Quality & Safety	Q1
17	Impact of policy and process design on the performance of intake and treatment processes in mental health care: A system dynamics case study	[57]	Jornal	Journal of the Operational Research Society	Q2
18	Process Modelling (BPM) in Healthcare – Breast Cancer Screening	[58]	Conferência	International Conference on Human-Computer Interaction	Qualis B2
19	Towards a Business Process Management Governance Approach Using Process Model Templates and Flexibility	[69]	Conferência	2016 IEEE World Congress on Services	Qualis B2
20	A BPMN-based automated approach for the analysis of healthcare processes.	[66]	Conferência	2016 IEEE 25th International Conference On Enabling Technologies: Infrastructure for Collaborative Enterprises	Qualis B1
21	Optimization and planning of operating theatre activities: an original definition of pathways and process modeling	[59]	Jornal	BMC Medical Informatics & Decision Making	Q2
22	Standardisation of risk screening processes in healthcare through business rules management	[67]	Conferência	28th Bled eConference	ERA B
23	Mapping patient path in the Pediatric Emergency Department: A workflow model driven approach	[60]	Jornal	Journal of Biomedical Informatics	Q1
24	An application of business process method to the clinical efficiency of hospital	[61]	Jornal	Journal of Medical Systems	Q1