

# **Maturity model development to evaluate hospital services' readiness in disaster and emergency situations**

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**Industrial Engineering and Management**

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# **Declaração**

Declaro que o presente documento é um trabalho original da minha autoria e que cumpre todos os requisitos do Código de Conduta e Boas Práticas da Universidade de Lisboa.

# **Declaration**

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

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# Abstract

Hospitals play a critical role in providing essential medical care to their communities. Depending on their scope and nature, emergency situations can lead to a rapidly increasing services' demand that can overwhelm their functional capacity and the healthcare system at large. To address the lack of preparedness and potential severe failures it is necessary to understand the roots of inefficiency to prevent them and achieve the desired effectiveness' level, a domain where maturity models can provide valuable help.

By combining quantitative methods with more qualitative aspects, maturity models prove to be an intuitive tool to allow the creation of a continuous improvement path towards a structured and systematic way of doing business.

After verifying a gap on this technique applied to the emergency preparedness and management scope, this thesis aims at developing a maturity model over the foundations of reviewed renowned practices and applies it to a set of Portuguese hospitals, assessing their current status over nine key domains on this area.

Results allow managers to take consciousness of the disaster preparedness levels of their hospitals and serve as indicators about which processes to review, by following the proposals made.

This research sets a note for the future work to be performed in this area and presents contributes in help allowing to maintain the services' quality, reconciling the treatment of emergency-caused patients with the remaining clinical activity, and avoiding last-minute decisions that result in long waiting lists, unnecessary waste of resources, and, ultimately, helping save lives.

# Keywords

Maturity Models, Healthcare, Hospitals, Emergency Response, Continuous Improvement.

# Resumo

Os hospitais são instituições relevantes na prestação de cuidados médicos essenciais à comunidade. Dependendo da sua natureza, situações de emergência poderão levar a um rápido aumento da procura de serviços e consequentemente à sobrecarga da sua capacidade funcional, assim como do sistema de saúde em geral. Para colmatar a falta de preparação e falhas graves, é necessário compreender as raízes da ineficiência para as evitar e atingir a eficácia desejada, um domínio onde os modelos de maturidade podem fornecer uma ajuda valiosa.

Combinando métodos quantitativos (abordagens multicritério e análises estatísticas) com aspetos de natureza mais qualitativa, os modelos de maturidade provam ser uma ferramenta intuitiva capaz de cobrir as dimensões económicas e sociais deste sistema, conduzindo a um caminho de melhoria contínua.

Verificando-se lacunas na aplicação desta técnica ao âmbito da preparação e gestão de emergências, esta dissertação visa desenvolver um modelo de maturidade assente nos fundamentos propostos por autores renomeados na área e aplicá-lo a hospitais portugueses de forma a avaliar o estado atual em nove domínios-chave.

Os resultados atingidos permitem aos gestores avaliação dos níveis de preparação dos seus hospitais e servirão de indicadores sobre os processos a rever, seguindo as propostas apresentadas.

Este estudo pretende ser o início de investigações futuras, contribuir para a manutenção da qualidade dos serviços em tempos de stress, conciliando a resposta às emergência e restante atividade clínica, evitando decisões imponderadas que resultem em longas listas de espera, desperdício de recursos e, em última análise, ajudando a salvar vidas.

## Palavras-Chave

Modelos de maturidade, Cuidados de Saúde, Hospitais, Respostas de Emergência, Melhoria Contínua.

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# Acronyms

<b>BIMM</b>	Business Intelligence in Healthcare Maturity Model
<b>CHUC</b>	Centro Hospitalar e Universitário de Coimbra
<b>CMM</b>	Capability Maturity Model
<b>CMMI</b>	Capability Maturity Model Integration
<b>CMMI-ACQ</b>	Capability Maturity Model Integration for Acquisition
<b>CMMI-DEV</b>	Capability Maturity Model Integration for Development
<b>CMMI-SVC</b>	Capability Maturity Model Integration for Services
<b>DDSCM</b>	Demand Driven Supply Chain Management
<b>DGS</b>	Direção Geral da Saúde
<b>DSR</b>	Design Science Research
<b>DSRM</b>	Design Science Research Methodology
<b>eHMM</b>	Electronic Healthcare Maturity Model
<b>EP</b>	Emergency Plan
<b>ERP</b>	Enterprise Resource Planning
<b>EU</b>	European Union
<b>HCMM</b>	Hospital Cooperation Maturity Model
<b>HISMM</b>	Hospital Information Systems' Maturity Model
<b>HR</b>	Human Resources
<b>HRHCM</b>	High Reliability Healthcare Maturity Model
<b>HUMM</b>	Healthcare Usability Maturity Model
<b>INEM</b>	Instituto Nacional de Emergência Médica
<b>IPSS</b>	Instituição Particular de Solidariedade Social
<b>IS</b>	Information Systems
<b>ISACA</b>	Information Systems Audit and Control Association

<b>ISO</b>	International Organization for Standardization
<b>ISO/IEC</b>	International Organization for Standardization / International Electrotechnical Commission
<b>IST</b>	Information Systems and Technologies
<b>IT</b>	Information Technology
<b>KPI</b>	Key Performance Indicators
<b>ML</b>	Maturity Level
<b>MM</b>	Maturity Model
<b>MOU</b>	Memorandum of Understanding
<b>NGO</b>	Non-governmental Organization
<b>NHS</b>	National Health System
<b>NSR</b>	National Strategic Reserve
<b>PaCMM</b>	Patient-centeredness Maturity Model
<b>PACS</b>	Picture Archiving and Communication System
<b>PDCA</b>	Plan-Do-Check-Act
<b>PIO</b>	Public Information Officer
<b>PMM</b>	People Maturity Model
<b>PPE</b>	Personal Protective Equipment
<b>PRQ</b>	Primary Research Question
<b>QMMG</b>	Quality Management Maturity Grid
<b>RHA</b>	Regional Health Administration
<b>ROI</b>	Return on Investment
<b>SAP</b>	System Applications and Products in Data Processing
<b>SCAMPI</b>	Standard CMMI Appraisal Method for Process Improvement
<b>SEI</b>	Software Engineering Institute
<b>SKU</b>	Stock Keeping Units
<b>SNS</b>	Sistema Nacional de Saúde

<b>SOP</b>	Standard Operating Procedure
<b>SPICE</b>	Software Process Improvement and Capability dEtermination
<b>SRQ</b>	Secondary Research Question
<b>US</b>	United States

# 1 Introduction

Section 1.1, introduces the problem at hand and the motivation to study it, considering the Portuguese health system context. Later, in Section 1.2, the goals of this dissertation are enumerated. To conclude, the proposed structure and outline of the document are explained in Section 1.3.

## 1.1 Contextualization and motivation

It has been 40 years since the great reform of Sistema Nacional de Saúde (SNS), conceived by António Arnaut, took its first steps, bringing widespread, universal, and free access to health care to all Portuguese citizens.<sup>1</sup> Over time, along with the construction of new hospitals and health care centers, increasing diversity of organisms became part of this network, making it a subject of great complexity and, consequently, hindering its sustained management, which has been an easy target for several criticisms throughout the years.

As a large governmental unit, a strong leadership capable of dealing with an immense number of trade-offs is required, however, the present strategy focused mainly on the accounting issues and the reduction of financial expenses has led to chronic disorganization of all units, generating a general dissatisfaction of both personnel and citizens. Ironically, but undoubtedly, we can say: the Portuguese health system is severely ill.

Currently, the crisis generated by the Coronavirus, a highly contagious pathogen, has not only affected Portugal but the entire world. Citizens and organizations were forced to quickly adapt to a new reality by creating and following contingency plans that made it possible to assure the continuation of their daily activities. However, with new cases emerging every day, the Portuguese health and economic situation is not expected to improve any sooner.

The emergency situation generated by the current pandemic aggravated and exposed the weaknesses of a system that became critically overloaded under such pressure. It has been possible to witness difficulties inside the hospitals in providing an organized and concerted response to COVID-positive patients and other patients with different pathologies simultaneously. In the face of this blatant lack of resources, it is necessary to concentrate our attention on good management and coordination.

Hence, now that the COVID-19 pandemic has alerted us to the hSNS's (Hospitais do Sistema Nacional de Saúde) palpable needs, big investments are expected to arise in the upcoming years and, therefore, it will be necessary to design plans for improving the prioritization and readiness of responses to similar emergency situations. For this purpose, and because this system is enclosed by a huge set of bureaucratic rules and entrenched practices, we believe that a step-by-step approach, like the one provided by the maturity models - involving several continuous improvement techniques both quantitative, such as

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<sup>1</sup> Portal SNS: <https://www.sns.gov.pt/sns/servico-nacional-de-saude/historia-do-sns>, accessed on May 25<sup>th</sup>, 2021.

multicriteria methods and statistical analysis, and qualitative, such as Lean techniques and others – can bring measurable benefits.

The focus of maturity models has long since started to diverge from the initial purpose for which was created by Richard Nolan in the '70s (Caralli et al., 2012), the use in IT organizations, having been, since the emergence of the Capability Maturity Model (CMM), already applied to several fields in science and business management. Accordingly, the present thesis intends to continue this trend, by creating a model that can be applied specifically to our national health system context and, at the same time, address the shortcomings of the existing models in the health sector.

## 1.2 Goals

The present thesis aims to develop a maturity model to measure and improve the performance of the Portuguese healthcare units in the preparation and provision of their services during disaster and emergency situations.

Therefore, to accomplish the purpose of this thesis, we delineated the following objectives:

1. To intensively describe and contextualize the problem at hand and the goal of the project;
2. To elaborate a literature review, including an overview of the existing maturity models' background and history and the clarification of the key concepts and essential principles to follow during the development of a maturity model;
3. To elaborate the state-of-art and critical analysis of maturity models that target hospital units' management;
4. To develop a maturity model that accounts for objective and subjective criteria for each set of evaluation's dimension and maturity levels, considering the hospital context;
5. To perform a relevant data collection within three Portuguese organizations, to be evaluated using the developed maturity model;
6. To implement the model, to discuss the results of the assessment and, to establish improvement plans accordingly.

## 1.3 Structure

This thesis is structured as follows:

- **Chapter 1 – Introduction**

The background and contextualization of the studied problem, the motivation underlying the study, the goals to be achieved, and the structure of the dissertation is concisely presented.

- **Chapter 2 – Problem Definition**

An inside look at the functioning of the Portuguese national health system is taken in more detail, revealing relevant statistics concerned with hospitals' main resources. Some of the actions taken during the last emergency witnessed in the country are reported, reinforcing the usefulness of the present work. The Chapter ends with the listing of the research questions which will guide the development of the model.

- **Chapter 3 – Literature Review**

The background and history of maturity models are generically introduced, highlighting the most important ones to date. A collection of several designing, development, assessment and continuous improvement methods is presented. Special attention is paid to maturity models for healthcare purposes getting together several models to be compared and discussed, narrowing the scope of the work for the topic on which the following chapters will focus on. At the end of the Chapter, the research approach and future work are briefly summarized.

- **Chapter 4 – Model Development**

Following the maturity model design and development approaches reviewed in the literature, it is started an iterative process to create a new maturity model that encompasses areas of importance in the disaster preparation scope, addressing, this way the existent gap in this domain.

Capabilities essential for a cohesive preparedness and response to disaster are ascertained and levels' characteristics are defined, all together culminating in a maturity table.

- **Chapter 5 – Hospitals' Assessment**

Delimiting a boundary between the theoretical and the more practical component of the dissertation, an evaluation of the proposed artefact is performed by applying it to a set of real organizational scenarios to test and demonstrate the value of the artefact and how it addresses the research questions. A detailed description of the assessment process is provided, following the initiation, planning, briefing, data collection and validation, and results reporting phases.

- **Chapter 6 – Conclusions**

The work presented in this document is recapitulated and discussed, revisiting the path taken through the dissertation, as well as the limitations of the study and opportunities for future work.



## 2 Problem Definition

In this Chapter, the problem addressed by this thesis is analyzed. Starting by characterizing the country concerning its topography and demography, Section 2.1 takes the reader on a reflective path through the characterization of the SNS to the present year, when the pandemic made it undergone its greatest capability test. Some examples of actions taken by hospitals to deal with this emergency are presented, filling in the motivation for this work in the conclusions of Section 2.2.

### 2.1 NHS Characterization

Located in south-western Europe, Portugal has most of its territory located on the Iberian Peninsula, also including the Atlantic archipelagos of the Azores and Madeira, which are both autonomous regions. Although the country is covered by rivers and a large part of its border being bounded by the Atlantic Ocean, Portugal is still one of the warmest European countries, with both facts reflecting on the top disasters affecting its population over the last 30 years (European Union & Civil Protection, 2019).

According to the same document, from 1990 to 2019, the top 5 severe incidents that caused bigger damage and killed more people had to do either with extreme temperatures, wildfires, floods, or more recently COVID-19. Apart from the latter, the remaining events are all still classified as of high national exposure and can trigger life-threatening situations to which hospitals must be prepared to respond, as well as to others of medium happening probability such as earthquakes or tsunamis.

Given the unpredictability of these events, this is logically a cross-cutting issue for all countries, and an imperative subject to be addressed in the risk management of each country and, more specifically, of each hospital since it will be their responsibility to be in the front line of healthcare provisions when such emergencies occur. This is an especially important matter in Portugal given its demography, since it holds a population particularly vulnerable to these incidents, which might cause difficult-to-manage demands on these institutions at the time of response.

Portugal hosts about 10.3 million inhabitants, a number that has remained more or less constant in recent years. With a decrease in birth rate contrasted with the immense increase in longevity, this consistency in the total population number makes unnoticed the immense demographic transformations that have taken place in the country, and that lead it to rank amongst the most aged in the world, with 22% of its population over 65 years (PORDATA, 2020), only preceded by Japan (27%) and Italy (23%).

To fulfill the needs of the population, the Portuguese National Health Services (known as SNS) was created in 1979, materializing the right to the protection and provision of global health care, as well as access to all citizens, regardless of their economic and social condition. It comprises a set of public entities (primary care centers, hospitals, and continued and palliative care) financed mainly through taxation that, together with the social entities (the *Misericórdias* and other *Instituições Particulares de Solidariedade Social* (IPSS)) and private centers (consultations, diagnostic and therapeutic examinations, hospitals, and other private clinics), compose the overall Portuguese health system. These three overlapping providers

are regulated at a central level by the Ministry of Health, while the management of the SNS occurs at the regional level, through five regional health administrations (RHAs) whose autonomy over budget setting and spending is limited to primary care (OECD, 2017).

It is expected that countries with demographic trends displaying a progressive ageing and, therefore, more susceptible to increased strain in health services, are those that make the largest investments in this area. However, the statistics seem to indicate otherwise. Immediately after the 2011 economic recession, the public health expenditure has witnessed a twofold reduction, namely in personnel and in capital expenses (Varanda et al., 2020). This necessity to implement cost contingency measures represents one of the main challenges that still exist today, which is to reconcile the insurance of SNS financial sustainability while still both maintaining the response capacity and improving underserved areas, such as mental health, dental care, and palliative care.

If, on one side, the number of physicians registered in 2017 (or the nearest year) was above the EU average (about 512 to 374 per 100.000 population), the situation relating to nursing staff is quite different. Although Portugal has steadily increased the nurses to inhabitants ratio, in that same year, the relative number of nurses was still way below the EU average (697 to 931 per 100.000 population), according to OECD (2021). Hospital beds are also a sensitive area. The number of intensive care beds, which is considered a crucial asset for the successful response to an outbreak is also underrepresented (345 to 459 per 100.000 population). Regardless, the Portuguese NHS is still ranked among the best in the world. <sup>2</sup>

The existing soft spots were put to a test in 2020. Upon the surge of the COVID-19 pandemic, the time lag between the first case detected in China (December 1<sup>st</sup> 2019) and the first case in Portugal (March 2<sup>nd</sup> 2020), and also later than Italy and Spain, might have acted as a buffer for the initial impact of the epidemic, giving the Portuguese government time to implement the necessary preventive measures (Varanda et al., 2020). Despite the various problems pointed out, a good response to the first wave fueled a sharp confidence increase in the SNS up to 71% of the population (ICS/ISCTE, 2020) when compared to the 45% of 2010 (Varanda et al., 2020).

Despite all the difficulties in dealing with an emergency that no country was prepared for, Portuguese hospitals have responded well from the start, even though the first quarter of 2021 made everyone in the SNS fear the worst. The following Sub-sections report some of the actions taken to handle this emergency.

### **2.1.1 At the birth moment: present or absent father? Depends on the maternity**

In the beginning, with no clear and comprehensive guidelines on how to act in maternities, each hospital started to define its own rules regarding escorts. In both maternities of Coimbra and Santa Maria da Feira, for example, the orders were of forbidding access to companions, while in Alfredo da Costa and São João, oppositely, it was possible to do it. <sup>3</sup>

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<sup>2</sup> Portal SNS: <https://www.sns.gov.pt/noticias/2016/09/23/portugal-no-22-o-lugar-do-ranking/>, accessed on April 13<sup>th</sup>, 2021.

<sup>3</sup> Expresso: <https://expresso.pt/coronavirus/2020-03-30-Covid-19.-No-momento-de-nascer-pai-presente-pai-ausente--Depende-da-maternidade>, accessed on April 13<sup>th</sup>, 2021.

Several measures continued to be discussed while COVID-19 cases soared, from increased testing to the creation of separated areas for infected and non-infected women. On March 30<sup>th</sup>, an order was published regarding this issue, which was changed during 2020 (Freitas, 2020), without hearing or consulting of obstetric specialists. Even so, some of the decisions in this regard are still left to the hospitals, depending on their capacity and facility conditions.

### 2.1.2 Ambulances' overflow

In the early morning of January 29<sup>th</sup>, 2021, almost 30 ambulances were parked outside the emergency rooms of Hospital de Santa Maria, waiting for vacancies to deliver patients. According to the emergency director, there was no information about the condition of the patients that were being brought in. Some lack of upstream control and reference was making the process difficult, and only later in that afternoon, with a new system of pre-screening tents provided by the INEM and Civil Protection, it was possible to start delivering patients. <sup>4</sup>

While in other hospitals in the country the situation was identical, Hospital de São João represented the extreme opposite. The internal medicine director reported that the winter planning of previous years, together with the lessons learned since the beginning of the pandemic, led to the conclusion that the answer was not necessarily to work harder, but differently, <sup>5</sup> which reflected in the capability of response in the face of the new overflow.

Although the fast adaptation capacity of central hospitals was praised, the discrepancy in capability compared to the north was highlighted, as well as the doubt as to whether the uncontrolled moments could have been avoided with timely planning, as it happened in the latter.

### 2.1.3 Patients' transfer

Almost one year after the first case appearance, on January 19<sup>th</sup>, 2021 there were still no structured plans to hire more health professionals or transfer patients across borders. <sup>6</sup> With the adoption of these measures by other European countries, this hypothesis began to be considered and eventually carried out a few days later on January 29<sup>th</sup>, with three critical patients being flown to Madeira. <sup>7</sup> Later, on February 5<sup>th</sup>, another ten were flown to Austria. <sup>8</sup> These actions were subject to discussion since the reasons for not accepting the help from Spain, which had also volunteered to receive Portuguese patients, are still unknown. At first

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<sup>4</sup> Público: <https://www.publico.pt/2021/01/29/sociedade/noticia/hospital-santa-maria-tendas-pretriagem-aliviam-fila-ambulancias-ha-dezenas-doentes-espera-internamento-1948545>, accessed on Abril 13<sup>th</sup>, 2021.

<sup>5</sup> Observador: <https://observador.pt/especiais/menos-doentes-mas-em-estado-mais-grave-e-mais-novos-no-hospital-de-sao-joao-a-situacao-esta-sob-controlo-ainda-avisam-os-medicos/>, accessed on Abril 13<sup>th</sup>, 2021.

<sup>6</sup> Rádio Renascença: <https://rr.sapo.pt/2021/01/19/pais/covid-19-portugal-sem-planos-para-transferir-doentes-para-o-estrangeiro/noticia/223127/>, accessed on Abril 13<sup>th</sup>, 2021.

<sup>7</sup> Portal SNS: [https://www.inem.pt/2021/01/31/inem-colabora-em-transferencia-de-doentes-covid-19-para-a-madeira/?utm\\_source=rss&utm\\_medium=rss&utm\\_campaign=inem-colabora-em-transferencia-de-doentes-covid-19-para-a-madeira](https://www.inem.pt/2021/01/31/inem-colabora-em-transferencia-de-doentes-covid-19-para-a-madeira/?utm_source=rss&utm_medium=rss&utm_campaign=inem-colabora-em-transferencia-de-doentes-covid-19-para-a-madeira), accessed on Abril 13<sup>th</sup>, 2021.

<sup>8</sup> Jornal de Negócios: <https://www.jornaldenegocios.pt/economia/coronavirus/detalhe/covid-19-governo-confirma-opcao-de-transferencia-de-10-doentes-para-a-austria#loadComments>, accessed on Abril 13<sup>th</sup>, 2021.

sight, this alternative would seem to be of less complex logistics and with less risk for the critically ill patients (in this case even ventilated), who could have been transported overland.

## 2.2 Chapter Conclusion

The present pandemic had undoubtedly represented the greatest challenge to the SNS since its creation. Following this stormy period of difficulties, one of two possible situations will be expected to unfold:

Firstly, the abnegation proven by many health professionals will reinforce the credibility of the SNS and the need to implement policies focused on them and their working conditions. It is important to reinvent attractive careers that no longer require extra hours to overcome operational service needs, where changes will also be required, namely in preparation for future identical scenarios. On the other hand, Portugal is expected to be amongst the most affected in the post pandemic era, owing to the major drop in tourism revenues that play a high contribution to the economy. Considering lower economic growth rates, the health system may become, once again, a target for cost containment in the long run (Shaaban et al., 2020).

In either case, this can be viewed as an opportunity to address solutions related to this theme. Taking into account that there is not an absolute reference to hospital performance (Oliveira & Ferreira, 2014, p. 709), tools that allow hospitals to prioritize the areas of improvement for a good redirection of investments are valuable. Here, maturity models can come in as a simple-to-understand tool that, additionally through benchmarking, will help to eliminate the discrepancies in responses, establishing, for several areas, a path for improvement and a capability standard for the several Portuguese hospitals.

To meet the pointed goals, it will first be necessary to divide the work to be done in research questions to be explored in the next Chapter, which will give guidance on the path to follow for the model development. Therefore, the primary research question (PRQ) is: How can the capability of the Portuguese hospitals (belonging to the Serviço Nacional de Saúde) to act in response to disaster and emergency situations be assessed?

The primary research question can be, however, broken down into secondary research questions to identify the key points that could support the fulfillment of the research goals mentioned in Section 1.2:

- SRQ1: How can a maturity model be used as an assessment and guidance tool to the development of roadmaps for process improvement?
- SRQ2: Are there maturity models focused on hospital units' management? If yes, do they follow the best practice for its development described in the literature?
- SRQ3: Are there maturity models that address disaster/emergency scenarios?
- SRQ4: Which are the key success factors that allow the achievement of adequate preparedness and response during emergencies in the Portuguese context?
- SRQ5: What are strengths and weaknesses of maturity models to improve readiness in disaster and emergency situations?

# 3 Literature Review

This Chapter, provides a theoretical perspective on the several fundamental components of the maturity models that will underlie the present work.

In Section 3.1, the background and history of both maturity models and assessment techniques is presented. Next, Section 3.2 refers to the maturity models' most basic terms, from a structural point of view, ending with an enumeration of the various benefits and criticisms that accompany this method. Section 3.3 focuses on making known two of the most popular works in this field – the CMMI and the ISO/IEC 330xx family. Section 3.4 gathers frameworks from several authors on the most important steps to follow during the design process, followed by Section 3.5 which goes by the same procedure regarding the development phase. In Section 3.6 a distinction between the different assessment methods is made, highlighting two of the most extensive ones, the ISO/IEC 33030 and SCAMPI, while Section 3.7 addresses the ISO/IEC 33014 improvement method. The Chapter ends with the current state of the art analysis and discussion about maturity models for healthcare, in Section 3.8, followed by the future work's summarization in Section 3.9.

## 3.1 Background and History

This Section focuses on the emergence path of the maturity models and their appraisal techniques up until the present day. The most relevant milestones during this period are highlighted, helping to contextualize this study and its relevance.

### 3.1.1 The emergence of maturity models

The beginning of the maturity model's history reports back to 1973, when Richard Nolan, while at Harvard University, proposed a staged maturity model which was recognized as a highly innovative technique for Information Systems and Technologies (IST). Based on the identification of the current characteristics of an organization, the model allowed to create a scale for the appraisal of its position in the evolution path, by providing criteria, and requirements to be fulfilled to reach each next particular level (Becker et al., 2009; Caralli et al., 2012). In 1979, Philip Crosby began to extend the fields of application of this new methodology with his Quality Management Maturity Grid (QMMG), one of the first in this area to assess quality maturity and to highlight the importance of the human factor in organizations (Albliwi et al., 2014).

Fast-forwarding to 1991, the popularity of maturity models was especially intensified with the presentation of a modified version of the CMM, which was firstly designed by Watts Humphrey to apply it to the US Department of Defense to improve contractors' selection techniques, but it evolved to a more general set of concepts that allowed its use in non-software institutions (Caralli et al., 2012; Rout et al., 2007).

The CMM and other derived models' expansion continued with the immense economic and technological upheaval of the '90s and early '00s. Organizations felt the urge to follow this emerging wave that required them to retain competitive advantages and, therefore, constantly reinvent products and services to keep up

with market trends while reducing costs and improving quality, for which this approach proved to be very useful. With continuous developments in this area, the CMM eventually was surpassed by the Capability Maturity Model Integration (CMMI) in 2000, according to the CMMI Institute.<sup>9</sup> By comprising several modules of software engineering - processes engineering and development (CMMI-DEV), systems acquisition (CMMI-ACQ), and service delivery (CMMI-SVC) - in a single model with a shared core (Caralli et al., 2012), its 2010 version allowed the organizations to focus on a specific area and apply each module according to their needs and priorities, avoiding time-consuming procedures and unnecessary investments in generalized processes that don't quite match the key areas of improvement.

Now, almost thirty years since the Software Engineering Institute (SEI) has launched the CMM, continuous improvement still occupies a top position on the organizational agendas and hundreds of maturity models keep being proposed by researchers and practitioners across multiple application domains.

### 3.1.2 Assessment Techniques' origin

Aligned with the evolution of maturity models, there was also the emergence of approaches for its appraisal. Back at the beginning of the '90s, the growth in popularity of the International Organization for Standardization (ISO) was becoming evident, driven by the launch of the ISO 9000, in 1987, which achieved enormous success becoming one of the most popular and sold ISOs. Good results stemmed from these standards usage that, with the increasing use of the technique in commercially-sensitive areas, motivated the development of an International Standard for software process assessment, as it is in the CMMI's case, as well as the emergence of innumerable other initiatives within the software engineering community (Barafort et al., 2017).<sup>10</sup>

In 1993, the SPICE (Software Process Improvement and Capability dEtermination) project came up, launching the ISO/IEC 15504, a systematized approach that became pivotal in the establishment of the basic requirements for performing process assessment and shaping similar projects in the area. One example was SCAMPI (Standard CMMI Appraisal Method for Process Improvement) in 2001 (Rout et al., 2007), destined to provide benchmark-quality ratings specific to CMMI models, or others of a broader nature that have been replacing it, such as the ISO/IEC 330xx family, which counts already with several versions and it is subject of periodic reviews up to the present day.

## 3.2 Fundamental Concepts

This Section is a short introduction to maturity models and their approach to helping in organizations' improvement. Sub-section 3.2.1 begins with a discussion of general maturity model principles followed by Sub-section 3.2.2 which provides examples of the most mentioned strongpoints and shortcomings found in the literature regarding this topic.

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<sup>9</sup> CMMI Institute: <https://cmmiinstitute.zendesk.com/hc/en-us/articles/360025569473-History-of-CMMI>, accessed on January 1<sup>st</sup>, 2021.

<sup>10</sup> ISO: <https://www.iso.org/the-iso-story.html#12>, accessed on January 1<sup>st</sup>, 2021.

### 3.2.1 General principles' overview

Maturity models have proven to be an important tool, allowing better organization positioning, and helping to find better solutions for change by deriving and prioritizing them and, subsequently, controlling the progress of their implementation.

Several authors have defined maturity. Proença (2018) compares it with the condition of chemical equilibrium in a chemical reaction, and to “a state in which, when optimized to a particular context, is not advisable to proceed with any further action”. Mettler (2014) states that maturity is related with the evolutionary progress in demonstrating a specific ability or the pursuit of a certain goal, from an initial to a desired or normally occurring stage, which Tonini et al. (2008) classifies as a “moving target” dependent of the market, business, and people. Still, Amaral and Araújo (2008) emphasize the existence of various paths to achieve this state of perfection, depending on the indicators measured by each organization.

However, to know how to draw a roadmap for improvement it is necessary to begin by acknowledging the organization's present condition (as-is situation) and, accordingly, to define the goals to achieve. It is, then, crucial that the first step in a plan for change lies in raising the company's awareness about its capabilities and quality of its assets and services, which requires a comparison with the external requirements, as well as benchmarks (Becker et al., 2009). This state defines the starting point and therefore represents the bottom stage in the evolution path provided by the maturity model, in which the company still has little mastery of capabilities.

From that point on, it is possible to establish an initial structure for the maturity model as it is known, composed by **attributes**, an expression of characteristics, indicators, or practices that compose the current state, grouped into diverse areas of importance (**domains**) that constitute the different **levels** (usually four to six) that make up the sequential path to the desired state: the top level of total maturity (Caralli et al., 2012). It is important to emphasize that, according to Röglinger and Pöppelbuß (2011), throughout the formulation process, the logical relationships between successive stages in a **descriptive**, **prescriptive**, or **comparative** way should be properly clarified. This allows to satisfy the several application-specific purposes of maturity models and to avoid an overly discrete nature that could result in an unclear representation of the continuous maturity path or how to go through it.

This structure allows the organization to have its **processes**, **objects** (products) and **people** evaluated iteratively against important standards, and to determine how well it is performing in carrying out the appropriate improvements in each particular state, which will enable the achievement of the subsequent one (Caralli et al., 2012).

### 3.2.2 Strong points and shortcomings

Despite the clear added value of this methodology to organizations already presented throughout this document, we decided to deepen further on this topic, by making a more extensive survey concerning the different benefits vs. limitations of maturity models. The following bullet points summarize the research made

along different papers from Caralli et al. (2012), de Bruin et al. (2005), Gomes et al. (2013), Uslar and Masurkewitz (2015), and Levin and Skumolski (2000).

#### **A. Benefits**

- Allows benchmarking the internal performance with different specialization degrees within the organization: it is possible to make the organization's assessment as a whole or of the more detailed aspects in each department, even allowing them to be compared with each other when common conditions exist;
- Allows benchmarking with other organizations in similar areas of knowledge, as well as establishing a "community" performance profile which may stimulate cooperation between peer organizations in finding solutions for common and shared challenging problems;
- Allows to perform uniform documentation during the evaluation process that can be later used both to promote better internal coordination and to improve communication with external parties and stakeholders concerning the company's current state;
- Identifies and understands the evaluated areas' bottlenecks more efficiently and their relationships and influences upon different domains, for better channeling of investments in the critical fields of improvement;
- Allows all involved employees to have a better understanding of the method through a step-by-step procedure that eases change implementation;
- Allows a somewhat consistent structure that can be easily adapted and replicated in different parts of an organization (or even to other entities), functioning as a good tool for standardization of best practices and promoting a better global acceptance of the developed model;
- Provides a framework that enables the organizations to increase their capability to deliver projects on schedule, within budget, and according to the desired technical performance, being this way able to cope with customers' expectations.

#### **B. Drawbacks and Criticisms**

- Some maturity models do not present good theoretical foundations and empirical evidence for their specific context, and are based on approaches that worked for different organizations (sometimes from different industry sectors) or in software maturity models that lack the same aspects;
- Maturity models tend to oversimplify reality and have limited flexibility, sometimes relying on the assumption that different organizations have the same progression, or neglecting the existence of multiple equally advantageous paths for improvement;
- Maturity models do not provide a procedure to configure the model to match new constraints that may arise from internal and external factors (available technology, customer and supplier relationships, market conditions, etc.), which may compromise its applicability;



- Most of the work regarding maturity models does not provide a way of routinizing its assessments nor address the topic of how to adapt the model over time.

### 3.3 Most well-known Maturity Models

Since its emergence, it has been possible to witness the tremendous importance of the role played by the CMM and CMMI in the maturity model's history. Those first models established, to a great extent, the foundations for the development of more recent ones, and encouraged the development of international assessment standards, where ISO/IEC 330xx family of standards takes prominence as a more generalized assessment technique aimed for the iterative model improvement process. The following Sub-sections explore in more detail the fundamentals of both these models.

#### 3.3.1 CMMI

Although firstly released in 2000, it was not until Version 1.3, made available in October 2010, that the biggest innovations to this model became relevant. This version comprised a more uniform and interconnected junction of several different modules for distinct purposes, which had started to be developed and improved separately until this date. Version 1.3 also included updates in the appraisal (SCAMPI) and training methods (Phillips & Shrum, 2010).

Currently, the CMMI is in its Version 2.0 (released in March 2018) and is presented as “an integrated product suite consisting of 5 components that, when used together, provide a clear and proven path to achieving the desired business objectives” (ISACA & CMMI Institute, 2020b, p. 1), in a certain way, resembling an ERP (Enterprise Resource Planning) system in its structure, but with a more specific scope.

The modules that previously made up the V1.3 also acquired new names in V2.0, with CMMI-DEV changing to CMMI Development, CMMI-SVC to CMMI Services, and CMMI-ACQ giving way to CMMI Supplier Management.

Continuing the previous version's work, the CMMI V2.0 still includes most of the older version capabilities but has proven to be much more complete, due to the addition of a few more applications (ISACA & CMMI Intitute, 2020). It exhibits:

- A **model** with a pathway to performance improvement;
- An **appraisal method** with increased reliability, while reducing overall costs;
- A more objective-oriented learning form for **training & certification**, including virtual and in-person options;
- An **Adoption Guidance** to help early users to get started and/or even to provide a smoother transition from CMMI V1.3, in case it had been previously adopted;
- A redesigned **System & Tools** providing access to online models and resources.

Moreover, it also stands out from the previous model by using tangible business performance results, demonstrating the impact of its implementation through financial indicators (pointing out the ROI), by including more non-technical language that facilitates its understanding, and by taking into account new emerging trends such as Lean methods, sustainable practices and a prominent focus on supporting an innovative culture (CMMI Institute, 2019a).

This maturity model recognizes two distinct representations - **continuous** or **staged** - that a company can choose to adopt, depending on its business goals. These differ in their way of evaluating a company's system and are a particularity solely and exclusively of the CMMI.

The CMMI is composed of **process areas** which, independently, are groupings of processes/practices for a common goal. The staged representation matures the organization as a whole, using predefined sets of process areas to form an improvement path characterized by **maturity levels**. The continuous representation allows to mature different individual process areas at disparate rates, according to **capability levels** (Chrissis et al., 2004). The advantages of each representation according to Cepeda (2005) are summarized in Table 1.

*Table 1 - Advantages of each representation (adapted from Cepeda (2005))*

Continuous Representation	Staged Representation
<ul style="list-style-type: none"> <li>• More flexibility for prioritizing process improvements and aligning them with business objectives;</li> <li>• Increased visibility of improvement in each process area;</li> <li>• Allows to identify and focus on risks specific to each process area;</li> <li>• Less upfront investment might be required.</li> </ul>	<ul style="list-style-type: none"> <li>• Predefined and proven path with a case study and ROI data;</li> <li>• Focuses on organizational improvement;</li> <li>• Overall results summarized in a maturity level;</li> <li>• Provides familiar benchmarking capability (normally used to qualify bidders).</li> </ul>

The model is divided into 5 maturity levels with 25 process areas (Albliwi et al., 2014), starting from Level 0 “Incomplete” that represents an ad hoc and unknown state, progressing to Level 5 “Optimizing”, which characterizes a stable and flexible organization with the ability to act swiftly and respond innovatively towards adversities.

It also has 3 capability levels, going from Capability Level 0 “Incomplete”, which illustrates an inconsistent performance of a process area, to Capability Level 3 “Defined”, where a process area focuses on achieving both project and organizational performance objectives.

Several case studies provided prominent evidence and very promising results, namely from Dynanet enterprise (ISACA, 2020) or Wipro (CMMI Institute, 2019b), which, in addition to other successful cases, allowed to gather a set of relevant statistics that are shown on the official ISACA website. <sup>11</sup>

<sup>11</sup> ISACA: <https://cmmiinstitute.com/cmmi> , accessed on January 6<sup>th</sup>, 2021.

Another salient feature is the easiness and intuitiveness with which companies can consult the ISACA's website, and that presents possible difficulties that they could be facing. Depending on the issue at hand, this website can constitute a primary source of advice on which module is the most appropriate for their case.

### 3.3.2 ISO/IEC 15504 and ISO/IEC 330xx family

The initial version of the ISO/IEC TR 15504 was first published in 1998 as a Technical Report. Later, during its refinement period, the ISO institute study groups shared a common opinion that there were still many aspects to be improved. Besides a clear need to reduce the Standard overall size, it was imperative to increase its flexibility and expand its scope of application to make this approach suitable to any kind of process, whatever the type and proportion of organization. Therefore, a new version arose, the ISO/IEC 15504, which, while being reduced in complexity, provides a mechanism for harmonizing different approaches to assessment (Rout, 2003).

Continuous research has led to the most recent update in 2014, which began to replace the ISO/IEC 15504 family with the ISO/IEC 330xx, that encompasses new measurement frameworks, addresses domains other than process capability, and that withdraws several unnecessary parts from the previous version (Barafort et al., 2017).

While there have been substantial changes, a big part of the new standards composing the ISO/IEC 330xx family still matches related ISO/IEC 15504 documents (Table A.1 in Appendix A). The ontology proposed by the latter allows it to be modified to meet the requirements of the newest version standards and some of the underlying concepts even can be viewed as still valid (terminology, vocabulary, and the process assessment model).

Figure B.1 in Appendix B depicts the overall structure of the ISO/IEC 330xx family of standards. It divides the domain of process evaluation into three components, each composed of a set of principles, its basic elements, and illustrative examples for its appliance. According to ISO/IEC (2015a) these components are:

- **Assessment Process**, that describe in detail the stages to be followed to conduct the appraisals;
- **Measurement framework**, that provides scales for evaluating specified characteristics (as capability) of the processes;
- **Process models**, that define the processes and the entities subject of evaluation.

## 3.4 Design Principles of Maturity Models

The development of maturity models is perceived as a matter of design science research by some IS (Information Systems) researchers (Becker et al., 2009; Mettler & Rohner, 2009). According to Turban and Aronson (2001), design theories also give prescriptions for the architecture of specific applications, in which decision support systems are included and, consequently, maturity models.

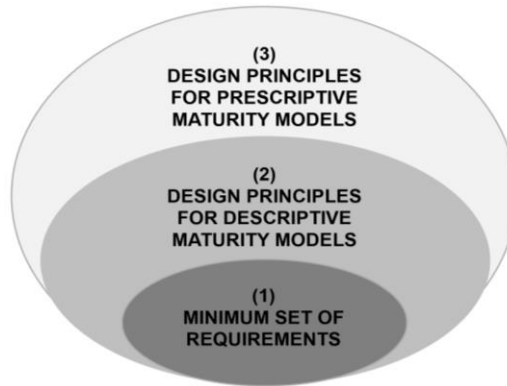


Figure 1 - Design principle requirements (adapted from Röglinger and Pöppelbuß (2011))

However, this subject has been rather neglected. Little attention has been paid to design theories and their communication, justification, and development, leading to the enduring under-explanation of some major issues in this field, which can be acknowledged by the small number of papers found in this matter when compared with other topics within the same area. This complicates further the search for a design that could optimally suit the developing model, forcing the adoption of satisfactory/suboptimal solutions that, even so, are often difficult to determine. Despite these difficulties, since the design process affects the final design of the model and, consequently, its “success”, it is important to ensure that it is adequate and aligned with the structure and purpose of the organization (Jones & Gregor, 2007; Simon, 1996), an issue that this Section will address.

Table 2 - Maturity models' requirements (adapted from Tonini et al. (2008))

Generic Requirements	Specific Requirements
Abstraction: encompasses a broad set of aspects.	Relevance: highlights the value-added elements of the organization.
Dynamic: allows for adaptations and customizations.	Opportunity: allows to identify and take on new business opportunities.
Systematic: provides a methodical and standardized course of action.	Specificity: takes into account particular characteristics of the organization.
Traceability: enables a retrospective analysis to identify strengths and vulnerabilities.	Viability: supported by a positive benefit-cost analysis.

The design process is perceived as one of the four development phases of maturity models. It focuses mainly on identifying and defining the artifacts or objects that should be present in the model and it depends on its nature as de Bruin et al. (2005) and Röglinger and Pöppelbuß (2011) describe:

- **Descriptive models:** a maturity model is descriptive if it is intended to identify and evaluate a company's current capabilities (as-is situation) to assign it a maturity level, without providing a path for improvement.

- **Prescriptive models:** a maturity model is prescriptive if it identifies desirable maturity levels as well as the appropriate measures to follow to attain it, considering the current state and while emphasizing the relationships between different domains.

Table 3 - A detailed framework of maturity model's design principles (adapted from Röglinger and Pöppelbuß (2011))

Group	Design Principles	
<b>(1) Minimum Requirements</b>	<b>1.1</b>	<b>Basic information</b> <ul style="list-style-type: none"> <li>I. Scope contextualization and prerequisites for applicability</li> <li>II. Purpose of use</li> <li>III. Target group</li> <li>IV. Class of entities to be investigated</li> <li>V. Comparison and distinctions from relevant models in the same area</li> <li>VI. Design and empirical validation process' explanation</li> </ul>
	<b>1.2</b>	<b>Definition of central constructs associated with the maturity path</b> <ul style="list-style-type: none"> <li>I. Maturity and maturity dimensions</li> <li>II. Maturity levels, their correspondent relationships and improvement path</li> <li>III. Levels of detail (granularity) to which the studies will be performed</li> <li>IV. Theoretical support means</li> </ul>
	<b>1.3</b>	<b>Definition of central aspects related to the application domain</b>
	<b>1.4</b>	<b>Target group related documentation</b>
<b>(2) Descriptive</b>	<b>2.1</b>	<b>Precise, concise, and clear criteria for each maturity level</b>
	<b>2.2</b>	<b>Assessment methodology focused on the target group</b> <ul style="list-style-type: none"> <li>I. Procedure model</li> <li>II. Guidance on the criteria's assessment process</li> <li>III. Recommendations on how to configure and adapt the criteria</li> <li>IV. Expert feedback from previous similar applications</li> </ul>
<b>(3) Prescriptive</b>	<b>3.1</b>	<b>Improvement measures for each maturity level</b>
	<b>3.2</b>	<b>Quantitative (calculus) based foundation for improvement measures' selection</b> <ul style="list-style-type: none"> <li>I. Explanation of relevant objectives</li> <li>II. Explanation of relevant influencing factors in the model's performance</li> <li>III. Distinction between external and internal perspectives of improvement reporting</li> </ul>
	<b>3.3</b>	<b>Decision methodology focused on the target group</b> <ul style="list-style-type: none"> <li>I. Procedure model</li> <li>II. Guidance on the variables' assessment process</li> <li>III. Recommendations on how to accomplish and adapt improvement measures</li> <li>IV. Advice on how to configure and adapt the decision calculus</li> <li>V. Expert feedback from previous similar applications</li> </ul>

- **Comparative models:** the maturity model is developed as a comparison technique, allowing for both internal and external benchmarks, i.e., concedes the possibility not only to compare an organization's capabilities against a set of criteria but also against other business units, by analyzing similar practices even across disparate industries. A comparative model also recognizes that similar levels of maturity in different corporations may not equal similar levels of business value.

According to Figure 1, it is possible to realize that the Minimum Set of Requirements should be addressed independently of the models' nature and, therefore, are common to both Descriptive and Prescriptive models. The number of specific requirements increases as the model evolves to a broader character and the Prescriptive, being the most complete and complex, must meet all the requirements previously imposed. Only in the last one, the principles related to improvement measures and their evaluation, are taken in consideration.

The issue of having different additional Design Principles considering the model's nature was not exclusively addressed by Röglinger and Pöppelbuß (2011). Tonini et al. (2008) also mentions this question by specifically distinguishing the basic/generic principles that should be met by all maturity models, from the most specific ones, that should be adapted to each organization that will use it (Table 2).

Röglinger and Pöppelbuß (2011) also intensively describe each requirement that a generic maturity model should comply with, once again, according to its nature (Table 3).

### 3.5 Development Methods of Maturity Models

Due to its interconnection, it is very easy and common to confuse design with development. Most papers do not distinguish both concepts. While the Design focuses more on defining what the maturity model should have, concentrating on its artifacts and objects, and being one of the inherent stages of the development process, the Development is mainly about defining what steps to take to construct and evolve a maturity model, i.e., the process itself. Thus, the discipline of Design Science Research (DSR) seems to serve not only as direct support in finding and meeting the requirements that make up the model's design, but also to help in its development, as suggested by Hevner et al. (2004) and Becker et al. (2009). The latter establishes eight requirements schematized in Figure 2.

- R1: A **comparison with previously existing models** is required, to decide whether to create or adapt an existing one to the systems' needs, complementing it and rectifying its gaps;
- R2: **Iterative procedures** are adopted to refine the model step-by-step accordingly to the emergence of new data;
- R3: An **evaluation** of all the development constructs, namely to the principles, quality, and effectiveness of the artifacts should be made iteratively;
- R4: A **multi-methodological procedure** must be carried out and accompanied by a good foundation and attunement;

- R5: An exact **identification of the problem and its relevance** to those involved (researchers and/or practitioners) must be demonstrated through scientific methods;
- R6: A **problem definition** should be made, highlighting the model's application domain, the conditions for its application, and potential benefits;
- R7: **Targeted presentation of results** to specific user groups on whom the model will impact and considering the application constraints;
- R8: **Scientific documentation** is required, registering and clearly explaining all the followed procedures to reach the final model and its results, while making explicit who are the people involved.

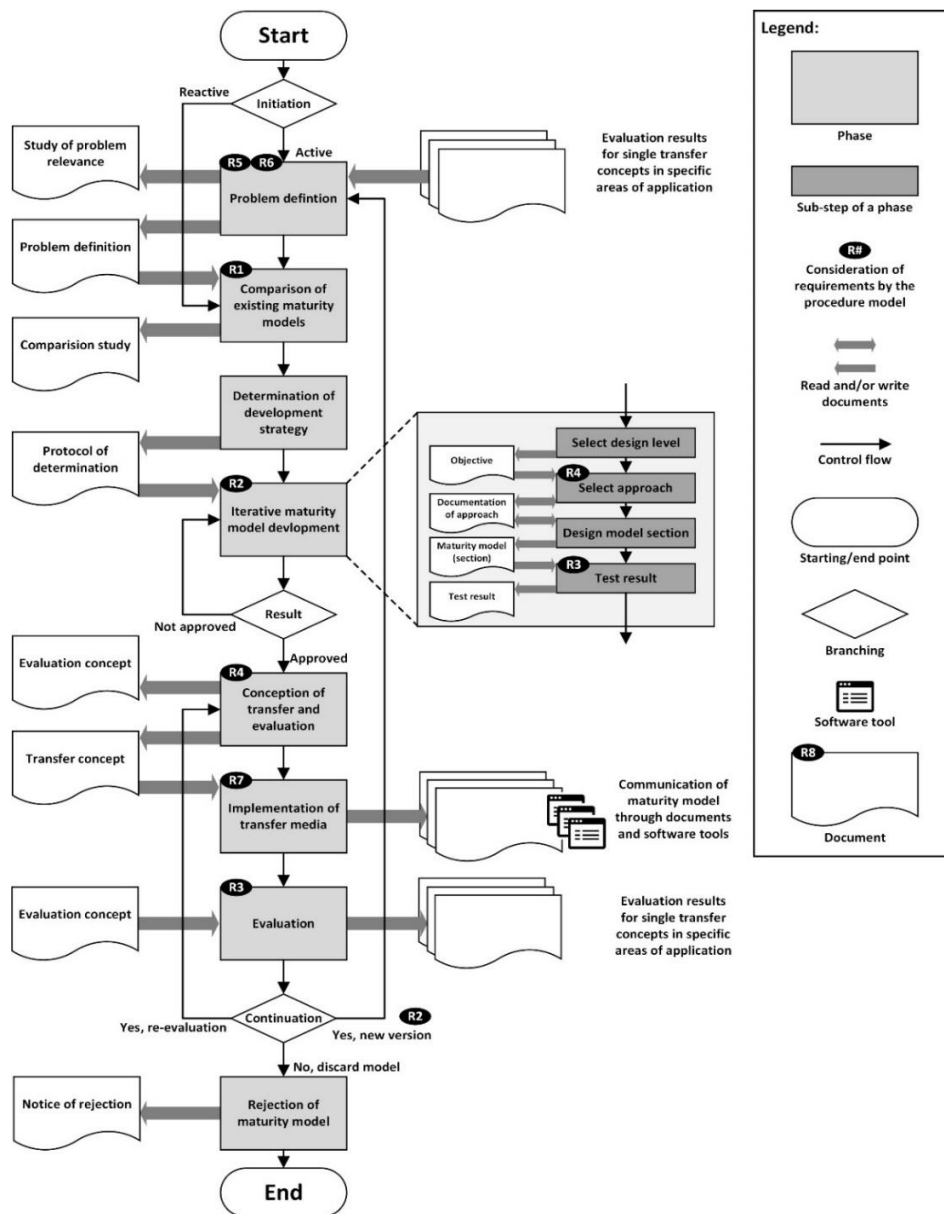


Figure 2 - Maturity model design procedure (adapted from Becker et al. (2009))

Mettler (2014) proposed a different approach, presenting the development process of a model from two distinct viewpoints - the developer's and the user's - the first more centered on the development itself and the second on its application. Each of these two cycles is composed of distinct phases with several parameters, where one must choose the most convenient characteristic to adopt to build a suitable model for the context in question that allows fulfilling the user's final goal.

Pinpointing the first cycle, as depicted in Table C.1 in Appendix C, the development itself is composed of four phases: (1) Define scope, which comprises the most important decisions of parameters that will affect the subsequent phases; (2) Design model, where the actual maturity model is built; (3) Evaluate design, which is concerned with the verification and validation of the designed maturity model; (4) Reflect evolution, where the design mutability of the model is contemplated.

A year later, Mettler (2010) distinguishes similar steps adding up a new one before the "Defining scope", seeing relevance in previously **Identifying a Need or New Opportunity**, similar to what happens when formulating a business plan. This stage is perceived as market research and starts with the review of the existing model base, as stated by himself, to assure informed decision making and secure that already existent knowledge is not integrated into the new model. We consider this addition to the developmental process a milestone of great importance because it allows us to identify market trends and exploit valuable and innovative organizational solutions, based on information collected from different sources.

This is a major prerequisite in a plan for a change, allowing to increase the likelihood that profitable opportunities can indeed be found, and minimizing the costs incurred by failed proposals that can compromise the overall model credibility. Also, given that "mature" technologies typically require less clarification than "emerging" ones, it is assumed that the utility of maturity models covering a highly innovative domain is higher.

In the same document, Mettler (2010) further adds the distinction between a top-down approach and a bottom-up approach in the "Design model" phase. The first determines that the design process should start by defining an architecture of the relevant domain dimensions and sub-dimensions and, only after, define the maturity levels, that should be validated afterward. The bottom-up approach implies firstly identifying the most important constructs that constitute the chosen domain and then, by recurring to questionnaires or secondary data, calculate the different levels of maturity using statistical methods.

On the other side, Maier et al. (2012) details a set of phases slightly different from the previous authors to develop new and evaluate existing maturity grids. Maturity grids present lots of similarities with maturity models but reveal some differences when it comes to work orientation, mode of assessment, and intent, being more generic and less complex than maturity models. However, in the context of this paper, this concept is misleading, with no distinction being made between the two. The authors introduce four phases for maturity model development, each containing a set of decision points. A schematic representation of the Maier et al. (2012) framework is illustrated in Figure D.1 in Appendix D.

In Phase I (Planning) the authors of the maturity grid decide on its expected users, clarifying all the stakeholders who will participate in various aspects of the assessment, defines the aim of the work, its scope, and decide on the key success criteria.



In Phase II (Development) it is necessary to define the architecture of the maturity grid. It is stated that recognizing organizational goals may be a good departure point for initiating the process and establishing the key process areas. It is then necessary to assign a rating scale - maturity levels - which can have a bigger emphasis on specific areas (process, people, organizational structure, a mixture, etc.) more relevant to each company. The cell descriptions need to be formulated and it is required to choose an administration mechanism either focused on raising awareness or on results.

In Phase III (Evaluation), as the assessment is used and feedback is obtained from the companies' experience, the grid should be continuously refined. Given this evolution over time, difficulties or limitations might be revealed and so the evaluation process should only be finished when the results verified against the success criteria previously defined (in Phase I) are considered as satisfactory and no more significant changes are being suggested by participants. It should be conducted a validation, for example recurring to case studies which, although not providing scientific rigor, can help to judge if the grid will benefit a project when put into practice.

Phase IV (Maintenance), is an ongoing one. Every practice is subject to its eventual outdated in an era where new technological developments prevail, especially if it has prescriptive components, making it necessary to constantly check the accuracy of the data storage. This update process must be precisely documented.

### 3.6 Assessment methods

At a time when new challenges arise every day, as well as innovations to meet them, organizations feel the need to constantly try to adapt, survive, perform, and influence, despite not always being successful. To better understand what they can or should change in the way they run their business, organizations can conduct organizational assessments (Rojas, 2015). An assessment consists of a systematic review of its processes, work environments, structure, and effectiveness in each of the measured parameters, allowing to obtain useful data on their performance, identify factors that inhibit the achievement of the pretended outcomes, and benchmark them in respect to other organizations.

The same rationale can be applied to model assessment, being the analysis mainly focused on the appliance of the maturity model, for which is required the determination of the reality's current (as-is) maturity/capability level. For such, companies may recur to a self-assessment questionnaire or following a full-scale standardized measurement approach with extensive guidelines, like the ones provided by ISO/IEC 330xx and SCAMPI (Proença & Borbinha, 2016).

Accordingly, Caralli et al. (2012) takes some considerations on this topic and Mettler (2014) distinguishes 3 possible assessment methods:

- **Self-assessment:** The processes and/or systems are evaluated using little or no outside assistance. It has the advantage of allowing its execution within a short timeframe using internal resources (an interdisciplinary team or a single person backed up by the top management) (Szewczyk, 2019), being powerful and cost-effective foremost for internal process improvement.

- **Third-party assisted:** An outsourced third party helps the organization in applying the assessment method. It provides an independent and verifiable evaluation and adds rigor to benchmarks that may be relied upon comparisons, particularly across a broad community. Despite bringing some loss of control, has the advantage of having a specialized entity performing the task, giving space to the organization to focus on other core functions.
- **Certified professionals:** Organizations can apply for certification, in which case a group of competent assessors will perform the evaluation.

The most recognized maturity models usually include the three methods, starting by providing guidelines for an entry-level self-assessment, while maintaining low costs and then, if the organizations recognize advantages on the maturity model, they can request for an external entity to perform a deeper assessment.

The following Sub-sections detail two of the most renowned assessment methods for maturity models, the ISO/IEC 330xx and the SCAMPI.

### 3.6.1 ISO/IEC 33030

In ISO/IEC 33030 (2017) are provided detailed guidelines to carry out a process assessment, including the required inputs, the description of the tasks to be performed as well as the correspondent roles and responsibilities of each involved subject and indication of the outputs that shall be achieved.

Since this procedure must be adjusted according to the company that carries it out, having unique and exclusive components to each one, and, as a way to tackle the variability inherent in every process, this standard also documents the eventual need for tailoring, that should be conducted in conformance with the ISO/IEC 33002 (2015c) requirements.

The seven main steps that compose the ISO/IEC 33030 method are:

- **Initiation:** The identification of all relevant parties involved (sponsors, participants, team, etc.) and their respective roles are made, along with the purpose and scope of the appraisal. Additional constraints or pertinent information to the establishment of the assessment plan should be gathered. The necessary inputs for the next phase need to be defined and approved by the sponsor.
- **Planning:** An evaluation plan describing all the activities and their schedule is developed, including the adopted strategy to effectively collect, review, validate and document all the data, both pre-requested or acquired in each stage. Based on the assessment scope, the necessary resources are identified and secured and the participants in the organizational unit coordinated according to it.
- **Briefing:** A briefing is undertaken by the Assessment Team Leader, who should ensure that the team understands all the inputs, processes, and outputs. The organizational unit is also briefed on the assessment's performance.
- **Data collection:** Data required for evaluating the processes within the assessment's scope is collected systematically. The strategy and techniques for the selection, collection, analysis of data,

and justification of ratings are explicitly identified and demonstrable. The objective evidence gathered for each attribute of each process assessed must be sufficient to meet the assessment purpose and scope and, since it is of great importance to support the assessor's judgment of the ratings and to verify the compliance with the requirements, should be properly recorded and maintained in the Assessment Record.

- **Data validation:** Using information obtained from first-hand, independent sources, past assessment results, and feedback sessions, the data should be validated for scope coverage, correctness, and accuracy.
- **Results determination:** A set of capability ratings that measure the achievement degree of a group of attributes in the process is determined. This step constitutes an evaluation process based on the ISO/IEC 33020 (2015b) framework aimed at measuring process attributes in an achievement scale ranging from Incomplete (in which the process does not achieve its defined process outcomes) to Innovating (in which the process is continually improved to respond to organizational change). However, such ratings do not warrant organizational performance but constitute its potential to achieve a certain capability level.
- **Assessment reporting:** The results of the evaluation are analyzed and exposed in a report, which should also encompass any key issues raised during the procedure, such as observed areas of strength and/or weakness and findings of high risk.

### 3.6.2 SCAMPI

Along with the CMMI launch, the SEI also released the Standard CMMI Appraisal Method for Process Improvement (SCAMPI), which details the method to assess the processes described in the three constellations of CMMI. Similar to the CMMI model, it has already been updated several times over the years.

SCAMPI is composed of 3 Classes, A, B, and C. The first class (A) is the most complete in terms of presented results (being the only one providing ratings) but also requiring more resources, a bigger work team, and a more experienced leader, while the latter (C) is the opposite (Guedes, 2012). Therefore, less stringent appraisals (such as Class B or C) are probably more cost-effective for organizations that do not have a clear understanding of the model yet (Armstrong et al., 2002).

Focusing on Class A (SCAMPI Upgrade Team, 2011), it is composed of three main processes divided into several steps, which the next Sub-sections A, B, and C will address.

#### A. Plan and Prepare for Assessment

The first phase begins with the initiative of a sponsor who considers it relevant to carry out an appraisal and sees himself/herself in a situation with the means to do so. All the other planning, preparation, execution, and reporting of results stem from this initial activity. The plan must be rectified multiple times (several

iterations and refinements) since a mistake in this first phase will impact the following steps and might bias assessment results.

- **Analyze requirements:** Ascertain the reasons to do the appraisal, i.e., what are the expected goals to be achieved, as well as additional requirements and constraints, to align them with the company's business goals, a task to be fulfilled collectively with the elected appraisal team leader. Determine a strategy for collecting information, which will form a basis for the data collection plan;
- **Develop appraisal plan:** Document in detail every aspect of the appraisal plan, including contextual information about the organization, agreements, estimates, risks, tailoring method, financial indicators (such as the projected return on investment), and practical considerations of each activity (schedule, its correspondent resources, and logistics). This phase must be completed with the review and approval of the plan by the affected stakeholders and sponsor;
- **Select and prepare team:** Ensure that an experienced, objective, trained, and appropriately qualified team is available and prepared to execute the appraisal process;
- **Obtain and inventory initial objective evidence:** Gather, organize and reanalyze the validity of relevant data already available at the company and determine the evidence to be yet discovered along with a plan to do it. Guarantee all the team members' understanding towards the collected information and organizational practices;
- **Prepare for appraisal execution:** Secure readiness to conduct the evaluation, including review and confirmation of the objective evidence's availability, team commitment, logistics arrangements, risk status, and correlated mitigation plans. Plan and document data collection strategies.

## **B. Conduct appraisal**

The second phase focuses on determining to what extent the model is implemented in the organization. Intrinsic to this approach is the concept of coverage, which implies two things: first, the collection of sufficient data for each model component within the model scope selected by the sponsor, and second, obtaining a representative sample of the ongoing processes.

- **Prepare participants:** Ensure that the involved members are appropriately informed about the process, purpose, objectives, and are available to participate and aware of their responsibilities;
- **Examine objective evidence:** Follow the data collection plan by organizing, gathering, analyzing, and comparing the collected information on implemented practices with the corresponding data from the reference model. Take the appropriate corrective actions and revise the data collection plan as needed;
- **Document objective evidence:** Use tools and techniques to ensure and monitor the proliferation of consistent team progress between all the members. Create lasting records of the gathered information, presenting the notes taken by different subjects throughout the multiple activities, which should then be transformed into more precise documents concerning the implemented practices (and its gaps);

- **Verify objective evidence:** Verify the existence of sufficient appraisal outputs to determine the extension to which the model practices are implemented, when compared to the reference model, and identify its strengths/weaknesses;
- **Validate preliminary findings:** Validate preliminary findings, including weaknesses (i.e., gaps in practice implementation) and strengths (i.e., an exemplary implementation of model practices) with members of the organizational unit and correct any perceived errors in the appraisal data;
- **Generate appraisal results:** Team review about goal satisfaction based on the extent of practice implementation throughout the organizational scope of the appraisal. The extent of practice implementation is judged based on the validated data (e.g., artifact and affirmation objective evidence) collected from the entire representative sample of the organizational unit. Aggregate ratings (process area ratings, maturity level ratings, capability ratings, etc.) are driven by the goal satisfaction ratings.

### C. Report results

In the third and last phase, the work team presents the achieved results to the sponsor and organization. These results become part of the appraisal's confidential record and must only be available to the elements/subjects who were defined in the data protection plan previously drawn in phase 1 in collaboration with the sponsor. A completed data package, which includes a subset of the contents of the appraisal record, is also provided to the SEI, to later be included in the databases with the overall profiles of the community.

- **Deliver appraisal results:** Delivery and presentation of the results-oriented to the appraisal's purpose (internal process improvement, supplier selection, monitoring purposes...), including ratings, strengths/weaknesses, and recommendations (if required) that reflect the capability or maturity level of the processes in use;
- **Package and archive appraisal assets:** Review the learned lessons. Retain and store all the collected results and records from the appraisal, paying special attention to the confidentiality's preservation of sensitive data.

Recently, in January 2019, the CMMI V2.0 Appraisal method was subject of updates and improvements, coming closer to the CMMI's format and modular composition while increasing quality, reliability, and consistency (CMMI Institute, 2018), providing companies a way to execute the intended evaluation with less effort, in a more target-oriented manner, and with reduced lifecycle costs.

The Method Definition Document presents 4 appraisal types: Evaluation, Benchmark, Sustainment, and Action Plan Reappraisal, which must be chosen to best fit the organization's business needs and objectives.

The Evaluation appraisal replaces both the SCAMPI Class B and C, which, with no underlying ratings, can continue to be used as a preparation for a deeper benchmark evaluation, despite not being a mandatory requirement. The Benchmark appraisal comes in substitution of SCAMPI Class A, remaining the most complete one and the only one that enables, almost in an interchangeable way, the comparison with

organizations of the same industry, starting from the ratings obtained. In some situations, an entity that had previously conducted an appraisal of this type can later recur to a Sustainment one, an entirely new module intended for those who desire to extend its maturity level rating to a longer validity period. Lastly, the Action Plan reappraisal is essentially intended for parts of an immediately prior appraisal that narrowly failed to achieve their targeted level.

### 3.7 Improvement methods

The unprecedented speed of innovations worldwide is propelling modern societies to become highly technological. This progression, aligned with globalization, which relates symbiotically with it, has been pushing the transition from an interconnected to an interdependent worldwide system, where the actions taken by one have repercussions for all the others, economically, operationally, and so on. As we are moving big steps to turn into a universal omni-channel, the communication in real-time between several devices from all the channels in a company, or even incorporating several companies, is already a normalized issue and the amount of increasingly informed and demanding consumers is exponentially growing according to it. Big changes in the business environment arise every day and the pressure on organizations to seek innovation and establish new goals right after achieving a previous one is large, which according to Sanchez and Blanco (2014), together with the aforementioned factors, led to the recognition of continuous improvement as a vital element for business excellence.

Accordingly, many methods emerged during the last years that came to address this topic. One of these is the ISO/IEC 33014 (2013), which describes in detail several steps to conduct a process improvement. This document provides a cyclical framework that deals with continual improvement on three levels: Strategic, Tactical, and Operational.

The Strategic level is the starting point in which the scope of change, the goals to achieve, and the overall change strategy is defined, forming the basis only for the rightest branch of improvement represented at the Tactical level. This second level divides the whole framework into three different perspectives, each providing guided steps on how to achieve the pretended goals either focusing on a project, process, or organization. The Organizational level focuses more on how to perform the improvement project itself and is common to all the dimensions, independently from its choice on the previous level.

The following schematization of Figure 3 is presented for a better understanding of the overall framework.

For the sake of brevity, we will proceed to clarify merely the second dimension on the Tactical level, the improvement of processes, since it appears to be the most relevant in this study's context and for the work that will be developed some Sections ahead.

- **S1: Examine organization's business goals** (defined at the strategy level) and, accordingly, identify which processes represent more added value, to better guide the improvement actions to be performed following the guidelines of a reference model that best fits the context;

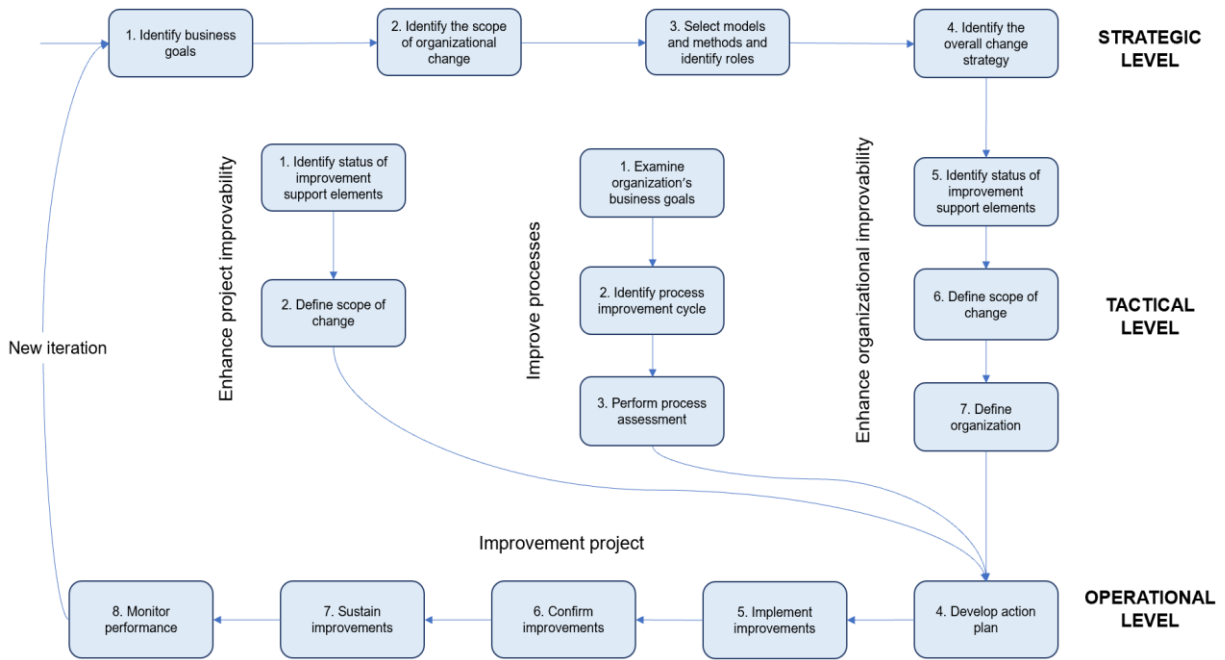


Figure 3 - Improvement framework of activities with steps and relations (adapted from ISO/IEC (2013))

- **S2: Initiate process improvement cycle**, which should be implemented as a project in its own right, including sponsorships, project management, accountability, and an exhaustive process improvement program plan (similar to a business plan, containing background, current status, stakeholder analysis, available resources, roles and responsibilities, risks and different paths to avoid/mitigate them, etc.);
- **S3: Perform a process assessment** in conformity, for example, with the steps described in ISO/IEC 33030 or SCAMPI (Sub-section 3.6.1 or 3.6.2, respectively);
- **S4:** Analyze the assessment results against the organization's business goals to target and prioritize the areas providing the best improvement opportunities, define specific objectives for each and **develop an action plan** that portrays thoroughly the actions to be carried out to meet the desired level;
- **S5: Implement improvements** according to the action plan which might contain more than one action to be performed. In this case, several individual projects should be initiated, each requiring the selection of the most appropriate implementation strategy and the preparation of an activities' program, from which the progress should be monitored;
- **S6:** Succeeding the full projects' implementation, the organization should **confirm** that the **improvements** have changed the organizational culture as desired and met the intended goals while presenting encouraging effects on cost-benefit and risk analysis re-evaluation. If not, it may be desirable to redefine the process improvement project by returning to an earlier step;
- **S7: Sustain improvements** across all the departments to whom the targeted processes may concern and monitor its progression;

- S8: **Monitor performance** of the processes, review constantly their suitability, and initiate new process improvements, based on previous experiences, as part of the continual process improvement program.

### 3.8 Maturity models for hospital unit’s management

This section provides a synthesis of the analysis of a set of maturity models with different focus and characteristics applied to healthcare. It is composed of Sub-section 3.8.1 which describes the conducted systematic literature review process and Sub-section 3.8.2, where the previously obtained final set of documents is discussed.

#### 3.8.1 Systematic literature review process

The search strategy was conducted based on the systematic literature review methodology described by Kitchenham et al. (2009), aiming at retrieving from the selected and validated research sources the highest number of potentially relevant documents. Figure 4 is a schematization of the overall process.

Due to their wide and universal adoption in the academic communities and their free access given to the academia, it was recurred to *Google Scholar* (<https://www.google.com/>), *Springer Link* (<http://link.springer.com/>), *IEEE Xplore* (<http://ieeexplore.ieee.org/Xplore/>), *PubMed* (<https://pubmed.ncbi.nlm.nih.gov/>) and *ACM Digital Library* (<https://dl.acm.org/>) as the indexing systems and digital libraries to be consulted.

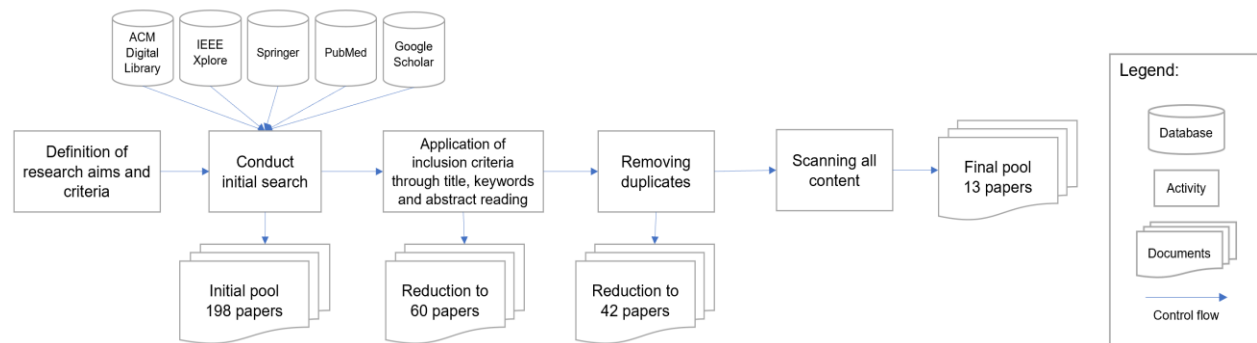


Figure 4 - Systematic literature review process

Having in mind the study subject and the defined search terms, they were used in combination with the Boolean operator to form an adequate expression to the data harvesting in each of the aforementioned sources – (“maturity model”) AND (healthcare OR hospital OR medicine OR medical) – which was adapted to their particularities and limitations at the time of research. The date range was set from 2010 to 2021, as it corresponds to the period between the launching of CMMI Version 1.3 up to the present day, February 11<sup>th</sup>. Completed this stage, a total of 198 results were identified, according to the Figure 5 distribution.



Subsequently, all the results were submitted to a first filtration, by reading their title, keywords, and abstract, to verify their possible fit into the defined inclusion criteria and, if positive, categorized accordingly, giving the lowest reading priority to the ones fulfilling only C1 and highest to C3. The results that did not meet any of the criteria were excluded, which lead to the remanence of 60 articles at the end of this stage.

- C1: Is there a clear statement that the study proposes a maturity model for healthcare?
- C2: Can the maturity model be directly applied to hospitals?
- C3: Does the maturity model present a case study (has been empirically tested)?

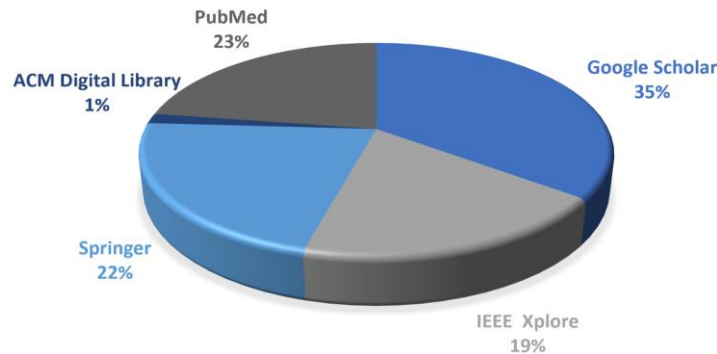


Figure 5 - Sources by contribution's percentage

Throughout the screening process, it was possible to find duplicate reports of the same study or fragmented pieces/chapters of a bigger document. When verified this situation, the most complete version of the study was included in the review. When pertinent, the snowball research method was used, that is, in specific cases, using a document as a starting point, its bibliography was consulted and the paper in question was substituted for one of a more relevant title or widespread scope within the same area.

The last stage before achieving the final pool consisted in scanning the full content of the 42 remaining papers, to bring together a diverse and pertinent set of documents within the broad field of healthcare. Here it was possible to clearly distinguish at least some of the maturity model components previously mentioned, which will serve as study objects in the next Sub-section. Among the set of articles left out of the selection, are those that merely focus on a specific case study, without presenting the models' theoretical basis and development methodology description, and the ones excessively centered on IT. Besides, due to our research criteria, more general models such as CMMI-SVC, People Capability Maturity Model, and others, have not been suggested as potential results nor analyzed, however, we recognize that their use could bring beneficial results in several healthcare branches.

### 3.8.2 Discussion

This Sub-section aims at comparing the final group of models obtained during the systematic literature review process. The selected articles as well as the parameters on which they were evaluated are depicted in Table 5.

Mettler (2014) proposes a set of phases to analyze a maturity model concerning its application: (1) Select model, (2) Prepare deployment, (3) Apply model, and (4) Take corrective actions. However, the last three already take into consideration the specific organizational scenario that will be the target of the chosen maturity model and, as a result, does not apply to this case yet. Proença and Borbinha (2016), based on the parameters of the “Select model” phase, put forward a different set of criteria more suitable to the analysis that is intended to make at this specific level, focusing on the (1) Model structure, (2) Model assessment and (3) Model support, and is, therefore, the ones that will function as our guide.

The model structure analysis focuses on the structural aspects of the maturity model. It is reviewed the name of the model and its main references, the number of levels, the name and number of attributes, whether the model provides a maturity definition, and if the practicality of the model’s recommendations are problem-specific or general.

From the analysis, it is possible to infer that there is no standard **number of maturity levels**, as the found models ranged between 4 and 7, although the average number is 5 because many of them continue to follow the CMMI guidelines.

When it comes to the **attributes’ quantity and name**, there is a bigger discrepancy. The sample shows some heterogeneity in terms of the number of attributes. As for the name, models based on CMMI tend to designate them as process areas, with these being aggregations of processes according to their objective/business goal, as is the case of eHMM and BIMM. However, others such as the HISMM, Health 2.0 MM, and DDSCM refer to dimensions instead, which represent different perspectives of the maturity model subject. Alternative designations like “Components”, “Domains”, “Elements” and “Perspectives” were also noticed, but all of them end up having the similar objective of decomposing the maturity model into easily understandable sections.

Although the areas on which the attributes focus are also quite dispersed, it is reasonable to affirm that the “business process”, “technology” and “people” aspects are the most covered ones. For example, the Networkability MM proposes an approach to improve healthcare organizations’ capacity to engage in business relationships, falling under the first topic, which consequently reflects in its attributes. The Game MM, for instance, introduces gaming as the next step in the application of information technology to healthcare, which goes according to the second aspect, while the PaCMM addresses new measurements for patient-centeredness in healthcare organizations, conforming with the third topic.

Many of the models do not present the direct underlying **concept of maturity** employed by the model, with only the Networkability, HCMM, MM for process management, and BIMM doing so. However, some, although not stating the meaning of the “maturity” term clearly, include the definition of “maturity model” from which it can be deduced.

Regarding **practicality**, on one hand, we found models created to raise awareness of the maturity in one subject and, as a result, only provide general recommendations and, on the other hand, we have maturity models that have undergone multiple development iterations and, therefore, have matured enough to be able to provide specific improvement activities.

Table 4 - Synthesis of the analyzed maturity models

Maturity model	Number of levels	Attribute's name	Number of attributes	Maturity definition	Practicality	Assessment method described	Strong/weak points identification	Continuous assessment	Improvement opportunities prioritization
Hospital information systems' maturity model (HISMM) (Carvalho et al., 2019)	6	Dimensions / influencing factors: data analysis, strategy, people, EMR, information security, system and IT infrastructure	6	No	General guidance	Yes	No	Yes	Yes
Networkability maturity model for healthcare providers (Fitterer & Rohner, 2010)	5	Components: strategic alignment, IT management, process management, organizational project management, cooperation management, systems architecture	6	Yes	General guidance	Yes	No	Yes	No
Electronic healthcare maturity model (eHMM) (Sharma, 2008)	7	Process areas: timeliness of process, data access and accuracy of data, process effort, cost effectiveness, quality of process results, utility or value to stakeholders	3	No	General guidance	No	No	No	No
Hospital cooperation maturity model (HCMM) (Mattler & Blondiau, 2012)	4	Dimensions: strategic layer, organizational layer, information layer	3	Yes	General guidance	Yes	No	No	Yes
Health 2.0 maturity model (Jami Pour & Jafari, 2019)	5	Dimensions: content, engagement and community, healthcare services, communication, social business, analytics and intelligence	6	No	General guidance	Yes	No	Yes	Yes
High reliability healthcare maturity model (HRHCM) (Chassin & Loeb, 2013)	4	Domains: leadership, safety culture, performance improvement	3	No	Specific improvement activities	Yes	No	No	No
Healthcare usability maturity model (HUMM) (HIMSS Usability Task Force, 2011)	5	Elements: focus on users, management, process & infrastructure, resources, education	5	No	General guidance	No	No	No	No
Demand driven supply chain management (DDSCM) maturity model for the public healthcare sector (Buchete, 2020)	5	Dimensions: distribution management, visibility, technology, collaboration, human resources, organizational alignment, performance management	7	No	Specific improvement activities	Yes	Yes	Yes	Yes
Game maturity model for healthcare (de Boer et al., 2016)	5	Perspectives: value, process, coverage, type	4	No	General guidance	No	No	No	No
Patient-centeredness maturity model (PaCMM) (Sanders, 2016)	4	Elements: leadership, design, infrastructure, culture, performance management	5	No	Specific improvement activities	Yes	Yes	Yes	Yes
Maturity model for process management in hospitals (Cleven et al., 2014)	5	Capability areas: culture, structure, strategy, practices, IT	5	Yes	General guidance	Yes	No	No	No
PACS maturity model (PMM) (van de Wetering & Batenburg, 2009)	5	Perspectives: strategy execution, technology potential, competitive potential, service level	4	No	General guidance	No	No	No	No
Business intelligence in healthcare maturity model (BIMM) (Brooks et al., 2013)	5	Process areas: organizational, people and team, technology, processes specific to complexities in healthcare	4	Yes	Specific improvement activities	Yes	Yes	Yes	No

The last 4 columns are concerned with the model assessment, which focuses on the maturity model's application. In this category, it is evaluated whether the assessment method is described if the strong and weak points of the organization resulting from the assessment are listed, whether the model strives for continuous assessment and if it prioritizes the proposed improvement measures.

The **assessment method** can be outlined by mentioning a self-assessment questionnaire or a full-scale method, as the ISO/IEC 33030 or SCAMPI, detailed in Section 3.6. Although none of the documents found have described this process exhaustively, most of them referred at least to the surveys/questionnaires or pilot tests and to the way they were conducted, with only the eHMM, HUMM, Game MM and PACS MM lacking on this point.

The **strong and weak point identification** is relevant as it will allow the creation of an improvement plan to enhance the weak points found during the assessment, as well as consider the replication of the work practices and elements that lead to the strong points across other sectors in the organization. As this parameter is directly correlated with the practicality, its classification was slightly more controversial, because usually the presence of specific improvement activities comes up allied to the identification of the strong/weak points, but, in some papers, the general-specific boundary was not clearly distinguishable, which reflected in this point.

The **continuous assessment** focuses on whether the model follows a schedule for further assessments and provides means to enable its successive performance over time, to keep the constant track of the organization's ongoing evolution. Scorecards, for example, might be a good tool to enable a continuous assessment. In the presented sample 6 out of 13 articles proposed means to tackle this issue.

The last consideration is concerned with the **improvement opportunities prioritization** which is important to ensure a better channeling of resources according to the weak points identified at the time of the assessment and to the company's goals. Methodologies that request for the decision-makers' impression or include formulas that can retrieve weights to each attribute fill this parameter. Noteworthy that most of the papers that fulfill this requirement are from more recent years, which might be justified by the exponential growth in the importance of multi-criteria decision-making methods, a context where the determination of criteria weights arises frequently and that may have influenced the newest models.

It was decided that the last field of analysis proposed by Proença and Borbinha (2016), the Model support, would not be included in this comparison since no sufficiently developed models were found in the healthcare field to be derived from earlier versions and, consequently, charged, nor incorporated any of the remaining evaluation characteristics pointed out by the authors, which is also in line with our final set of conclusions regarding this analysis. In other words, although the scope of maturity models has been widening over the years, this literature research revealed and confirmed the embryonic stage at which their development is found, especially in the health field, and which, moreover, continues to be heavily influenced by the IT theme. Despite this, answering the second secondary research question (SRQ2) from Section 2.2, there are, indeed, several maturity models focused on hospital units' management and it is visible a growing interest in addressing this theme.

Another interesting observation is that, despite the Lean concept being relatively new in healthcare, it was possible to identify some papers through manual search that associate both areas, nevertheless, the HRHCM, apart from other preliminary studies, was the only found where all these components are linked and appear as a constituent of the maturity model's improvement path. Recalling all the benefits coming from Lean methodologies this fact represents a great innovation opportunity for future researches.

Summarizing Table 5 and, still meeting the second secondary research question (SRQ2), although some of the analyzed models follow the practices considered fundamental for their complete development, the majority still lack on including some of the essential elements, incurring in the shortcomings pointed out in Sub-section 3.2.2.

Overall, the number of studies that have healthcare/hospitals as a subject is still very small, and, to answer the third secondary research question (SRQ3), no research was found that directly tackle strategies of improving hospital's effectiveness and efficiency in emergency situations. This literature gap in maturity models' theory allied to the current socio-economic crisis calls for action and in-depth exploration of this research domain.

### 3.9 Research Method

The research approach adopted in this work emerges as a crossing between development procedures that present similar and complementary characteristics. Firstly, Becker et al. (2009), already mentioned in Section 3.5, in addition to worthwhile topics concerning the model development, follows the guidelines presented by Design Science Research to form a solid methodological foundation, which is also suitable for application in the research approach. Secondly, Peffers et al. (2007) get together several authors' literature to reach a consensus-building approach to DSRM (Design Science Research Methodology) with well-accepted elements amongst the scientific community, which is also relevant to our study.

As depicted in the procedure model in Figure 6, the first step focused on **problem identification** and motivation. Although further evidence on the relevance of this study is pointed out throughout this paper, it was mainly in this first Chapter that the problem was defined and detailed why a solution for it is valuable. It was also important to clarify the **main research questions and goals to be achieved** at the end of this thesis by the solution artifact, in this case, qualitatively.

Following the delineated research questions and overall research goals, and, recalling the concepts and procedures analyzed throughout the literature reviewed in Chapter 3, a new maturity model will be then **designed and developed iteratively**. To initiate this stage, a comparison of existing maturity models was made. Here it was found relevant to explain in advance the methodology used to conduct a systematic literature review, as an intrinsic process of DSR. As the final output, an analysis of the differences and similarities in existing maturity models in the domain was obtained, as well as the identification of their weaknesses and strong points that will be useful to keep in mind when advancing further in the development stage. This also represents a crucial step, as it determined the direction to follow: if a maturity model that addresses emergency management capabilities already existed *a priori*, an adaptation could have been

made to better suit the Portuguese context by adding the lacking capabilities; as the research revealed otherwise, there is a reason to build a model from scratch. The work that immediately follows will consist in determining which emergency capabilities (or dimensions) in Portuguese hospitals require the most attention from the improvement agents, based on their capability of response in recent years. Together with the levels' definition, this will constitute part of the maturity model's structure, which will be succeeded by the assessment criteria identification.

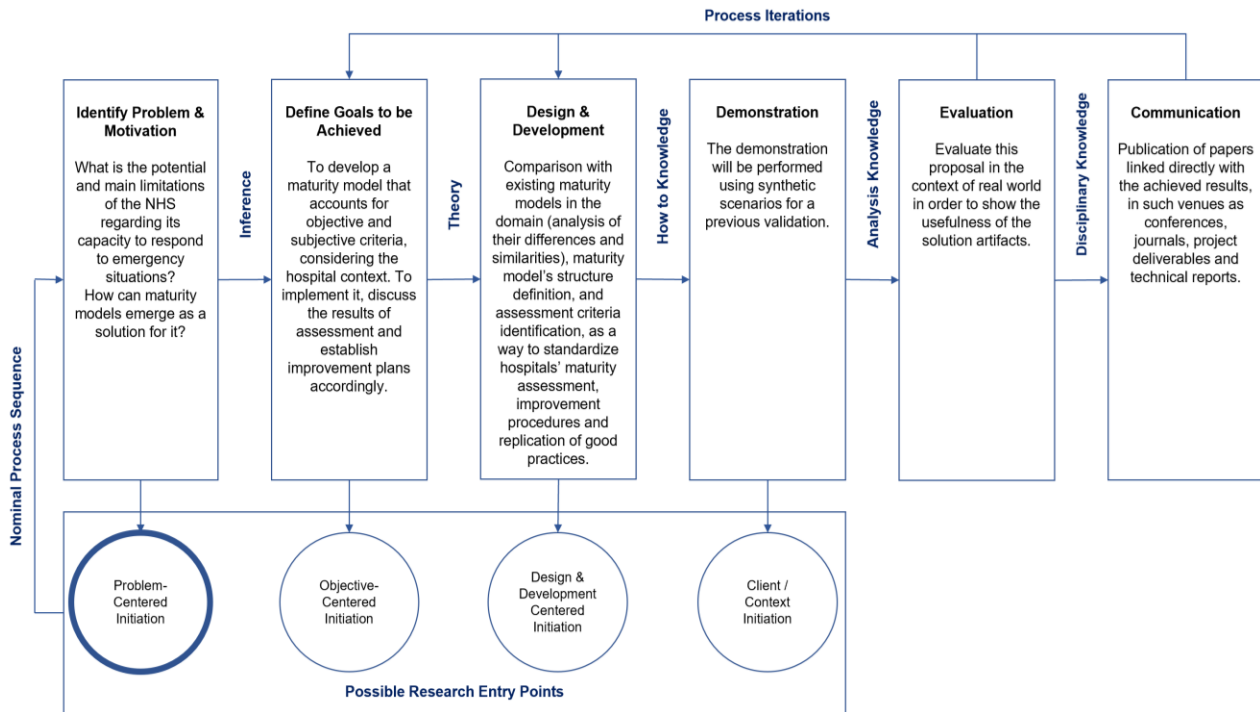


Figure 6 - Design Science Research method applied in this work (adapted from Peffers et al. (2007))

As a way to conduct a **demonstration** and first validation, the solution will be proven against artificial scenarios and only then **evaluated** by applying it to a set of real organizational scenarios. For that purpose, it will be tested how well the proposed artifact supports a solution to the identified problem, by implementing it in three different hospitals to compare and demonstrate its functioning and usefulness. Good assessment practices should be followed, either from SCAMPI or ISO/IEC 33030, since both methods have common underlying principles. The same should happen for the improvement method, taking as reference the ISO/IEC 33014. When no more improvement suggestions from the decision-makers and interviewees arise, it is taken as concluded the end of model development and, therefore, the results may be **communicated** to the interested parties (as the hospital administrations) and the scientific community, as the last stage of the iterative process.

The Gantt Chart with the different stages' schedule that composes the overall plan is available for consultation in Figure E.1 in Appendix E.

## 3.10 Chapter Conclusion

This Chapter provides the description and analysis of relevant work that responds to the first three secondary research questions (SRQ1, SRQ2, and SRQ3) leading the path to meet the first three goals raised in Section 1.2 while supporting the proposals to be made ahead in this work.

The Chapter starts the literature review dating back to maturity models' first appearance in 1973, from which they have had a constant evolution. With the CMMI and the ISO institute constantly releasing new and more complete versions and publicizing the promising results that companies applying their methods were able to achieve, their popularity grew and its scope widened accordingly, with the concept of "maturity" broadening further to keep up with each maturity model aim.

Despite this, the proposed characteristics for design and development remain considerably within the same standards, with their frameworks continuing to be based on the discipline of DSR. For the design, models can be presented as descriptive, prescriptive, or comparative, and should fulfill an increasing number of requirements, the broader their nature. For the development stage, there is also a consensus among the steps that the various authors propose to develop a complete and sound model. On a general note, it is recommended that this process presents a clear identification of the problem and its relevance to the market, and goes through several iterations underlying the design of the model, its evaluation, and proposals for improvement until no more significant changes are suggested. Periodic review and adaptation of the model in face of new constraints that may emerge after its completion must be encouraged to avoid this tool from turning into a simple snapshot in time.

Assessment methods as a way to determine the organizations' as-is situation before starting the improvement path are also an essential part. Three possible assessment methods are distinguished – self-assessment, the third party assisted, and certified professionals – as well as others, suggested by renowned institutions, with very specific guidelines, such as ISO/IEC 33030 and SCAMPI.

Regarding improvement methods, there are many ways to go. While ISO institute also here suggests a framework to follow, focusing on strategic, tactical, and operational components, we believe that the inclusion of other complementary methods should not be ruled out and can bring measurable benefits, as is the case of Lean methodologies.

This Chapter ends with an analysis of the current state of the art, by comparing several models under the healthcare topic. Our main conclusion was that no maturity models directly tackling strategies of improving hospitals' effectiveness and efficiency in emergency situations were found (in the current literature).

# 4 Model Development

In accordance to the maturity model development approach of Becker et al. (2009), a new maturity model must be developed, if no existing or advancement of an existing one is capable of addressing the identified problem, which is in line with the present situation, as verified previously. Therefore, in Chapter 4, the appliance of an iterative process for the model development is started. Beginning with Section 4.1, it will be ascertained which capabilities are essential for a cohesive preparedness and response to disasters and if, despite not existing a maturity model designed for targeting specifically emergency situations, any model presents attributes with relevant aspects to ground our construction on it. In Section 4.2 the level definition is detailed, all together culminating in Appendix F.A, the table representing the newly developed maturity model. Lastly, in Section 4.3, presents some criteria extracted from the complete maturity table that we considered as the minimum set of questions to determine whether an organization meets a certain level for a given capability or not.

## 4.1 Emergency Capabilities

As defined by WHO (2011), an emergency is *“a sudden and usually unforeseen event that calls for immediate measures to mitigate its impact”*. Sánchez and Amor (2002) agree on a similar base definition, also denoting some underlying characteristics such as *“the emergence of severe consequences”*, *“large quantity of affected people”*, *“social disorganization”*, or, my personal favorite, *“forces so powerful that they render traditional response measures ineffective”*.

Thinking of catastrophes, natural causes come easily to mind (hurricanes, floods, earthquakes), however, their triggering elements can also extend to technological, war-related (nuclear, chemical, biological, terrorist) or social factors (riots, etc.), all of which produce distinct consequences and have different probabilities of occurrence, varying in virtue of location. Despite its time and nature’s unpredictability, the preponderance of evidence seems to suggest that there is more similarity than difference in response behaviors across different types of disaster agents (National Research Council, 2006, p. 114).

Impacted populations must rely on local institutions’ preparedness to coordinate and collaborate with cross-sector partners to decrease the potentially devastating effects, with the assurance of healthcare provision included. However, speeding up disaster relief assistance and increase its effectiveness implies the implementation of disaster preparedness measures and, with hospitals often playing a key role in emergency response, their capabilities for such situations should be targeted.

### 4.1.1 Establishing capabilities and criteria

According to Kunz et al. (2014), the nature, likelihood, and scope of impact of the different disaster's occurrence in each environment is an important factor when planning which capacities to address, and must



be taken into consideration to allow a better channeling of the available funds. Following this, to avoid the tendency to build an overly generalized model, the chosen capabilities were based on preparedness and capability evaluation reports of the Portuguese SNS in past disaster situations, as Gripe A, Ébola, Zika, wildfires, and floods. This allowed to find the most dysfunctional areas and, consequently, to select a set of capabilities that might portray a greater progression margin and, at the same time, that reflect more accurately the national context, meeting the secondary research question four (SRQ4). These are the ones that will be assessed and improved later on in each of the selected hospitals.

**A - Hospital preparedness:** Represents the ability to prepare for and withstand public health incidents both in the short and long term. It is a continuous activity that may include the study of hospital vulnerabilities and potential threats to later discuss improvement measures to mitigate them, according to its probability.

Effective and efficient management of catastrophic emergencies requires more than just responding when an event occurs. Kunz et al. (2014) report that hospitals that invest both in physical (inventory and infrastructure-related) and intangible preparedness activities reach a better service level with significantly less cost expenditure when a crisis strikes than the ones that don't, also pointing out the significant improvements achieved merely by enhancing disaster management capabilities.

For disaster preparedness, continuous education and training are two major foundation stones. Programs to address them are to be developed at a national and international level, to improve the knowledge and skills of healthcare providers regarding the treatment of victims. Additionally, it might be useful to:

- Pre-position inventory and have pre-prepared emergency kits;
- Strengthen partnerships with stakeholders so there is a solid foundation for well-coordinated work through each crisis;
- Use computational modeling as an opportunity to integrate theories and empirical findings from natural sciences, engineering, and social sciences into models that can be used for decision making (National Research Council, 2006, p. 276). In other words, create forms of codified knowledge used to represent “reality” of things not known from things that are known (Waisel et al., 1997).

**B - Impact assessment and surveillance:** Represents the ability to provide all decision-makers with relevant information concerning the nature and extent of the hazard, vulnerable elements, and resources required. This includes maintaining an on-time track record of the ongoing situation and any potential consequences that may arise during and after an emergency, to ensure efficient, timely, and appropriate support for communities (NSW Government, 2020).

The importance of observing disaster response operations while they are ongoing, or as soon as possible after the disaster impact, has long been a hallmark of the disaster research field. In many cases, quick-response research and perishable data on disaster impacts and the organizational and governmental

response has led to the subsequent rapid mobilization of scientists for in-depth studies on response-related issues during the post-impact reconnaissance (or recovery) phase (National Research Council, 2006).

Additionally, the current pandemic situation confirmed that having immediate/timely reports of other catastrophe epicenters' status and measures taken can help managers plan accordingly, allowing them to formulate a more efficient response. Regateiro (2021), reports that the information stemming from other countries, namely Italy and Spain, and the constant direct benchmarking with hospital units similar to Centro Hospitalar e Universitário de Coimbra (CHUC), both in size and functional content, greatly influenced the planning in helping to mitigate posterior unnecessary errors.

Another example is the importance of the first intervention time span in wildfires, where the response times of the INEM's vehicles can be crucial to save lives, functioning also as a source of assessment to determine the possible need for greater mobilization of resources.

This capability may also include other functions as:

- Grants' provision destined to support the collection of perishable data and enable science researchers' prompt mobilization;
- Conduct frequent laboratory analysis and report results.

**C - Internal and external information sharing:** Represents the ability to conduct an exchange of health-related information with the government, the private sector, and the stakeholders, as well as to manage a permanent, clear, concise, and reliable dissemination of warnings, alerts, and notifications to the public.

In an environment of great insecurity, doubts, and risks, internal information sharing is a key leadership component, contributing to reinforcing the proximity between the different parties, allowing a greater involvement in the processes, and also enhancing affective and cognitive dimensions. External communication, on top of these points, also requires an additional balance between the benefit that can constitute providing information to the public, *versus* the relevance of communicating what is experienced daily inside the hospital to a society that already lives moments of great vulnerability (Regateiro, 2021).

Knowing the current national status point regarding this capability, it might be useful to keep in mind to:

- Work towards both a downstream and sideways (between similar organizational levels) decentralized information chain and also upstream acceptance of feedbacks and suggestions;
- Conduct reunions with the most relevant decision-makers (from governmental parties, scientific committees, healthcare, etc.) to discuss impartially technical aspects of the emergency;
- Brief the hospital staff on their roles, responsibilities, and reasons behind the adopted procedures;
- To have a single hospital information recording system up-to-date and user-friendly that facilitates information exchange within and between organizations;
- "*Fight not only pandemics but also infodemics*", that is, seeking ways of eliminating fake news/mal-information that ultimately might mislead people to adopt risky behaviors as discrediting preventive measures, causing panic, or others (Azim et al., 2020).

**D - Human resources management:** Represents the ability to recruit, distribute, train and monitor the performance of all clinical and non-clinical staff responsible for public and individual health intervention. It includes reassuring enough staff to cope with increasing demand while maintaining enough resources to provide continuity to the remaining medical activity.

As arguably one of the most important of the health system inputs, the capability of response and benefits a system can provide depend largely upon the knowledge and skills of those individuals responsible for delivering health services (Kabene et al., 2006). Considering that Portugal lacks in human resources for healthcare, and hospitals are one of the most stressful workplaces, it is important to ensure that employees are aware of their vulnerabilities and prepared physically, emotionally, and intellectually, so it reflects in high motivation and, consequently, professionals performing at the top of their abilities, attenuating the effects of its shortage in numbers.

In the national context it may also be incorporated in these activities:

- Promote a democratic, proactive, and participative leadership style, centered on encouraging collaboration, consultation, and focused on problem-solving, which can greatly impact the delivery of healthcare services, specially amid chaos, when the need for leadership is even greater (Govender et al., 2018; Proches et al., 2020; WHO, 2007).
- Measures to reduce employees' turnover, namely the migration from healthcare professionals;
- Ensure an appropriate mix between different types of health promoters and caregivers;
- Creating timely measures to avoid overloading professional's working hours;
- Being aware that some professionals directly or indirectly affected by the disaster may be absent, and define a priori processes for personnel hiring.

**E - Logistics and management of clinical and non-clinical supplies:** Represents the ability to manage inventory (prepare, conserve, substitute, adapt and re-allocate) and operations and to provide the bridge between aid materials and the areas of disaster. It is responsible for ensuring the availability and delivery of essential commodities, equipment, supplies and get the professionals' teams to the incident site (e.g., INEM) to provide pre-hospital emergency care, including psychosocial support.

According to Regateiro (2021), characteristics such as self-education in the face of new concepts and materials that become necessary to manage, and the ability to work in teams are crucial, together with the flexibility in knowing how to radically adapt plans that become outdated by each day, requiring the seek for alternative suppliers and, more generally, solutions.

- Have a diverse range of suppliers;
- Adoption of digital means as a tool of creating a single repository for real-time access to user and stock information, to promote the optimization of resources and processes;
- In a more advanced stage, innovations in this area should be considered, embracing drones, unmanned or remote-control vehicles that might help to save more lives in less time, especially in remote areas (e.g., in building collapse, etc.).

**F - Intra and Inter-hospital coordination:** Represents the ability to articulate between departments in the same institution or amidst different health institutions (including the private and social sector), not only regarding the transfer of patients, human resources, medical materials, and know-how but also in the response to patients with pathologies unrelated to the crisis event.

With the SNS being the main healthcare provider, in a crisis/catastrophe situation, depending on its dimension, the success of the system's response will rely, in part, on this ability. Taking the current situation in the SNS as an example, the national fight against COVID-19 was decisive, however, this is far from being the only disease in the country, and it can be concluded that an almost exclusive dedication to the pandemic has penalized millions of Portuguese with other pathologies. Consequently, various entities have appealed to an urgent investment in the recovery of more than a million hospital consultations that were cancelled and thousands of screenings (including oncological ones) in waiting queues, which will require a good articulation of operation with the private and social sector, reconciling the fight against the virus that will have to be maintained.

Additionally, through coalitions relationships and contacts are built overtime bringing a different level of trust and support when calls or requests are made in a need for a quick reaction at the time of disaster (Adelaine et al., 2016).

- End the ideological prejudice regarding the articulation between the public and private sector;
- Revise plans for national and international cooperation, namely of medical supplies, human resources and patients transfer.
- Build coalitions and work with external partners to promote greater harmonization and alignment with national health policies (as with DGS and Health Ministry) (WHO, 2007).

**G - Fatality management:** Corresponds to the ability to coordinate with partner organizations and agencies to search, recover and identify the victims, document incident evidence, support storage and processing operations of the remains, and assist relatives of the victims (Finegan et al., 2020).

Following some disasters, the need for fatality services might face a big demand difficult to deal with. Although during an emergency the priority should fall on assisting survivors and maintaining basic services, the recovery of dead bodies should not be overlooked. For example, in case of chemical disasters, the presence of infectious agents, or even merely due to bad conditioning, the presence of dead bodies might represent risks for public health. Furthermore, at an intra-hospital level, the influx of a large number of severe victims can lead to an exponential increase in the number of hospital deaths, and a consequent lack of response capacity to preserve them. All these factors combined may cause a need for expanded storage structures or coordination with institutions in the community.

It should always be kept in mind that the way corpses are managed has a significant impact on the wellbeing of surviving family members and communities (PAHO, 2006).

**H - Volunteer management and NGOs:** Represents the ability to coordinate with the operations management department and partner agencies (private sector, NGOs, etc.) to identify, recruit, verify, train, and engage volunteers to support the public agency's preparedness, response, and recovery activities during pre-deployment, deployment, and post-deployment (CDC, 2019).

Activities such as searching for and rescuing victims, donating blood and supplies, inspecting building damage, collecting funds, providing medical care and psychological counseling, and granting food and shelter to victims (Wenger & James, 1994) may be carried out by volunteers, which play a significant role in helping to augment the response capacity through additional skills and abilities. Given this diverse range of possible help fields, job profiling and post-recruitment interviews may be useful strategies to include in the overall volunteer management plan, as it will help in the screening of candidates and matching of the volunteers expectations to the most adequate opportunities (VOAHR, 2016).

On the other side, as reported by the National Research Council (2006), researchers also indicate that the mass convergence of volunteers and donations can create significant management problems and undue burdens on disaster-stricken communities. In their eagerness to assist, people may "over-respond" to disaster sites, creating congestion and putting themselves and others at risk or insisting on providing resources that are not needed.

Based on the current Portuguese context, some of the actions to be promoted with the target groups inherent to this capability may also include:

- Recruit students from healthcare areas of study, such as medicine, nursing, and psychology institutes to assist directly in hospitals, home care, emergency lines (*Linha SNS24*, psychological support line, etc.), or others;
- Break the bureaucratic barrier that prevents/hinders retired healthcare professionals from enlisting for emergency response;
- Encourage initiatives from local students' associations and/or universities that might target alternative help, such as food provisions or material supplies (*as Socorrer a Linha da Frente*).

**I - Hospital recovery:** Represents the ability to identify critical assets/systems/services (tangible and intangible) that may need recovery operations and restore its level of functioning to a level compared to the pre-incident one or to an improved stage. It includes the revision of the taken course of action during the disaster and comparison with former mitigation plans to adjust them, if necessary, according to the learned lessons.

In Medtronic (2020) it is said to "*never let a good crisis go to waste*", meaning that an event that forces changes over a very short time that, heretofore, were unimaginable, should be used as a catalyst for positive change, as the crisis subsides. Looking back at the years that followed 9/11, Americans focused their attention on events that could generate mass casualties and addressed the lack of frameworks on this area with the creation of innumerable initiatives in the emergency management capabilities field (Sauer et al., 2009). At the time of the pandemic, many of these created frameworks already had relevant points to take

into account that, with a few changes, revealed to be pertinent for the COVID-19 response, some of them even serving as a basis for action in Portugal, as is the case of (Minnesota Department of Health, n.d.).

- In case of an epidemic, critical incident (“after event”) reviews of the probable cases reported by *Saúde 24*, as an opportunity to acquire operational feedback on system capability.
- Existence of mechanisms, such as surveys, for obtaining opportune client input on appropriate, timely, and effective access to health service during the emergency (WHO, 2010).
- Promote psychotherapeutic intervention programs to the victims and health professionals. Mental health problems such as anxiety, depression or PTSD, are prevalent in the setting of disasters. As the use of specially-trained counselors focused on coping skills and improving functionality over a brief time period likely contribute to symptomatic improvement, it should be part of the standard response to emergencies (Coldiron et al., 2013).

On a more conclusive note, it is noticeable that many of these capabilities are dependent on each other or interrelated. For instance, logically, by making progress in the field of information sharing, a hospital will also more easily improve its intra- and inter-hospital cooperation capacities, since this an inherent and necessary dimension of it. Also, if, by performing recovery procedures, a hospital manages to improve beyond the level it was at before the disaster, this will already mean that it is better prepared than before, although this does not mean that it can then neglect this capability.

It will be up to each hospital to make trade-offs to decide which capabilities will provide the best return to improve first, according to the relative importance attributed to each one by the decision-makers and with the risk studies carried out regarding the nature and probability of occurrence of each emergency.

It is important to recall that other capabilities, in addition to the ones previously gathered directly related to hospital management, are necessary for an efficient nationwide crisis response, and those capabilities can be beyond institutional control. The issue of governance, for example, is often taken into account in frameworks that are not directly studying hospitals, and that greatly impacts the overall quality of response and even more specific aspects of some of the characteristics present here that are dependent on it.

While no two emergencies or disasters are alike, we believe that the development of those capabilities, along with a realistic adaptation of the Portuguese hospitals’ improvements needs concerning emergency responses, will enhance the hospitals’ capability to respond to future events.

#### **4.1.2 Do the analyzed maturity models assess some of these capabilities?**

As clarified in the previous Chapter, there is no maturity model designed for targeting specifically emergency situations. Thus, we decided to carry out one last study to ascertain if any of the existing models presents attributes with sufficiently relevant aspects or resemble enough to the emergency capabilities we have listed to justify the construction of the new model with capabilities from scratch, before proceeding to the first iteration of model development.

To this end, the previously models analyzed will first be classified according to a Likert scale, in which each model will be rated on a scale of 0 to 3 for each capability. A score of 0 will be assigned if the model makes no reference to the capability in question, and a point will be added if conforming to the parameters outlined below. Thus, for example, a score of 2 will be given for a particular capability if it complies only with P1 and P2.

- P1: Does the maturity model refer to the emergency capability “Cx”?

Table 5 - Attributes' resemblance to the intended capabilities

Maturity model	A: Hospital preparedness	B: Impact assessment & surveillance	C: Internal & external information sharing	D: Human resources management	E: Logistics & management of medical supplies	F: Inter & intra-hospital coordination	G: Fatality management	H: Volunteer management & NGO's	I: Hospital recovery	Total
Hospital information systems' maturity model (HSM) (Carvalho et al., 2019)	0	0	2	2	0	0	0	0	0	4
Networkability maturity model for healthcare providers (Filterer & Rohner, 2010)	0	0	0	2	0	2	0	0	0	4
Electronic healthcare maturity model (eHMM) (Sharma, 2008)	0	0	0	0	0	0	0	0	0	0
Hospital cooperation maturity model (HCM) (Mettler & Blondiau, 2012)	0	0	0	0	0	2	0	0	0	2
Health 2.0 maturity model (Jami Pour & Jafari, 2019)	0	0	2	0	0	0	0	0	0	2
High reliability healthcare maturity model (HRHCM) (Chassin & Loeb, 2013)	0	0	0	3	0	0	0	0	0	3
Healthcare usability maturity model (HUM) (HMSS Usability Task Force, 2011)	0	0	0	0	0	0	0	0	0	0
Demand driven supply chain management (DDSCM) maturity model for the public healthcare sector (Bvuchebe, 2020)	0	0	0	3	3	3	0	0	0	9
Game maturity model for healthcare (de Boer et al., 2016)	0	0	0	0	0	0	0	0	0	0
Patient-centeredness maturity model (PaCMM) (Sanders, 2016)	0	0	3	0	0	3	0	0	0	6
Maturity model for process management in hospitals (Cleven et al., 2014)	0	0	0	2	0	2	0	0	0	4
PACS maturity model (PMM) (van de Weering & Baenbrug, 2009)	0	0	0	0	0	0	0	0	0	0
Business intelligence in healthcare maturity model (BIMM) (Brooks et al., 2013)	0	0	0	2	0	0	0	0	0	2
<b>Average</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>3</b>

- P2: Does the maturity model indicate how to assess the current state of development of the capability “Cx”?
- P3: Does the maturity model indicate how to improve each level of capability “Cx”?

After finishing the scoring process, the models will be ranked according to their total scores, which composes the sum of all the capabilities’ scores. It is also defined as a baseline of 20 (75% of the maximum achievable points), meaning that if a maturity model scores in total 20 points or superior, it is feasible to rely on some of its elements as a basis to build a completer and more adequate model. However, if no maturity model scores more than that, it is reasonable to believe that none of them has sufficiently directed features for the intended scope and, therefore, a completely new model should be built.

During the analysis, it was often observed that, although some attributes focused on different areas, they address very similar aspects to those of the listed emergency capabilities. For example, in the HISMM, although there is no direct reference to internal and external information sharing, it is strongly focused on the electronic medical records component, which is a very useful strategy for transparent, transversal, and convenient communication between both patient-provider and health workers and, therefore, considered a branch of the information-sharing capability. Regarding the HRHCM, all of it, in general, is very focused on human factors, addressing themes like trust, work safety conditions, or training in several instances.

As portrayed in Table 5, all models fell far bellow of the maximum score of 27, with the set achieving an average total score of 3. The best count was accomplished by the DDSCM, totaling 9 points. Emergency-related issues allied to maturity models are still an underexplored area and, for this reason, less generic attributes such as fatality and volunteer management or impact assessment and surveillance, among others, are not mentioned in any of the models, which explains the observed low scores. Therefore, the use of those models as a basis to our context seems unviable. However, some of the more extensively developed attributes, especially on HRHCM, DDSCM, and PaCMM will be useful to consult when building our model.

## 4.2 Maturity Levels

Since the CMMI contains the foundational concepts of maturity model literature, providing guidelines on how to improve processes, from an initial to a more advanced state, the maturity model for response improvement to emergency situations adopts five maturity stages similarly to the CMMI.

The main goal of the developed maturity model will be to improve the impact of emergency response preparedness on the business value of the organization, which will increase when going from a lower to a higher maturity level. To attain each subsequent level (level X+1) presupposes that the organization complies with all characteristics of the previous level (level X) in a similar or improved way, which makes this maturity model follow a “stages” approach.

Initial stages of the maturity model represent practices that are poorly understood and managed, with the lack of procedures and policies resulting in low quality responses and higher risk of incurring in a deficient healthcare provision at the time of disaster. Going to higher maturity stages reduces this risk, as



policies and procedures become well understood, defined, implemented, documented and assessed. Figure 7 summarizes the overall level progression.

In addition to the already discussed maturity levels 1-5, it is also considered a level 0, meaning that the organization is not executing any emergency preparedness process or task at all. Therefore, level 0 is not explicitly mentioned within this maturity model.

To note that these stages refer to the global degree of maturity that the institution should be able to achieve, being, therefore, described in a more general way, with many of its characteristics applicable in a common way to the various capabilities within the same level of maturity.

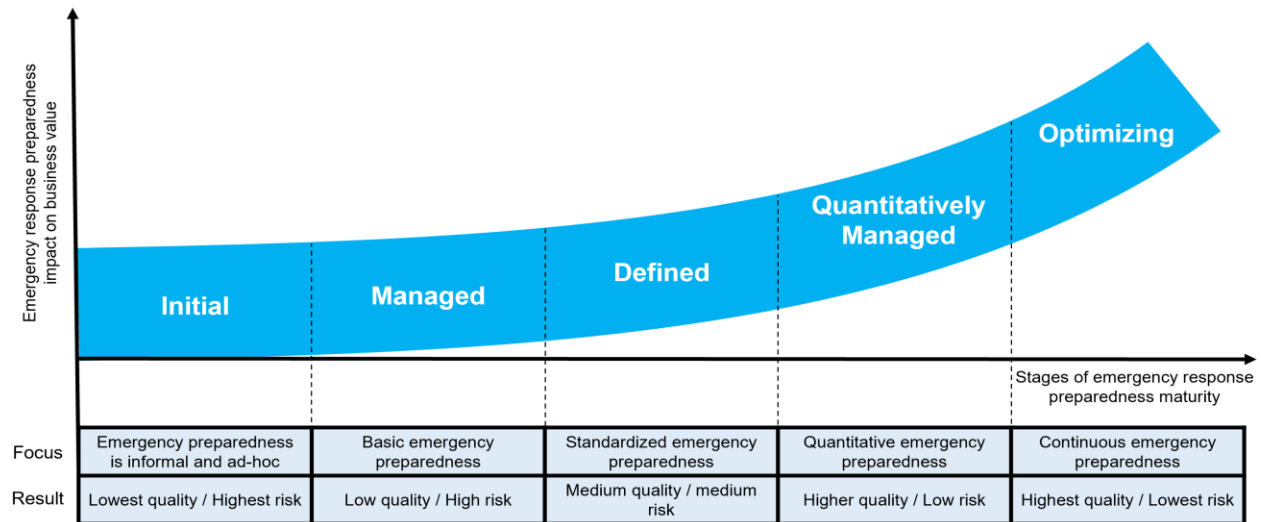


Figure 7 - Emergency response preparedness maturity curve (adapted from Proença (2018))

### Level 1 – Initial

To move from level 0 to level 1, the organization needs to at least have a perception that emergency preparedness is useful as a component of a solid business strategy. Despite this notion, there is raw management of this constituent translating into a first level characterized by an ad-hoc stage of big organizational disorganization in face of a possible disaster. There is poor knowledge of the processes' functioning in all areas inherent to disaster management and a complete lack of a viable disaster plan. With tasks poorly defined or not defined at all, this plan is elaborated as the different outcomes occur (reactive instead of preventive), leaving aside important procedures, which results in unpredicted schedules, budgets, and response quality.

With a lack of a stable environment to establish emergency preparedness processes, their hard to replicate nature tend to depend more on the competences of people than the use of a proven process. Since practices are not documented nor shared within departments, are noticeable variable levels of success.

Maturity level 1 organizations are also characterized by a small ability to repeat their successes and dangerously abandon proven practices in a time of crisis.

## **Level 2 – Managed**

The organization makes an effort to plan and perform the activities of disaster management in line with the policies established with the stakeholders. Despite these efforts, the actions end up being influenced by the repetition of elementary emergency operating conducts that have worked in the past instead of formal processes, which, leastways, when emergencies occur, ensure that basic existing practices will be followed during times of stress. As there are not precisely defined procedures and up-to-date plans, there might happen some differences in each specific iteration, and the standardization of more complex procedures proves to be difficult to accomplish. Hence the organization lacks uniformization, denoting significantly different approaches across departments to tackle similar problems.

Management activities are assigned to people with capabilities, clear responsibilities, and enough resource to produce repetition in some extent. Also, at maturity level 2, the status of services is visible to management at defined points (e.g., at major milestones, after completing major tasks).

Innovative solutions might be observed, however, the structure is not in place to control or benefit from them and they could be unnoticed or have undesirable consequences.

Resources are provided through irregular means, with hospitals often lacking defined policies or established financial commitments to resource emergency management as well as with stakeholders.

A general review is done following the incident, to the extent that measures that had positive outcomes are assimilated to be used in a posterior similar situation, but it is unlikely that there will be further analysis of the response or significant learning from it at this maturity level.

## **Level 3 – Defined**

At level 3 the responses become well-defined, standardized and consistent in quality, and the organization is capable of operating with readiness and under uniform procedures given identical circumstances. As a result, exists more consistency across the organization and there is a centralized approach to disaster management, which is a critical distinction between maturity levels 2 and 3.

It begins to exist an understanding of the relationships between emergency capabilities and rigor in detailing measures of work, work products, and services. Accordingly, processes clearly state the purpose, inputs, entry criteria, activities, roles, measures, verification steps, outputs, and exit criteria. With these standards defined, the organization should be able to start focusing on building a more sustainable response and try to gain competitive advantage, or “do better” than peer organizations, by improving emergency management overtime.

Visible and invisible barriers between departments noticeably diminish and senior management, as well as chief physicians, abandon their authoritarian leadership style, and doctors and other employees are aware of processes up and downstream of the chain. This allows to establishing a synergy between their full-time responsibilities and the development of their emergency response roles, which should be often included in the workers' training plan.

At a logistics and inventory level, emergency management aims to ensure that sufficient resources are available to deal with the risk portfolio that is likely to escalate to an unstable or dangerous level. For this, stakeholders to whom response assurance is required (either being alternative suppliers, volunteers, etc.) are raised as part of the planning strategy.

#### **Level 4 – Quantitatively Managed**

At level 4 organization would be expected to quantitatively collect, analyze, and manage indicators (and targets) for its performance to every capability throughout the life of projects, using statistical and other quantitative techniques to forecast and adapt preparedness plans to each particular emergency. These quantitative objectives are based on the needs of end users and of the organization. All this analysis of fine-grained data in which predictions are based translates into predictability of performances, a critical distinction between maturity levels 3 and 4.

The organization will use quantitative risk assessment methods to assess risks, understand its impact, and prioritize actions, also exploiting the risk knowledge and experience of partner agencies in planning its response, which is easily done once the processes are quantified and predictable. Stakeholder's satisfaction and customers' opinions are integrated into the effectiveness measures and allows to better coordinate and establish possible joint responses with other participating agencies.

Emergency management resources and facilities are managed in the same way as any other organizational asset, so there is a budget allocated for emergency response and financial target and expenditure are integrated into the normal hospital business plans.

Decisions on alterations, both regarding patient care, hospital organization, or direct primary emergency care are made collectively.

#### **Level 5 – Optimizing**

Level 5 of effective emergency response in hospitals is characterized by a closed loop of improvement, based on the conjunction of measurable processes with a quantitative understanding of business objectives and capability needs. Past experiences' performances are neatly recorded and analyzed, assisting in the plans and procedures' update overtime, according to new emerging knowledge.

Everyone has a high level of commitment and disaster management is regarded as a strategic tool. The organization can detect changes in demand, understand its root causes and, accordingly, using both conventional methods and technology, be capable of adapting the systems to cope with new circumstances, which might be internal events or changes in the external environment. Predictions and emergency preparedness plans are regularly revised, accompanied by a cost-benefit analysis of potential technological and systems trends in the various disaster capability areas to incorporate in continuous improvement proposals. The effects of deployed improvements are measured using statistical and other quantitative techniques and compared to quality and performance objectives. As a result, this kind of organization is

always innovating and is in place to make scientific contributions to the development of disaster management as a domain.

Logistics, inventory, and fatality management are monitored through informatics systems that allow transparent and real-time information sharing between coworkers, departments and different health units, increasing the collaboration with national and international partner associations.

A critical distinction between maturity levels 4 and 5 is the focus on managing and improving organizational capability. At maturity level 4, the organization and projects focus on understanding and controlling performance at the procedures level, using the results to manage projects. At maturity level 5, the organization is concerned with the overall organizational capability using data collected from multiple projects. Analysis of the data identifies shortfalls in the capability, which are used to drive organizational procedures improvement that generates measurable overall improvement in capability.

### 4.3 Maturity Table and Assessment Criteria

This Section details on the maturity table. A maturity table consists of a table that crosses maturity levels with the maturity dimensions (in our case capabilities) and characterizes each dimension in each level.

The complete maturity table is portrayed on Appendix F.A. From there, were extracted some criteria that we considered as the minimum set of questions to determine whether an organization meets a certain level for a given capability or not. These are organized from Table 6 to 14.

For each criterion there is an identifier that is defined as “Capability (correspondent letter)”“Maturity level”.”Criterion ID”. For example, the second criterion of for maturity level 4 of the hospital preparedness capability would be “A4.2”.

*Table 6 - Hospital preparedness capability assessment criteria*

Maturity Level	Criteria and Purpose
Level 1	No criteria.
Level 2	<p><b>A2.1 - Processes' approval:</b> Procedures that require third-party/administrators' approvals are handled by e-mail (or other mean), without any standardized documentation.</p> <p><b>A2.2 - A priori delegation of leadership:</b> It is known who probably will be the delegated elements/managers to become responsible for leading the operations in a potential emergency, however there is no formal document indicating it.</p>
Level 3	<p><b>A3.1 - Teams testing:</b> Teams are, in theory, familiar with the procedures to adopt during emergencies, but they were never put into practice.</p> <p><b>A3.2 - Ease of EP consultation:</b> Emergency plan is easily accessible to all staff.</p> <p><b>A3.3 - Processes' approval:</b> Procedures of major relevance and that require third-party approvals are archived following the already standardized documentation norms.</p> <p><b>A3.4 - Delegation of leadership:</b> A specific crisis group is formed only at the time of the emergency.</p>
Level 4	<p><b>A4.1 - Teams testing:</b> The current plan and correspondent involved teams were put to test (at least once), guaranteeing that every party is familiar with the procedures to adopt during crisis of different nature.</p> <p><b>A4.2 - Data and studies of past emergencies:</b> Data and studies of past emergencies were done and are well-organized and available for consultation.</p>

	<p><b>A4.3 - Pre-preparation of emergency kits:</b> There are pre-prepared emergency kits available for some variety of contexts and/or according to the number of potential victims.</p> <p><b>A4.4 - Delegation of leadership:</b> A specific crisis group/department to take responsibility of incident command and control, crisis communication and cooperation, and after-event recovery is established <i>a priori</i>.</p> <p><b>A4.5 - Crisis group constitution:</b> Crisis group/department comprises head nurses in permanent surveillance of the disaster which are in charge of channeling information to the intermediate administrators.</p>
<b>Level 5</b>	<p><b>A5.1 - Emergency plans:</b> Emergency preparedness plans exist, detailing tasks to be accomplished and by whom, being periodically revised (at least yearly).</p> <p><b>A5.2 - Crisis scenarios forecasts:</b> EP target several catastrophe scenarios according to the up-to-date forecasts made.</p> <p><b>A5.3 - EP and teams testing:</b> On-site plan and involved teams are tested regularly (at least yearly) via a matrix of emergency exercises, which reflects the range of major credible scenarios contained in the safety case. Any gaps in the testing program/emergency plan are immediately identified and corrected within a year.</p> <p><b>A5.4 - Crisis group constitution:</b> A specific group/department to take responsibility of incident command and control, crisis communication and cooperation, and after-event recovery comprises administrators (senior leaders) from the most significant emergency response areas, experienced head nurses, and specialists.</p> <p><b>A5.5 - Cost-benefit analysis:</b> Cost-benefit analysis of new solutions or potential trends related with the different capabilities are carried out in order to create a continuous path of improvement.</p> <p><b>A5.6 - Simulations:</b> Computer modelling simulations are conducted to help testing the performance of different components of the organization, in the face of a sudden increase in demand for services.</p>

Table 7 - Impact assessment and surveillance capability assessment criteria

<b>Maturity Level</b>	<b>Criteria and Purpose</b>
<b>Level 1</b>	No criteria.
<b>Level 2</b>	<p><b>B2.1 - KPIs to measure emergency status:</b> Few basic KPIs exist, reflecting the current emergency and organizational status towards it.</p> <p><b>B2.2 - KPIs revision:</b> Processes are in place for periodic review of KPIs to ensure that they always remain appropriate to the actual status of emergency.</p> <p><b>B2.3 - Staff's reporting:</b> Staff is aware of disaster reporting requirements but does not always comply with them.</p>
<b>Level 3</b>	<p><b>B3.1 - KPIs to measure emergency status:</b> KPIs are defined to measure the current emergency status and organizational performance. Through them it is possible to recognize triggers for emergency plan activation (or when to transit to the next warning level).</p> <p><b>B3.2 - KPIs creation:</b> KPIs to measure current emergency status were selected based on existent standards and legislation.</p> <p><b>B3.3 - Measuring of staff's absenteeism:</b> Procedures are in place to monitor employee absenteeism on a daily basis. Alternative workers are defined to handle the tasks of the respective missing members.</p> <p><b>B3.4 - Checklists:</b> Equipment checklists are ensured.</p> <p><b>B3.5 - Information exchange with field teams:</b> Exchange of information within front-line workers and hospital/hospital leaders is done when urgent issues need to be communicated.</p> <p><b>B3.6 - Staff's reporting:</b> Staff is aware of and complies with disaster reporting requirements.</p>
<b>Level 4</b>	<p><b>B4.1 - Checklists:</b> Equipment checklists for several occasions are ensured and accompanied with instructions for usage.</p> <p><b>B4.2 - Information exchange with field teams:</b> The hospital exchanges permanent information with deployed field teams, to know the number of patients that may need to be brought in to the facility.</p>

	<b>B4.3 - Staff's reporting:</b> Staff is aware of and complies with disaster reporting requirements, making some considerations and proposals on how to deal with disaster response.
<b>Level 5</b>	<p><b>B5.1 - Information transmittal to leaders:</b> There is a process to provide a rapid situation report to the incident managers (crisis group) that includes an assessment of the extent of the event (magnitude, the status of operations, disrupted critical services, etc.). The process is periodically reviewed and optimized based on past experiences.</p> <p><b>B5.2 - Checklists:</b> Succinct and easy-to-carry checklists are ensured separately into the different subject-matter (e.g., main duties, initial response aid-memoir, equipment lists, etc.).</p> <p><b>B5.3 - Information exchange with field teams:</b> The organization exchanges permanent information with deployed field teams, to quickly assess risks and/or health needs of communities recently affected, constituting this a primary source of information about the needed treatment for patients who may be transported to the hospital.</p>

*Table 8 - Internal and external information sharing capability assessment criteria*

<b>Maturity Level</b>	<b>Criteria and Purpose</b>
<b>Level 1</b>	No criteria.
<b>Level 2</b>	<p><b>C2.1 - Patients' records:</b> There is more than one electronical repository for patient records, being these non-interoperable.</p> <p><b>C2.2 - PIO and senior emergency managers skills:</b> PIO and senior emergency managers (leadership) are trained in risk communication skills.</p>
<b>Level 3</b>	<p><b>C3.1 - Information disclosure to public:</b> Disclosure of information to the public is done through traditional means (TV channels, radio, etc.).</p> <p><b>C3.2: - Patients' records:</b> There might be more than one repository for patient information's recording, but most systems are interoperable. Data transfer from the ones which are not is possible, despite the unnecessary time spent.</p> <p><b>C3.3 - Contacts:</b> Workers have access to the contacts they are most likely to need to reach. These considerations are also applicable for volunteers.</p> <p><b>C3.4 - Horizontal communication:</b> Communication in the hospital crosses departmental boundaries.</p> <p><b>C3.5 - Vertical communication:</b> Communication in the hospital covers different hierarchical levels.</p> <p><b>C3.6 - Language standards:</b> There are language standards for recording patients' information on the platform, to ensure a common understanding of every party.</p> <p><b>C3.7 – Information's quality:</b> Access to quality information (accurate, timely, and transparent) is ensured and shared with other members in the organization and also from the supply chain.</p>
<b>Level 4</b>	<p><b>C4.1 - Communication methods:</b> Communication with rescue teams/front-line workers are ensured mainly via telephone and institutional e-mail, however there are also two-way radio communication systems (walkie-talkies) available for all units and essential personnel.</p> <p><b>C4.2 - Contacts:</b> Everyone's contacts can be easily accessed to, if needed.</p> <p><b>C4.3 - Conferences' presence:</b> The hospital has practice of assigning members to attend conferences with the government, scientific committees, and the media to make known/discuss relevant aspects of the emergency response and/or results obtained.</p>
<b>Level 5</b>	<p><b>C5.1 - Information disclosure to public:</b> The disclosure of relevant information to the public is done through a variety of means, allowing it to reach all age groups and social classes, seeking also for original/innovative methods to raise awareness and educate the population.</p> <p><b>C5.2 - Mal-information:</b> Communication means address manners to eradicate mal-information.</p>

	<p><b>C5.3 - Patients' records:</b> There is a single hospital information recording system (EMR) up-to-date and user-friendly, supporting clear and understandable data interaction for any employee on the organization (and/or partner and stakeholders) authorized to consult/edit them.</p> <p><b>C5.4 - Workers' participation on improvements:</b> Improvements must also come from the workers and are implemented when considered pertinent.</p>
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*Table 9 - Human resources management capability assessment criteria*

Maturity Level	Criteria and Purpose
Level 1	No criteria.
Level 2	<b>D2.1 - Staff's satisfaction:</b> Satisfaction and personnel sustainability are theoretically incorporated in HR management, however practically there are no motivating activities outside the normal work environment being dynamized.
Level 3	<p><b>D3.1 - Team arrangements:</b> Roles of emergency team members are defined, however there is heavy reliance on team leader and senior managers.</p> <p><b>D3.2 - Training of professionals contracted during emergency:</b> Contracted professionals during emergency receive a brief instruction on the tasks to be performed and are then integrated into the already existent teams. There they will accompany a worker with similar tasks to theirs until they can systematize and replicate the same work.</p> <p><b>D3.3 - HR reallocation:</b> There are well-defined plans or policies for the reallocation of human resources in case of an emergency.</p> <p><b>D3.4 - Staff's preparation to integrate volunteers:</b> Staff at various hierarchical levels is prepared to integrate and assist volunteers who are called upon to intervene in the disaster response.</p>
Level 4	<p><b>D4.1 - Training plans:</b> There is a defined plan comprising several steps to educate staff on the necessary emergency competencies (adequate to each personnel group), with feedback on individual performances being provided at the end of the program. These trainings have both a transversal and a department-specific component.</p> <p><b>D4.2 - Senior managers' skills:</b> Senior emergency managers have significant experience in dealing with emergencies, being present during critical moments, despite not participating actively in simulacrum of this type.</p> <p><b>D4.3 - Training of professionals contracted during emergency:</b> Contracted professionals during emergency receive a brief instruction on the tasks to be performed and are then integrated into the already existent teams. There they will be accompanied by a "mentor".</p>
Level 5	<p><b>D5.1 - Training plans:</b> Staffing integrates emergency management competencies training with regular work, to ensure continuous practice and enhancement of skills, obtaining periodic feedback on their performance. These training sessions are conducted frequently, focusing on the teams' weak points demonstrated in previous sessions. Intermediate managers also take part on them.</p> <p><b>D5.2 - Team arrangements:</b> There are well-defined work teams, with employees being aware of the positions/roles and responsibilities they will take in emergencies.</p> <p><b>D5.3 - Flexibility to integrate other teams:</b> The quality of team training allows flexibility for workers to maintain efficiency while taking on roles in other emergency teams, if needed.</p> <p><b>D5.4 - Previously arranged portfolios:</b> There are pre-defined processes for potential urgent hires that may be needed (e.g., the hospital already has resumes in its portfolio, employment grants, etc.) destined for these purposes.</p> <p><b>D5.5 - Training of professionals contracted during emergency:</b> There are detailed training plans specially for rapid instruction of contracted healthcare professionals during the emergency period.</p> <p><b>D5.6 - Staff's satisfaction:</b> Satisfaction and personnel sustainability are incorporated in HR management, and there are strategies and non-monetary incentives to motivate employees (e.g., creative group dynamics, etc.).</p>

Table 10 - Logistics and management of clinical and non-clinical supplies capability assessment criteria

Maturity Level	Criteria and Purpose
Level 1	No criteria.
Level 2	<b>E2.1 - Order tracking:</b> The organization loses track of the order from the moment it was placed. The organization knows the agreed quantities with companies, but relies on the supplier to get them to the hospital's warehouses in the right volumes and on time, as stipulated in the contracts.
Level 3	<p><b>E3.1 - Warehouses:</b> The organization possesses traditional warehouses in which stock levels have to be checked and updated in the system daily in person by the head nurse.</p> <p><b>E3.2 - Lean:</b> There is recognition of the Lean concept as a valuable way of thinking, but its application is only done to a very small extent (e.g., in a small number of departments), as it is not a priority to the organization.</p> <p><b>E3.3 - Back-up suppliers:</b> There are alternative suppliers' contacts in the portfolio in case of urgent requests for supplies or medicines.</p>
Level 4	<p><b>E4.1 - Software:</b> There is a daily monitorization of purchases, transportations and inventory levels, with regular data reviews to ensure data accuracy. If any information is proven to be wrong/outdated, the error is immediately corrected.</p> <p><b>E4.2 - Order tracking:</b> It is not possible to get complete real-time transportation visibility, however the organization can recognize if orders have been placed, shipped, are in transit, have arrived at a warehouse, or if it is already at the wharf.</p> <p><b>E4.3 - SKUs tracking:</b> It is possible to get accurate information about all SKU's location within the organization.</p> <p><b>E4.4 - Warehouses:</b> Most of the organization's warehouses are advanced, allowing the consultation of stock levels without the need for presential identification by a head nurse.</p> <p><b>E4.5 - Lean:</b> Lean solutions or innovative ideas are implemented at request of the team leader or when a specific project is carried out to think of such solutions. It was implemented successfully in several departments, but it is not a continuous activity despite the positive outcomes achieved.</p>
Level 5	<p><b>E5.1 - Order tracking:</b> It is possible to keep real-time visibility/track (location) of the transportation order/deliveries, which allows to perform studies on routes' optimization and, generally, to have a better insight into supply chain performance.</p> <p><b>E5.2 - SKUs tracking:</b> It is possible to get accurate real-time information about all SKUs location within the organization, which is used to optimize inventory's placement and picking routes.</p> <p><b>E5.3 - KPIs:</b> A set of useful KPIs in this area are established according to the organization's goals to help monitor processes, identify critical points and problems, and improve them continuously (e.g., waiting lines, processes' time, quality, economic, etc.).</p> <p><b>E5.4 - Capacity KPIs:</b> Capacity KPIs on this area are used to predict changes in stock consumption, helping to plan accordingly.</p>

Table 11 - Inter and intra-hospital coordination capability assessment criteria

Maturity Level	Criteria and Purpose
Level 1	No criteria.
Level 2	<b>F2.1 - Preparedness cooperation with other hospitals:</b> At least in theory, interdepartmental and inter-clinic/inter-hospital cooperation is a key element of the hospital's strategy.
Level 3	<p><b>F3.1 - Demonstrated collaboration with supply chain partners:</b> There is a low-conflict and symbiotic collaboration with supply chain partners and hospitals, which was already demonstrated in real situations.</p> <p><b>F3.2 - Relationship with local hospitals:</b> Although there are no local emergency planning meetings of official nature, senior manager/crisis office representatives are in regular contact with the other hospitals' representatives and maintain good relations with them.</p>



	<b>F3.3 - Articulation between departments:</b> Departments within the same hospital address the emergency collectively, discussing and articulating the future course of action to take with each other.
<b>Level 4</b>	<b>F4.1 - Resources' sharing:</b> Plans for resource sharing and pooling (both of medical equipment and staff) are included in the organizational strategy and integrated into national partnerships. <b>F4.2 - NSR management:</b> It is possible to obtain up-to-date information about the levels and type of inventory available in the National Strategic Reserve, and its distribution is managed in conjunction with the government and the other hospitals in the Portuguese network.
<b>Level 5</b>	<b>F5.1 - Preparedness cooperation with other hospitals:</b> The hospital is part of a community-wide, integrated, inter-agency national network of hospitals (coalitions), which meet regularly and work collectively to surge overall capacity and do strategic decision making. <b>F5.2 - Joint trainings and drills:</b> Local hospitals conduct joint trainings and drills. <b>F5.3 - Risk and reward sharing:</b> There is risk and reward sharing between NHS care systems. <b>F5.4 - Resources' sharing:</b> Plans for resource sharing and pooling (both of medical equipment and staff) are included in the organizational strategy and integrated in national and international partnerships.

*Table 12 - Fatality management capability assessment criteria*

<b>Maturity Level</b>	<b>Criteria and Purpose</b>
<b>Level 1</b>	No criteria.
<b>Level 2</b>	<b>G2.1 - Mass fatality plan:</b> There is an informal mass fatality management plan which can be reactive and unreliable. <b>G2.2 - Cultural and religious procedures:</b> In cases where remains are infectious, contaminated, or evidence, the fatalities management plan addresses cultural and religious needs of deceased and survivors.
<b>Level 3</b>	<b>G3.1 - Mass fatality plan:</b> There is a well-defined mass fatality management plan, comprising treatment, transportation, and storage phases. <b>G3.2 - Coordination with institutions for fatality management:</b> A group is in place to coordinate contacts with institutions involved in emergency fatality management processes, including mortuary houses/coroner. <b>G3.3 - Extra refrigerated storage facilities:</b> The hospital has extra refrigerated storage facilities/structures (such as additional refrigerated trucks/containers) in its possession, or established contacts for quick rental/purchase of these, if needed more of them. <b>G3.4 - Institutions to manage deceased:</b> The hospital has the capacity to cope with mass fatality incidents without the need to resort to other institutions (e.g., for storage purposes).
<b>Level 4</b>	<b>G4.1 - Mass fatality preparedness:</b> Mass fatalities management is included in the overall emergency management plan (comprising treatment, transportation, storage phases, etc.) and correspondent staff was already put to test on it. <b>G4.2 - Electronic data registration system:</b> There is an electronic death registration system.
<b>Level 5</b>	<b>G5.1 - Extra refrigerated storage facilities:</b> The hospital has extra refrigerated storage facilities/structures in its possession and MOUs for quick rental/purchase of these, if needed more. There are also MOUs with secondary or back-up providers in case of the primary ones not being available. <b>G5.2 - Decedents' data registration:</b> Systematic processes are in place to ensure that all agencies and structures involved work coherently and collaboratively (e.g., dead body, missing persons and body identifications' standardized sheets and forms).

Table 13 - Volunteer management and NGOs capability assessment criteria

Maturity Level	Criteria and Purpose
Level 1	No criteria.
Level 2	<p><b>H2.1 - Volunteer management plans:</b> Procedures for volunteers' acceptance are elementary, not including all phases recommended in an appropriate volunteer management plan.</p> <p><b>H2.2 - Supervision:</b> Volunteers are assigned to a supervisor to whom they can turn for guidance.</p> <p><b>H2.3 - Asked feedback:</b> Feedback on volunteering experience is not collected.</p> <p><b>H2.4 - Organization's perception of volunteers:</b> Volunteers other than former healthcare professionals are not seen as valuable resources for the hospital and are given tasks that do not provide much added value to the organization.</p>
Level 3	<p><b>H3.1 - Volunteers' data management:</b> Standardized sheets are used during candidates' application to collect personal information about volunteers that might want to enroll in the programs and take knowledge about their desired areas of work.</p> <p><b>H3.2 - Given feedback:</b> An informal evaluation (at least) of the volunteers' work is provided.</p> <p><b>H3.3 - Asked feedback:</b> Informal feedback on their experience in the organization is asked for at the end of the working period.</p> <p><b>H3.4 - Protocols with universities:</b> Protocols are established with universities to receive students from healthcare areas and academic research projects.</p>
Level 4	<p><b>H4.1 - Volunteers' data management:</b> There are standardized form sheets that facilitate the management of data information on enrolled volunteers by those responsible for their placement, as well as for their performance evaluation, feedback registration, and others.</p> <p><b>H4.2 - Electronic data registration:</b> All the information on volunteers who have already served in the organization and potential future candidates is registered electronically, and their contacts used to spread new related news on the on-site programs.</p>
Level 5	<p><b>H5.1 - Volunteer management plans:</b> There is a well-structured volunteer program, which includes strategies for job profiling and post-first-selection interviews to help manage volunteer expectations and link them to the organization's needs.</p> <p><b>H5.2 - Asked feedback:</b> In the end of the volunteering period, the volunteer is asked for feedback on their experience so that the program can be continuously improved.</p> <p><b>H5.3 - Protocols with universities:</b> Strategies are in place to establish and encourage collaboration with universities/ student associations that can provide either direct help in the hospital, home care and emergency lines, or alternative help such as food provisions or medical supplies.</p> <p><b>H5.4 - Protocols with NGOs:</b> There are protocols established with NGOs and/or with volunteer application platforms that facilitate the search and recruitment of volunteers coming from these institutions.</p>

Table 14 - Hospital recovery capability assessment criteria

Maturity Level	Criteria and Purpose
Level 1	No criteria.
Level 2	<b>I2.1 - Registration and revision of previous responses:</b> A general and superficial review is done following the incidents, to the extent that only measures that had positive outcomes are assimilated to be repeated in a posterior similar situation.
Level 3	<b>I3.1 - Rest days as recognition for extra-work:</b> Provision of rest days are given as recognition mechanisms for front-line workers who paid extra duty hours during disaster.

	<p><b>I3.2 - Remuneration incentives:</b> Remuneration incentives for professionals working extra-hours during the emergency are attributed.</p> <p><b>I3.3 - Equipment's recovery:</b> There are norms for reviewing the need for equipment and/or infrastructure recovery.</p> <p><b>I3.4 - Adjustments of procedures for materials' acquisition:</b> After the most critical phases of the emergency, new procedures for acquisition of consumables and equipment are defined according to the learned lessons.</p>
Level 4	<p><b>I4.1 - Psychological help provision:</b> There is a possibility for psychology or psychiatry appointments, and/or a psycho-emotional emergency line available to all the workers in the organization.</p> <p><b>I4.2 - Review on users' experience:</b> Users who recurred to hospital care are asked for a review, as an opportunity to acquire feedback on system performance.</p> <p><b>I4.3 - Equipment's recovery:</b> There are norms for reviewing the need for equipment and/or infrastructure recovery. The necessary measures are immediately put in place.</p>
Level 5	<p><b>I5.1 - Registration and revision of previous responses:</b> Each department's response to the emergency is properly recorded and periodically reviewed, looking for alternative ways to make them more efficient.</p> <p><b>I5.2 - Plans adjustments:</b> Enhancements on the organization's action plans are made taking into account the projection of new critical episodes.</p> <p><b>I5.3 - Psychological help provision:</b> Specific psychotherapeutic intervention programs are implemented for the public and the professionals most exposed to the emergency situations (e.g., psycho-emotional emergency line).</p>

## 4.4 Chapter Conclusion

This Chapter describes the development of the maturity model meeting the fourth goal of this dissertation, mentioned on Section 1.2.

The Chapter derives mainly from the unfold of the 1<sup>st</sup>. iteration, focusing on the definition of the characteristics and structure of the maturity model. We started by ascertain the most meaningful areas to master when trying to grow an institution prepared to provide an organized response at the time of a disaster, ending up with 9 capabilities: hospital preparedness, impact assessment and surveillance, internal and external information sharing, human resources management, logistics and management of clinical and non-clinical supplies, intra and inter-hospital coordination, fatality management, volunteer and NGOs management and, hospital recovery.

Five maturity levels, initial, managed, defined, quantitatively managed, and optimizing, which can be found with similar designations in various well-known models, such as the CMMI were proposed. For each capability, we then modeled what was the manifestation of that capability at the different maturity levels, which culminated in our maturity table presented in Appendix F.A.

However, the 1<sup>st</sup>. iteration will only be finished after conducting a trial assessment using the maturity model (covered in the next Chapter), which will allow to reveal imperfections to then fine-tune the maturity table accordingly, in addition to other adjustments in the assessment tool (questionnaire) and interview mode that we consider as necessary.

# 5 Hospitals' Assessment

The following Chapter delimits a boundary between the theoretical and the more practical component of this dissertation, making reference to the evaluation step, a main element of DSR, which is imperative to show the “utility, quality, and efficacy of a design artifact” (Hevner & Chatterjee, 2010). A detailed description of the assessment process is provided, which was performed in accordance with the ISO/IEC 33030 and SCAMPI procedures explained, respectively, in Sub-sections 3.6.1 and 3.6.2, testing and validating, this way, the applicability of the developed maturity-mapping tool. To bear in mind that this Chapter also denotes the end of the 1<sup>st</sup>. iteration, constituted by the first “round” of interviews, and the beginning of the 2<sup>nd</sup>., where the enhancements made allowed to perform the assessments with an already refined model.

First off, Section 5.1 will provide insight on the preparation for the assessment, elaborating on the hospitals' sample selection, the questionnaire's development process, and on the projection for the interview unfolding. Section 5.2 will elaborate further on how the interviews took place, distinguishing between the methods used in the 1<sup>st</sup>. and 2<sup>nd</sup>. iteration. Lastly, Section 5.3 will focus on the presentation and discussion of the data collected during the assessment.

## 5.1 Plan and Prepare

It would be desirable for this study to obtain a sample comprising establishments of different sizes and regions, which would allow to secure a bigger variety of work environments and come across different practices and, consequently, solutions for a change that might be pertinent to replicate among hospitals. Furthermore, it was intended to take conclusions about whether the much-criticized unequal provision of healthcare between regions in Portugal (Baganha et al., 2002) would also be correlated with / influence the hospitals' quality of response to emergencies. It was possible to obtain the desired set with all the 12 contacted hospitals across different regions of the country showing willingness to collaborate in our study. This distribution is shown in Figure 8.

The main goal was to conduct interviews aimed at capturing information regarding the several capabilities from different perspectives, thereby leading us to more accurately assess the maturity level of each hospital's capability and, ultimately, of the hospital itself. For that, the best possible scenario would be to include several professionals from different hierarchical levels in each individual department in the covered areas, to guarantee an organization-wide view. As we were aware that not only this was a target very difficult to accomplish, but also would lead to an excessive amount of data, we aimed at reaching, per hospital, at least three members familiar with the identified capabilities. When contacting the institutions, they were asked to ensure the presence of professionals dealing with one of the following areas: (1) Risk management (and/or the person who carries out the risk management report); (2) Certification processes; (3) Audit processes; (4) Human resources; (5) Procurement and logistics (purchasing/definition of purchasing processes); (6) Patient management (user/inbound processes); (7) Communication department.



Figure 8 - Geographical distribution of collaborating hospitals

In an attempt to dispel the reluctance raised by some interviewees in participating, they were assured complete anonymity, as well as of the organizations. Still, many of them insisted in getting clearance from ethic committees and numerous intermediates, which largely hampered a process that even without that was already cumbersome. In the end, the number of participants' projection was reached, as we managed to gather responses of four workers in each of the hospitals where in-person interviews were performed, and, due to the limited availability of time, a participant per hospital in the Google Forms filling stage, which we consider sufficient to consider the study as feasible.

Table 15 – Interviewees' profiles

	Interview Format	Hospital	Participant	Organizational role	Accumulated experience (years)
1 <sup>st.</sup> Iteration	In Person	H1	P1	Clinical and Non-Clinical Risk Manager	6
			P2	Project Manager and Investment and Assets Office Coordinator	3
			P3	Human Resources Director	7
			P4	Procurement and Logistics Administrator	2
2 <sup>nd.</sup> Iteration	In Person	H2	P5	Human Resources Director	6
			P6	Clinical Material's Strategic Manager	2
			P7	Hotel Services Manager and Risk Manager	12
			P8	Patients Manager	12
	Google Forms	H3	P9	Clinical and Non-Clinical Risk Manager	5
		H4	P10	Logistics Manager	3
		H5	P11	Supply Chain Director	6
		H6	P12	Chief Information Security Officer (CISO)	3
		H7	P13	Accreditation and Certification Director	3
		H8	P14	Supply Chain Manager	4
		H9	P15	Information Systems Director	5
		H10	P16	Chief Risk Officer	5
H11	P17	Human Resources Manager	6		
H12	P18	Emergency Services Logistic Responsible	4		

Interviewed participants' provided information by virtue of their knowledge and experience in dealing with previous emergencies, or in their preparation for such situations. Table 15 summarizes some information about the interviewed personas.

A semi-structured interview mode was prepared, guided by a previously elaborated questionnaire comprising a set of questions to be explored. The application of semi-structured interviews in multiple contexts ensures consistency and allow corroboration of data emerging from multiple sources (Maree, 2011). Additionally, this method enabled, not only to gather more general information about the organization, participants, and their future's expectations on it, but also to obtain a broader perception of the institution, leveraging from the format in which the open questions were formulated. During the "in-person stage", this approach allowed openness for discussion to new ideas that emerged throughout the interview regarding the topics addressed, while not neglecting the overall purpose of it and the assessment standards proposed by the ISOs. Figure 9 schematizes the projection for the assessment unfolding.

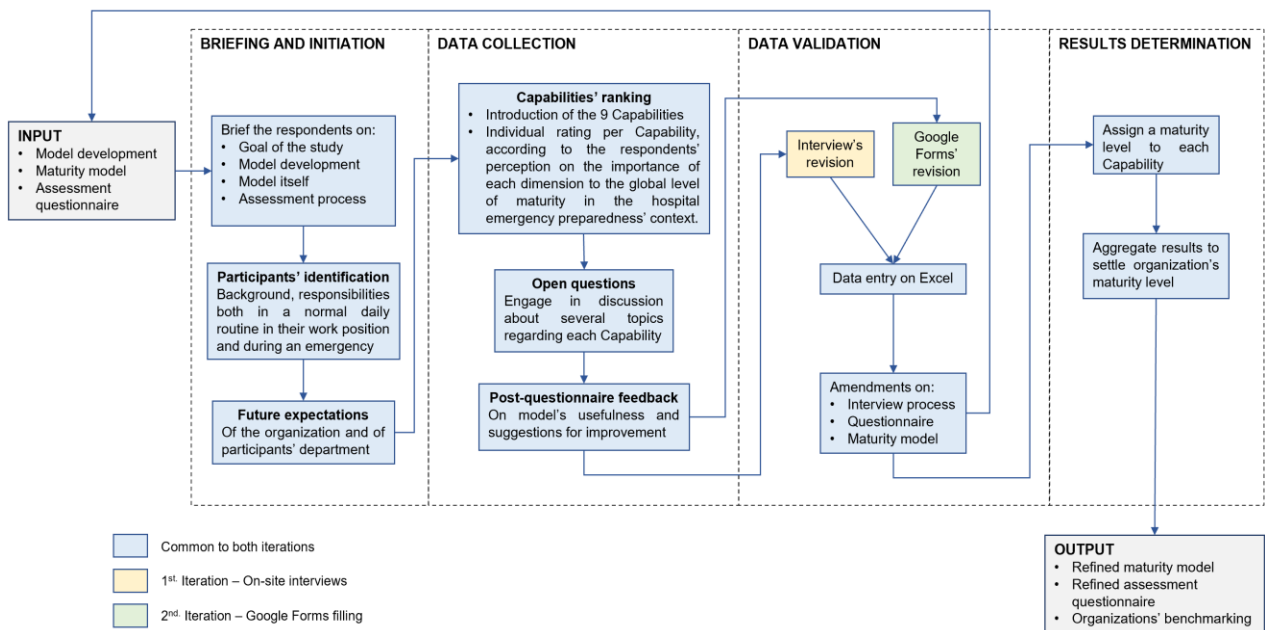


Figure 9 - Projection of the assessment's unfolding

As a mean to avoid difficulties for the participants and confusion regarding the terminology, the questionnaire was translated to Portuguese (i.e., participants' native language). Later, the assessment in H1 confirmed the importance of this translation, as one of the participants referred to not be very fluent in English.

According to Becker et al. (2009), the evaluation step of the maturity model also includes the "conception of transfer and evaluation". This means that there should be a description of the rationale behind the development of the questionnaire to be used to assess an organization's maturity. Therefore, despite the questionnaire being available for consultation in Appendix F.B, briefly, its composition can be summarized as follows:

- A. Respondent's background:** Basic information concerning the targeted group, namely about their background in the organization and tasks assigned both in what would be a normal daily routine in their work position and during an emergency (recalling mainly the COVID period). The respondents' contacts were also collected in case for further need of clarifications.
- B. Future expectations:** Regarding both the organization as a whole and the interviewees current department, which will allow to obtain an additional insight into the future goals in a post-pandemic era beyond the general strategic ones available for consultation on the institutions' websites. This will constitute an essential step later on to better align the business goals with the proposed improvements (as recommended in S1 of ISO/IEC 33014, described Sub-section 3.7.1).
- C. Capabilities' ranking:** Individual rating per capability on a 5-point Likert's scale, according to the respondents' perception on the importance of each dimension to the global level of maturity in the hospital emergency preparedness' context. At the end, taking into account the rankings of all interviewees, it will be possible to assign different weights to the capabilities, which combined with our level attribution followed by a posterior aggregation, will provide a more accurate overall level of maturity of each organization.
- D. Open questions:** Composed of 120 questions related to the capabilities mentioned in the previous topic, which will serve to infer the level at which the hospital under consideration is ranked. One aspect to consider is that each question is created independent from all the others and all the questions have the same weight to the maturity level calculation.  
 Respondents were instructed to either answer with YES or NO, providing evidence to justify their answers, or DON'T KNOW, if they were not sufficiently familiar with the subject. The latter was also attributed at the time of data validation (while reviewing the interview's recording), when the provided answers were considered out of context, which happened quite often.
- E. Post-questionnaire feedback:** 5-point Likert's scale classification to the questions regarding the usefulness of the model, which will serve as basis for the enhancements deemed as necessary to the questionnaire, the interview mode, and the model, drawing the line between 1<sup>st</sup>. and 2<sup>nd</sup>. iteration.

It was decided that the participants would not be assigning a level to each capability themselves, but instead that we would evaluate the organizations' capability afterwards, once received the questionnaire results of all participants from each hospital. This option was chosen not only to avoid further lengthening the duration of the interview, which was already exhaustive due to the questionnaire's extension, but also to make a more careful/thoughtful decision regarding the levels, taking into account all the criteria presented in the maturity table and the coherence of answers given by the various participants.

## 5.2 Conduct Appraisal

From now on we will be referring to the different hospitals as H#, to the participants as P#, and to the capabilities using the correspondent letters.

In total, the data collection took place over a period of 10 weeks, during the months of July, August, September and October. The appraisal correspondent to the 1<sup>st</sup>. iteration took place only in H1, which will be more detailed in Sub-section 5.2.1. Then, based on the preliminary findings in that period, the data collection method was revised, weaknesses on it identified and corrective actions taken as needed (Sub-section 5.2.2). The 2<sup>nd</sup>. Iteration comprises a presential phase on H2 and an online phase based on Google Forms filling, which required an adaptation of the assessment tool (questionnaire) to fit it into the new molds.

### **5.2.1 On-site interviews in H1 – 1<sup>st</sup>. iteration**

All face-to-face interviews were conducted in the respective institutions, recurring to the use of a voice recorder, previously authorized by each interviewee. Four meetings were conducted with an average span of 02h:16min (1h:06min for the one that took least time and 04h:01min for the one that took the longest). At the end of the questionnaire answering with P4 was also possible to visit the hospital's warehouse, however the visit's duration was not taken in consideration for these statistics. This visit was considered of big importance since it was useful to corroborate some of the questionnaires' answers and also because it is easier to propose improvements to something that we have actually analyzed. Furthermore, it was possible to get more operational feedback from some of the warehouse's field workers that were present at the moment, which helped to understand certain efficiency problems in that area.

### **5.2.2 Enhancements**

After the trial assessment using the maturity model several relevant issues were identified. For a better arrangement, we have decided to report the changes according to the sections of the questionnaire where the errors were perceived, however the adjustments were not only done to the questionnaire, but also to the maturity table.

#### **A. Respondent's background**

While on a first phase of the on-site interviews it was found useful to retain personal data such as telephone number, e-mail, and current employment institution in case of a posterior need for further clarifications, in later interviews participants seemed skeptical in providing this type of information, arguing that "being an anonymous questionnaire, they did not understand the motive behind the collection of these data".

As we sensed that this detail could alienate people's willingness to collaborate in the study, it was decided that the "telephone" and "e-mail" fields should be removed and that, once it was not imperative for the study to know the exact institution's location of each hospital, we could ask for the hospital's district instead. This would not cause interference in the data collection and analysis during the 2<sup>nd</sup>. iteration, since we would only assess hospitals in different districts, therefore with no possibility of more than one hospital belonging to the same district causing potential erroneous data processing (e.g., in that case it would not be possible to distinguish if two surveys corresponded to two people both from the same hospital or from different hospitals).



## **B. Future expectations**

A certain difficulty was noticed among the participants in answering the questions addressed in this topic. With some respondents reporting that their organization and/or department did not have future expectations or “had nothing to improve” we realized that the cause could come not only from a lack of post-catastrophic analysis but also from the broad scope in which our questions were formulated. Thus, an adaptation was made by adding on various “check” options with suggested answers of relevant examples for each of the two questions, plus a final option “other” with the possibility to fill in with any other alternative that the respondents considered relevant.

## **C. Capabilities**

The trial revealed that there was a difficulty in understanding terms related to the engineering/management area, as well as a misconception in our use of more specific language in the medical area. As an example, although participants could understand the definition of capability E, which initially was described as “Logistics and management of medical supplies”, it was pointed out that the term “medical supplies” was not the most appropriated to use in that context, and suggested “clinical and non-clinical supplies” instead. This led to a revision of the assessment questionnaire and an overhaul of the maturity table to accommodate the changes to the assessment questionnaire.

Likewise with the term “atividade médica” for “atividade assistencial”, although this problem was exclusive to the Portuguese version of the questionnaire and, therefore, did not require the same changes.

Through the post-questionnaire feedback (questionnaire’s E section), P4 (participant 4) indicated us, in paragraph b), that a leadership component was crucial for emergency management and should be a more present segment in the model. Accordingly, it was decided to incorporate the leadership topic as an integral part of capability D, human resources management, being also necessary to include a criterion in the maturity table to address this subject matter.

Furthermore, P3 proposed the inclusion of a capability related to governance, justifying it with the poor performance demonstrated by DGS (Direção Geral da Saúde) and the Ministry of Health in managing the national strategic reserve and, consequently, in cooperating with hospitals in PPEs (Personal Protective Equipment) provision. As mentioned before, since it is a domain that somehow transcends the boundaries of the institution and, moreover, integrates components already present in other capabilities (such as human resources and information management) (WHO, 2007, p. 5), it was not considered appropriate to include a whole capability referring exclusively to this area. However, we tried to adapt the suggestion and add a criterion referring to stewardship in capability F, intra and inter-hospital coordination.

## **D. Open questions**

Once again, in this section the main difficulty was related to the understanding of management terms, with most of the interviewees, except those linked to logistics and procurement, not understanding the reference

to “members of supply chain” in C3.7, assuming that it was a mention to the internal workers and not to external partners in the chain, as intended.

Also, there was a question, “Logistics software that integrates purchasing processes and allows to obtain real-time information about transportation of goods and current inventory level (e.g., SAP or similar) is used”, that we realized to have too much information aggregated from fields that were not necessarily interrelated. As an example, P4 in H1 stated that they used logistic software, that it allowed, in fact, to integrate purchasing processes, and, lastly, that it was possible to know the current level of “informatic inventory”. However, the organization could not have access to current accurate information about the transportation of goods, beyond the order placing date. It was then decided to segment the question in four different ones: Do you use logistics software that allows to integrate purchasing processes? Does it allow to know current accurate information about the transportation of goods? Does it allow to access current inventory level?

With regard to the questions concerning capability G, fatality management, here too it was necessary to run through the aborced topics, since we were including procedures that were no longer to be handled by the hospital, once they are only responsible for the bodies until the moment they leave the facility. Therefore, a question about the need for mass graves usage was excluded.

### **5.2.3 On-site interviews in H2 + Google Forms filling – 2<sup>nd</sup>. iteration**

The objective of the second iteration was to build on the success of the results of the 1<sup>st</sup>. iteration.

The 2<sup>nd</sup>. iteration started with a another “round” of presential interviews, this time conducted in H2. Once again, a voice recorder was used, which helped to review the answers later while making the data entry on Excel (Appendix F.C) and on its validation. Four meetings were done with an average time of 01h:10min (00h:38min on the shortest and 1h:34min on the longest). Similar to P4 in H1, P6 in H2 also made themselves available to give us a guided tour through the general warehouse.

On the second phase of 2<sup>nd</sup>. Iteration, in addition to the adjustments carried out in the content of the assessment questionnaire and maturity table, an adaptation had to made to the structure, in order to accommodate the Word version to the Google Forms one. The briefing on the study had to be written down to make up on the lacking of this oral step. Also, all questions were placed as compulsory, with exception of the justifications for the open questions, since enforcing answers in this field would possibly oblige respondents to abandon the questionnaire to perform other tasks or gather further information to complete it. Nevertheless, these justifications/comments/clarifications were to be considered by the assessment team when evaluating the answers.

The questionnaire was sent to the pilot owners and available online at <https://drive.google.com/file/d/1H5kewUAfkgQksBxDYBdp4WFFJ0xK8qT/view?usp=sharing>. It was divided in sections (A, B, C, and D), with the latter presented in a set of nine tabs, one for each of the dimensions (capabilities) of the maturity model. In the beginning of each section, a short description of how to fill it out was presented.

## 5.3 Report Results

The first stage of analysis aimed at running through each hospital identifying the least mature emergency capabilities that have high impact on the organization and require low effort to implement/sustain. Subsequently interventions are planned to address these capabilities, which will lead to the improvement of the organization’s overall capability.

This Section details the analysis of the results obtained. Sub-section 5.3.1 starts with the presentation of all answers provided by the respondents and goes through the data processing method in order to determine each capabilities individual level. In Sub-section 5.3.2, the procedure to determine the overall maturity level of each organization is detailed. Sub-section 5.3.3, culminates the results of the previous ones, making comparisons between the different hospitals and initiating the transition to the next Sub-section, the improvements proposal for the underperforming areas.

### 5.3.1 Capabilities’ maturity level

Table 16 details the answers provided to each question by each pilot, where “Y” means “Yes”, “N” means “No”, and “DK” means “Don’t know”.

To bear in mind that the answers are according to the questionnaire, which are not always formulated in the same words as the criteria they correspond to. Also, some questions had to be adjusted when entering their answer on Excel, since they either were dependent on other answers of an upper level or were formulated in the negative form. This way, in questions: A2.1=Y if A3.3=Y; A3.1=Y if A4.1=Y; A4.1=Y if A5.3=Y; A3.4=Y if A4.4=Y; C2.1=Y if answered as N and C2.1=N if answered as Y; I2.1=Y if I5.1=Y.

For hospitals H1 and H2, since in some cases there was not a consensus on the answer, to determine it we had to run through each of these questions to check justifications and consider the most plausible ones. These can be consulted in the Excel document (Appendix F.C), on the “Interviews” separator. The considered answer in these situations is highlighted in bold. Also, in cases where every respondent in the hospital answered “DK” we considered as a N.

Table 16 - Final results of the answers of all respondents

Q#	H1				H2				H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
<b>A: Hospital Preparedness</b>																		
	<b>3</b>				<b>2</b>				<b>4</b>	<b>1</b>	<b>4</b>	<b>5</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>3</b>	<b>4</b>
A2.1	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
A2.2	Y	DK	DK	DK	DK	DK	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	Y
A3.1	Y	DK	DK	Y	DK	Y	DK	DK	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
A3.2	Y	DK	DK	DK	DK	DK	DK	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A3.3	Y	Y	Y	Y	Y	DK	DK	DK	Y	N	Y	Y	Y	Y	N	Y	Y	Y
A3.4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A4.1	N	DK	DK	N	DK	N	DK	DK	Y	Y	Y	Y	Y	N	N	Y	N	Y
A4.2	N	N	Y	DK	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A4.3	Y	Y	DK	Y	Y	Y	Y	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A4.4	N	DK	DK	DK	DK	DK	N	DK	Y	Y	Y	Y	Y	Y	N	N	Y	Y
A4.5	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A5.1	Y	DK	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y

A5.2	Y	DK	DK	N	Y	Y	Y	DK	N	N	N	Y	Y	N	Y	Y	Y	Y	
A5.3	N	DK	DK	N	N	DK	N	N	N	N	N	Y	Y	N	N	Y	N	Y	
A5.4	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N	Y	Y	N	
A5.5	N	Y	DK	Y	N	N	DK	DK	Y	Y	Y	Y	Y	N	N	Y	Y	N	
A5.6	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	Y	Y	N	N	
<b>B: Impact assessment and surveillance</b>																			
	1				2				1	2	1	3	3	3	4	3	3	3	
B2.1	Y	DK	Y	Y	Y	DK	Y	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
B2.2	N	DK	DK	DK	N	Y	Y	DK	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	
B2.3	Y	DK	Y	DK	Y	DK	DK	DK	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	
B3.1	Y	DK	Y	Y	Y	Y	Y	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
B3.2	Y	DK	Y	Y	Y	Y	N	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
B3.3	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
B3.4	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	
B3.5	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
B3.6	DK	DK	DK	DK	DK	DK	DK	DK	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	
B4.1	DK	DK	DK	Y	DK	Y	DK	DK	Y	N	Y	Y	N	N	Y	Y	Y	Y	
B4.2	Y	Y	Y	Y	Y	DK	Y	DK	Y	Y	Y	N	Y	N	N	Y	N	Y	
B4.3	Y	DK	DK	DK	DK	DK	DK	DK	N	Y	Y	N	N	N	Y	N	Y	N	
B5.1	DK	DK	DK	DK	DK	DK	DK	DK	Y	N	Y	N	Y	Y	N	N	Y	Y	
B5.2	Y	Y	Y	Y	Y	Y	N	DK	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	
B5.3	Y	DK	DK	DK	DK	DK	DK	DK	N	N	Y	N	N	N	N	N	N	Y	
<b>C: Internal and external information sharing</b>																			
	4				1				1	3	1	3	1	3	1	3	1	5	
C2.1	Y	Y	Y	Y	Y	Y	DK	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	
C2.2	Y	DK	DK	DK	DK	DK	DK	DK	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	
C3.1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	
C3.2	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	
C3.3	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
C3.4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
C3.5	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
C3.6	Y	Y	DK	DK	Y	DK	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	
C3.7	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
C4.1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
C4.2	Y	Y	Y	Y	DK	DK	DK	DK	Y	N	Y	N	Y	N	N	N	N	Y	
C4.3	Y	Y	Y	Y	Y	N	N	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
C5.1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	
C5.2	Y	Y	Y	Y	N	DK	Y	N	N	N	N	N	N	N	N	N	N	Y	
C5.3	N	Y	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	
C5.4	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
<b>D: Human resources management</b>																			
	2				2				2	2	2	3	2	2	2	2	2	3	
D2.1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
D3.1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
D3.2	Y	DK	DK	Y	DK	Y	Y	DK	N	N	Y	Y	N	Y	N	Y	Y	Y	
D3.3	N	DK	N	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	
D3.4	Y	Y	Y	N	Y	DK	N	N	N	N	N	Y	Y	N	N	N	N	Y	
D4.1	Y	N	Y	N	Y	Y	Y	DK	Y	N	Y	Y	Y	N	N	N	Y	N	
D4.2	Y	Y	Y	Y	Y	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
D4.3	Y	DK	DK	Y	DK	N	Y	DK	Y	Y	N	N	Y	Y	Y	N	N	Y	
D5.1	N	DK	DK	N	DK	N	DK	DK	Y	Y	Y	Y	N	N	Y	Y	N	N	
D5.2	Y	N	DK	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	
D5.3	Y	DK	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	Y	
D5.4	Y	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
D5.5	N	DK	N	N	N	N	Y	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y	
D5.6	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
<b>E: Logistics and management of clinical and non-clinical supplies</b>																			
	2				1				3	2	3	2	4	3	3	2	2	5	
E2.1	DK	DK	DK	Y	DK	N	DK	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
E3.1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
E3.2	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	
E3.3	DK	DK	DK	N	DK	N	DK	DK	Y	Y	Y	N	Y	Y	Y	N	Y	Y	
E4.1	Y	Y	DK	N	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
E4.2	DK	DK	DK	N	DK	N	DK	DK	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	
E4.3	N	DK	DK	N	Y	N	N	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
E4.4	N	N	N	N	N	N	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	

E4.5	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	N	N	N	N	Y	
E5.1	DK	DK	DK	N	DK	N	N	DK	N	Y	Y	Y	N	Y	Y	Y	Y	Y	
E5.2	N	DK	DK	Y	Y	N	N	DK	Y	Y	Y	Y	Y	Y	Y	N	N	Y	
E5.3	Y	DK	DK	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
E5.4	Y	DK	DK	Y	N	N	N	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
<b>F: Intra and inter-hospital coordination</b>																			
	2				3				4	4	4	2	4	4	4	4	2	2	
F2.1	Y	Y	Y	Y	Y	Y	Y	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
F3.1	N	DK	DK	N	Y	Y	Y	DK	Y	Y	Y	N	Y	Y	Y	Y	N	N	
F3.2	Y	DK	Y	Y	Y	Y	Y	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
F3.3	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
F4.1	N	DK	Y	Y	N	Y	N	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
F4.2	N	DK	DK	N	DK	DK	DK	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	
F5.1	Y	DK	Y	Y	Y	N	Y	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
F5.2	DK	DK	DK	DK	DK	N	DK	DK	Y	N	Y	N	Y	N	N	N	N	Y	
F5.3	N	DK	N	Y	N	N	Y	N	N	N	N	Y	Y	N	Y	Y	Y	Y	
F5.4	N	N	DK	Y	N	DK	N	DK	N	N	N	N	N	N	N	N	N	Y	
<b>G: Fatality management</b>																			
	1				1				2	2	2	2	2	2	2	2	2	2	1
G2.1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
G2.2	N	DK	DK	DK	DK	DK	DK	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	
G3.1	DK	N	DK	DK	DK	DK	DK	DK	Y	Y	Y	N	Y	N	Y	Y	Y	Y	
G3.2	Y	DK	DK	DK	Y	Y	DK	DK	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	
G3.3	Y	Y	DK	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	
G3.4	Y	DK	DK	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
G4.1	Y	Y	DK	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	N	Y	
G4.2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
G5.1	DK	DK	DK	DK	DK	DK	DK	DK	Y	N	Y	N	Y	N	Y	N	N	N	
G5.2	Y	DK	N	Y	N	DK	DK	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
<b>H: Volunteer management and NGOs</b>																			
	1				2				4	2	3	2	2	2	2	2	3	3	
H2.1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
H2.2	Y	DK	DK	DK	N	Y	N	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
H2.3	N	Y	N	N	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
H2.4	Y	DK	Y	DK	DK	Y	DK	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
H3.1	N	DK	DK	DK	N	N	N	N	Y	Y	Y	N	Y	N	N	N	Y	Y	
H3.2	N	DK	DK	DK	N	Y	N	DK	Y	N	Y	N	N	N	N	Y	Y	Y	
H3.3	N	DK	DK	DK	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
H3.4	Y	DK	Y	DK	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
H4.1	N	DK	N	DK	DK	N	N	N	Y	Y	Y	N	N	N	Y	N	N	N	
H4.2	N	DK	DK	DK	DK	N	DK	DK	Y	N	N	Y	Y	N	Y	Y	N	N	
H5.1	N	DK	DK	N	N	DK	N	DK	N	N	Y	Y	Y	Y	Y	Y	Y	Y	
H5.2	N	DK	DK	DK	N	N	N	DK	Y	N	N	N	N	N	Y	N	Y	N	
H5.3	N	Y	Y	DK	N	N	N	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
H5.4	N	DK	DK	DK	N	N	N	DK	N	N	N	N	N	N	N	N	Y	Y	
<b>I: Hospital recovery</b>																			
	3				2				2	5	5	3	5	3	3	5	2	2	
I2.1	Y	DK	DK	DK	DK	DK	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
I3.1	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	
I3.2	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
I3.3	Y	Y	DK	DK	Y	Y	Y	DK	N	Y	Y	Y	Y	Y	Y	Y	N	N	
I3.4	Y	DK	DK	Y	Y	N	N	DK	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	
I4.1	Y	Y	Y	Y	Y	Y	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
I4.2	N	N	DK	DK	DK	DK	DK	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
I4.3	N	DK	DK	DK	DK	N	DK	DK	Y	Y	Y	N	Y	N	N	Y	Y	Y	
I5.1	N	N	N	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
I5.2	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
I5.3	Y	Y	Y	Y	Y	N	N	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	

Note that each criterion has a specific assigned level corresponding to the maturity level definition. Consequently, an organization can only be on a specific level if it meets the criteria for the previous level and all the criteria correspondent to that level. For example, if the organization fulfills some criteria from level 4, while some level 2 criteria are still missing, it will be classified as level 2 in that capability. This

means that they have focused on improving certain aspects further when they have yet to develop more basic ones. The idea is that organizations can identify and develop an improvement path.

Then, to attribute levels to each capability in each hospital, a formula was created on Excel, adapting it to the number of questions in each capability. As an example, for capability F: =IF(L93="N";1;IF(OR(L94="N";L95="N";L96="N");2;IF(OR(L97="N";L98="N");3;IF(OR(L99="N";L100="N";L101="N";L102="N");4;5))).

A curious observation when analyzing the data was that according to the second data collection method (Google Forms filling), none of the participants answered DK to any of the questions.

### 5.3.2 Overall maturity level

The overall maturity level of the organization is calculated differently, by using a weighted distribution of points. Consequently, the maturity level represents the maturity with regards to the total number of criteria met, i.e., the order by which the criteria is obtained in the organization is not considered in the result.

Here it was decided to take into account the importance perceived by the participants in regard to each capability for the overall level of maturity of the institution (determined through the questionnaire's F.B.C Section in Appendix F.B) to obtain the final value.

The perceived importance was firstly transposed to a new scale ranging from 0 to 20, in which an importance of 5 (on questionnaire's scale) corresponds to 20 points, 4 to 15, 3 to 10, 2 to 5, and lastly 1 to 0 points. This way the maximum achievable score would be 180 points, if all the 9 capabilities would have been classified with a score of 5, as it happened for example with P2. As this not happens for all participants, the maximum achievable score (in  $\sum$  of Table 17) varies and, consequently, the points per level in different hospitals also differ and will have to be used individually to match the final score achieved by each hospital to a maturity level.

Table 17 - Perceived importance by participant

Perceived importance by participant (New scale)																				
C#	H1				H2				H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	Count	
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18		
A	20	20	15	15	10	15	20	20	20	20	20	15	20	15	15	20	20	20	11	
B	20	20	20	20	20	15	20	20	15	20	20	20	20	15	20	20	20	15	14	
C	15	20	20	20	20	20	20	15	10	15	15	20	20	20	20	15	20	15	11	
D	20	20	20	15	20	15	20	15	15	15	10	15	20	10	10	15	20	10	7	
E	20	20	20	20	20	20	20	20	10	20	20	10	15	20	10	10	5	20	12	
F	20	20	20	20	20	20	15	15	15	15	15	15	20	10	20	15	20	10	9	
G	15	20	15	10	15	20	20	15	5	5	5	5	10	5	5	5	5	5	3	
H	15	20	10	5	10	10	15	10	5	5	5	5	10	5	5	5	15	5	1	
I	20	20	15	20	15	10	15	15	15	15	15	20	20	15	15	20	15	20	7	
$\sum$	165	180	155	145	150	145	165	145	110	130	125	125	155	115	120	125	140	120		
Points per level	33,0	36,0	31,0	29,0	30,0	29,0	33,0	29,0	22,0	26,0	25,0	25,0	31,0	23,0	24,0	25,0	28,0	24,0		

This transposition of scales was considered necessary once using the first scale ranging from 1 to 5 could be too minimal and ending up lacking in detail, leading to erroneous data. This assumption was confirmed in the experience available for consultation in Excel's "OL smaller test scale" sheet (Appendix F.C), where H4 obtained a maturity level 4 instead of 3.

Since H1 and H2 had several interviewees, the highest degree of importance was considered. This way the maximum achievable score for H1 is 180 points (9×20) and for H2 is 170 (7×20+2×15).

Table 18 - Number of questions per level in each capability

Level	Threshold (0-20)	Number of questions per Level								
		A	B	C	D	E	F	G	H	I
1	0	0	0	0	0	0	0	0	0	0
2	5	2	3	2	1	1	1	2	4	1
3	10	4	6	7	4	3	3	4	4	4
4	15	5	3	3	3	5	2	2	2	3
5	20	6	3	4	6	4	4	2	4	3
<b>Total</b>		17	15	16	14	13	10	10	14	11

For each hospital, we proceeded to divide the points of perceived importance in each capability (Table 17) by the total number of questions in that capability (Table 18), determining the points per question for each capability. These were then multiplied by the number of questions awarded with YES (identified with COUNTIF functions) for each level and each capability. This process was repeated to all the levels in all capabilities, which summed all together corresponded to a value between 0 and 180 and, therefore, to a maturity level as described above (Table 19). All these calculi can be consulted in Excel's sheet "Overall level" (Appendix F.C). As an example:

$$\text{Points (A) in H4} = \frac{20}{17} * (1 + 3 + 5 + 3) = 14,12$$

$$\text{Total points in H4} = 14,12 + \text{Points(B)} + \text{Points(C)} + \text{Points(D)} + \text{Points(E)} + \text{Points(F)} + \text{Points(G)} + \text{Points(H)} + \text{Points(I)} = 100,69$$

$$\left\{ \begin{array}{l} \text{if Total points in H4} < 26 \text{ then Level 0} \\ \text{if } 26 \leq \text{Total points in H4} < 52 \text{ then Level 1} \\ \text{if } 52 \leq \text{Total points in H4} < 78 \text{ then Level 2} \\ \text{if } 78 \leq \text{Total points in H4} < 104 \text{ then Level 3} \\ \text{if } 104 \leq \text{Total points in H4} < 130 \text{ then Level 4} \\ \text{if Total points in H4} = 130 \text{ then Level 5} \end{array} \right.$$

Table 19 - Hospitals' overall maturity level

Hospitals' overall maturity level													
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	
<b>Total points</b>	114,90	93,88	87,69	100,69	109,30	101,54	135,10	88,17	97,36	101,15	104,07	106,83	<b>Average</b>
<b>Level</b>	3	2	3	3	4	4	4	3	4	4	3	4	3

Hospitals' overall maturity level ranged from 2 to 4 – H2 classified with level 2; H1, H3, H4, H8, and H11 with level 3; H5, H6, H7, H9, H10, and H12 with level 4. The average level was of 3 (Table 19). This total score should be seen only as an indicator, so that the decision-makers can have in mind the overall situation of the hospital. In practical terms, the usefulness of this study lies on the levels of each capability, since it is from there that is possible to identify the most underserved areas in which improvement measures should be implemented, and that, consequently, will then impact the overall maturity level of the organization.

At the end of all these procedures, all the calculi were validated against a set of synthetic scenarios to guarantee the accuracy of the Excel tool. The experiments were conducted by placing all the criteria as Y to determine if all the organizations would achieve the maximum scorable points and, consequently, level

5, and, in a posterior moment, by placing all the criteria as N, which should lead to a score of 0 points correspondent to level 0. With this procedure, we managed to identify some minor formulation errors in the functions, which were immediately corrected.

### 5.3.3 Comparison

From Figure 10 to Figure 13, it is possible to better visualize the calculated maturity levels in each capability, for each hospital. These range from: (1) 1 to 3 in H2 and H11; (2) 1 to 4 in H1, H3, H8, and H9; (3) 1 to 5 in H4, H5, H7, H10, and H12; (4) 2 to 5 in H6.

Does not seem to exist a pattern in terms of underperformance of a specific capability. Otherwise, with regard to the significance attributed to the capabilities, there seems to be more or less a consensus that capabilities B (with a count of 14 as shown in Table 17), E (with a count of 12), and A and C (with counts of 11) are crucial for good disaster preparedness and response. Another curious note is that in none of the hospitals was verified capability I among the less developed ones.

H1 seems to fail to develop necessary skills to deal with processes related with capabilities B (impact assessment and surveillance), G (fatality management) and H (volunteer management and NGOs). Since all of them are classified with the highest importance degree, it will be up to the organization to decide which improvement should constitute a priority.

H2 do not perform well in C (internal and external information sharing), E (logistics and management of clinical and non-clinical supplies), and G (fatality management). Once again, all three have been classified with the highest importance degree, so there is not a specific recommended order for improvement.

In H3, B (impact assessment and surveillance) and C (internal and external information sharing) are the least developed capabilities. Measures taken should follow this prioritization order, since it coincides with the importance degree attributed to them. These considerations are also applicable to H5.

In H4, capability A (hospital preparedness) is the only one placed at level 1, corresponding also to one of the highest degrees of importance. Therefore, this should be firstly addressed, before seeking the improvement of level 2 capabilities. Later they should focus on B and E.

In H6, among the least developed group is E (logistics and management of clinical and non-clinical supplies), F (intra and inter-hospital coordination), G (fatality management), and H (volunteer management and NGOs), with any corresponding to those that the hospital considers the most important for a good response to emergency situations, which is a positive factor, since in this case all of them are at level 2, being the only hospital that has none at level 1. This means that those considered most important are at level 3 or above, thus in a stage characterized by well-defined processes and halfway on the road to excellence. The organization should strive to improve F first, E second, followed by G and H.

In H7, the lowest levels belong to A (hospital preparedness) and C (internal and external information sharing). Furthermore, in questionnaire's F.B Section, in Appendix F.B, P13 indicated that, in the future, aspires to improve factors in these domains, which confirms the accuracy of results in classifying the capabilities this low. Since their significance to the organization was equally quantified by P13, it is advisable



to further analyze the added value of each of these areas for the institution at issue, to determine which should be improved first.

H8 has only capability A (hospital preparedness) in level 1, which should be improved prior to the ones placed at level 2.

In H9, the most deprived capabilities are A (hospital preparedness) and C (internal and external information sharing). The organization should primarily focus on capability C, according to the attributed importance by P15.

H10, H11, and H12 only have a single capability in level 1, being these A (hospital preparedness), C (internal and external information sharing), and G (fatality management), respectively.

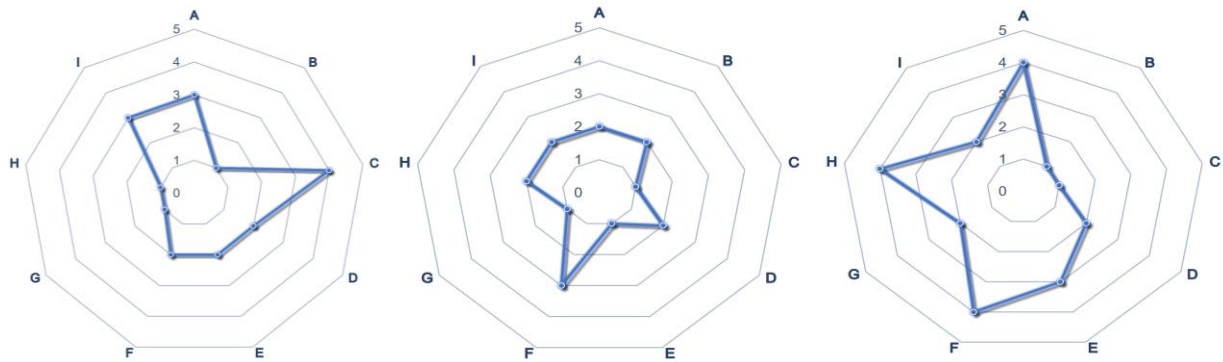


Figure 10 - Capabilities' maturity level in H1, H2, and H3, respectively

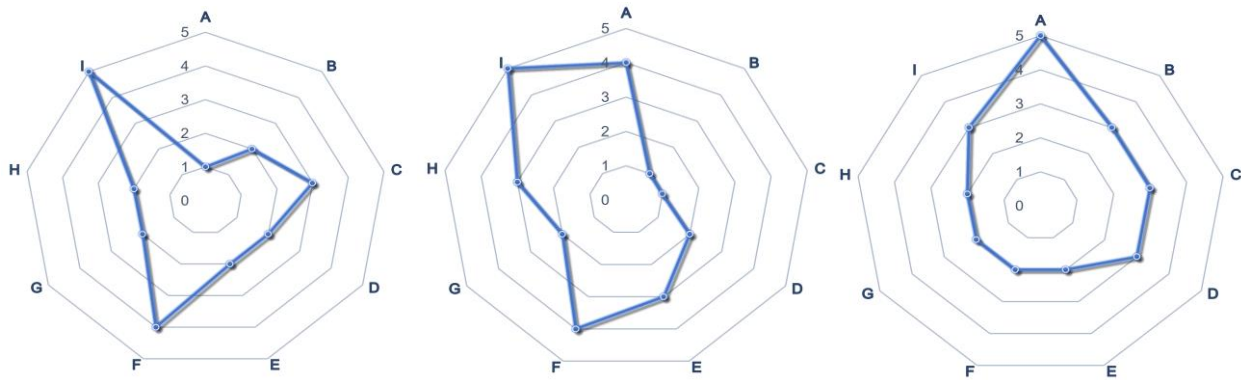


Figure 11 - Capabilities' maturity level in H4, H5, and H6, respectively

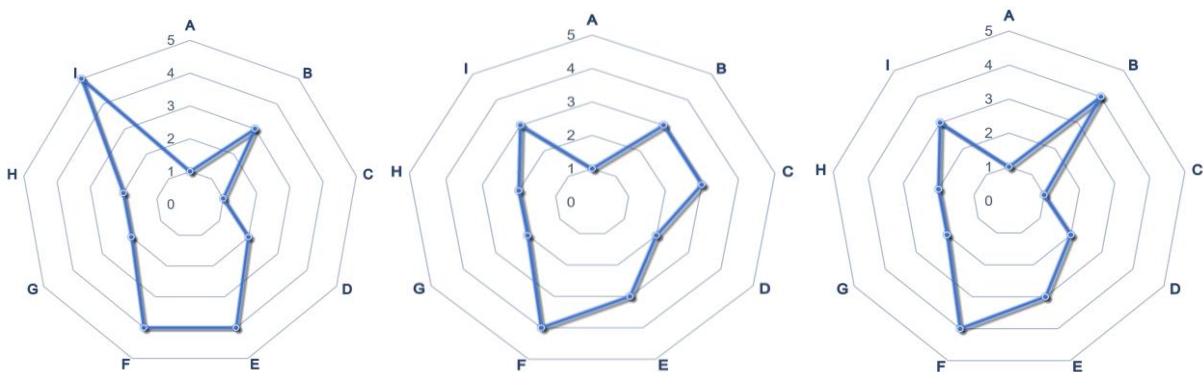


Figure 12 - Capabilities' maturity levels in H7, H8, and H9, respectively

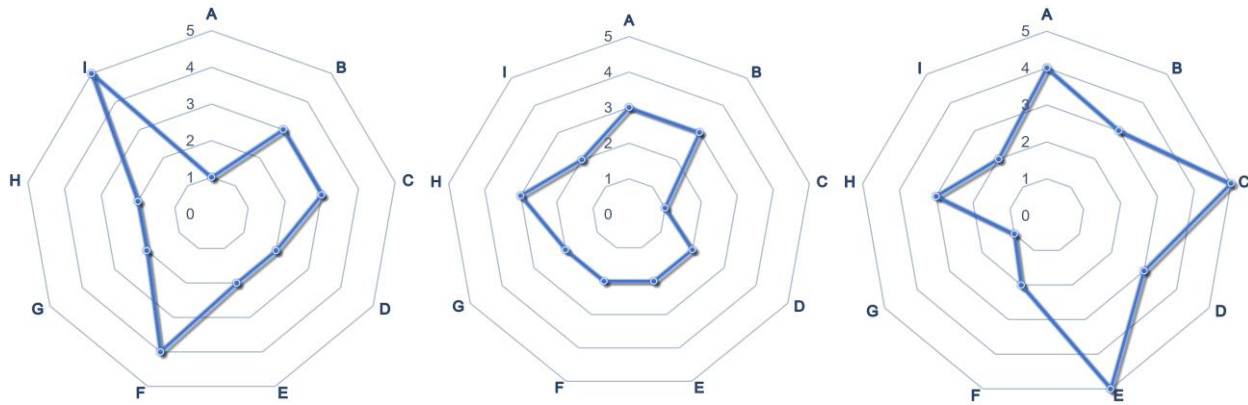


Figure 13 - Capabilities' maturity level in H10, H11, and H12, respectively

By looking at Table 20, which depicts the percentage of capabilities in each level, it is also possible to conclude that none of the hospitals stand out as having a capability neither excessively bad nor very good, which corroborates the results obtained in the previous Sub-section regarding the general maturity, that mostly were either of level 3 or 4 (with exception of H2). H12 seems to have achieved the best results, with 66% of its capabilities rated with level 3 or higher, while H2 seems to have the worst ones, with 89% of its capabilities rated as level 2 or lower. These comparisons are also available on Excel's "Comparison" sheet (Appendix F.C).

Moreover, contrary to what would be expected, no relevant discrepancy was noted between the capability of hospitals in the interior and coastal regions of the country.

Table 20 - Percentage of capabilities in each level

Percentage of capabilities in each level												
Level	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
1	22%	33%	22%	11%	22%	0%	22%	11%	22%	11%	11%	11%
2	44%	56%	33%	56%	22%	44%	33%	33%	33%	44%	56%	22%
3	22%	11%	11%	11%	22%	44%	11%	44%	22%	22%	33%	33%
4	11%	0%	33%	11%	22%	0%	22%	11%	22%	11%	0%	11%
5	0%	0%	0%	11%	11%	11%	11%	0%	0%	11%	0%	22%

There are still several capabilities at level 1 or 2 for all pilots (except in H6 which has none in level 1). In fact, all hospitals (except from H8 and H12) have the biggest percentage of their capabilities rated as level 2 or have the highest percentage in level 2 tied with other levels (H3, H5, and H6). These should be addressed as soon as possible to reach at least maturity level 3 for the focus capabilities. This is due to the fact that level 3 is considered as an intermediate state between the lack of mechanisms and procedures' consistency, characteristic of level 1 and 2, and the documentation and assessment of mechanisms and procedures, typical of maturity levels 4 and 5. Maturity level 3 depicts aspects that are consistent and defined and represents a state of change in this context from "no or little definition" to "improvement".

### 5.3.4 Improvements

This Sub-chapter will identify the weak points found during the assessment in each hospital. Weak points are answers that show that there is a lower maturity level on a specific question and that hinder the achievement of a higher maturity level for that capability, according to a stages approach where the criteria for a certain maturity level must all be in place for achieving that maturity level.

Ideally the process for improvement should follow the steps proposed in ISO/IEC 33014, aforementioned in Sub-section 3.7.1. As the aim of this study was mainly to take the first steps in the introduction of maturity models for emergency contexts, the dissertation focused above all on developing the maturity model and testing it through a first assessment, not giving much room for detail in the improvement measures. However, we will propose some general measures which the organizations should later look at with closer attention and analyze their viability.

#### A. Hospital 1 (H1)

- **Capability: Impact assessment and surveillance / Question: B2.2 / ML: 1 / Importance: 5**

This question is related with the existence of processes for periodic revision of KPIs to ensure an accurate measurement of data during emergencies. H1 answered that this revision is not done as such processes are not established. KPIs are sometimes only needed for a specific period of time and, without an expiry or review date, these can continue indefinitely, causing unnecessary work. Even if indicators are not time- or emergency-specific they should be assigned a review date to ensure that the metrics being measured remain relevant in help improving disaster response and stay aligned with the changing environment. Decision-makers should meet regularly and take a look at performance for this. Questions such as “Why is that outcome important?”, “How can I define progress?”, “How will I know I’ve reached the end goal?”, “How much will it cost to collect and analyze this data?” might influence the decision of maintaining a KPI as it is or not, or even in help defining new ones.

- **Capability: Fatality management / Question: G2.2 / ML: 1 / Importance: 5**

This question is related with hospitals’ respect for cultural and religious needs of deceased and survivors on the population they serve, during and after catastrophes. As the hospital seems to lack on this point, the document elaborated by the United Kingdom Home Office Cabinet (2005) details information on this topic and it is recommended to be consulted. Also, the guide by Los Angeles County Emergency Medical Services Agency (2013, pp. 104–134) can constitute a sample and a starting point, indicating concisely important steps to follow in order to accomplish this criterion and already presenting arranged information on several groups. On a more advanced stage, coordination with leaders from local cultural, religious, and ethnic groups to ensure that current and preferred practices are included in the institution’s plan should be fostered.

- **Capability: Volunteer management and NGOs / Question: H2.3 / ML: 1 / Importance: 5**

This question is related with the collection of feedback on volunteering experience. The answer from this organization indicates that any kind of feedback is asked for and, therefore, the organization is losing an opportunity to obtain suggestions on areas to be improved on the volunteer program. VOHR provides

some examples of forms to be delivered upon volunteering period completion on (2016, pp. 77–78) and (2016, pp. 82–83), that should be adopted by H1. For more comprehensive considerations on how to manage volunteers McCurly & Lynch's (2011) and Linda L. Graff's (1992) books are recommended.

## **B. Hospital 2 (H2)**

- **Capability: Internal and external information sharing / Question: C2.2 / ML: 1 / Importance: 5**

This question addresses the training of PIO and senior emergency managers for emergency risk communication. The answer provided reveals lack of knowledge in this area. To address this, WHO (2021) provides a course with self-use learning materials addressing key knowledge that is required for the practice and mastery of these skills, including practical exercises as well. Alternatively, FEMA (2021) also offers a very complete course in this area.

- **Capability: Logistics and management of clinical and non-clinical supplies / Question: E2.1 / ML: 1 / Importance: 5**

This question is concerned with the knowledge of hospitals about order expedition from suppliers. H2 answered that it cannot obtain this information. In fact, H2 is not able to obtain any information from the moment it places the order, therefore not having any track of the supplies from that moment on, which hampers largely logistic flow management. Despite the ideal scenario would be to have a real-time order tracking system that would cover external (from the order placement to its arrival to the warehouses) and internal organizational flow, this would imply extremely high implementation costs and redefinition of processes to reach the desired state. As the Portuguese government's legislation regarding the mandatory issuance of electronic invoices will soon come into effect, and as these are associated with the company's inventory management software, this may serve as a primary method to infer order shipment confirmation (or, at least, an indication that the process is already underway). The suppliers may be asked to collaborate in order to issue these invoices on time.

- **Capability: Fatality management / Question: G2.2 / ML: 1 / Importance: 5**

This question is related to hospitals' respect for the cultural and religious needs of deceased and survivors on the population they serve, during and after catastrophes. Proposals on H1 are also applicable to H2.

## **C. Hospital 3 (H3)**

- **Capability: Impact assessment and surveillance / Question: B2.3 / ML: 1 / Importance: 4**

This question is related with the staff ability to comply with disaster reporting guidelines. With a negative answer on this question, H3 indicates that reporting requirements are not followed. It is important to specify when and how often the data will be reported. It makes sense to coordinate the data collection and reporting frequency to ensure the data it is reported is as current and up-to-date as possible. For this, it is necessary the collaboration and active participation of staff on this task. To address the lack in this field, the importance of data to be reported must be introduced and explained to employees. This will promote a feel of connection

between what they do on a daily basis and the corporate strategy, augmenting the likely for them to be engaged.

- **Capability: Internal and external information sharing / Question: C2.1 / ML: 1 / Importance: 3**

This question is related with the existence of several repositories of information which by being non-interoperable potentiate duplicated or overlaid data. This is an underlying problem of H3, which hinders the assurance of complete, accurate and up-to-date medical information, thus hampering the assurance of safety, the coordination of care for individuals who see multiple medical professionals, and, ultimately, might lead to increasing costs, especially during times of added stress. While it is not possible to migrate all information to a single data repository, some approaches the organization could aim for go through unique identifiers for all patients (unique numbers, use of smart cards with encoded numbers, or biometrics), patient-empowered approaches (establishment of a process for patients to ensure their records are matched completely and correctly, in order for them to bear some ability to help health care facilities match their records), refinement of demographic data standards (formatted in the same way), and referential matching (use of data outside of health care).<sup>12</sup> Additionally, the Pan-American Health Organization also presents some considerations on the importance of interoperability of systems during emergencies (2020) and strategies to strengthen health related information systems (2020), which should be consulted.

#### **D. Hospital 4 (H4)**

- **Capability: Hospital preparedness / Question: A2.1 / ML: 1 / Importance: 5**

This question is about the inexistence of standardized documentation for operating procedures and the use of e-mail (or similar) for that purpose. As H4 stated that not uses e-mail to handle processes approval, neither standardized documentation (later on A3.3), we are left with no indication of how these are treated. Using a standard format for all organizational policies makes it easier for staff to read, retain, and organize information, as well as scan documents later for specific guidelines and rules. Showalter (2017) describes good practices for developing a SOP, also presenting an editable example.<sup>13</sup> For a more complete document, the United Lincolnshire Hospitals NHS Trust (2012) also present a pertinent template.

#### **E. Hospital 5 (H5)**

- **Capability: Impact assessment and surveillance / Question: B2.2 / ML: 1 / Importance: 5**

This question is related with the establishment of methods for KPIs periodic revision. The negative answer to this question shows that procedures for this are not in place. Considerations for H1 in this question are also valid for H5.

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<sup>12</sup> PEW: <https://www.pewtrusts.org/en/research-and-analysis/reports/2018/10/02/enhanced-patient-matching-critical-to-achieving-full-promise-of-digital-health-records>, accessed on October 24<sup>th</sup>, 2021.

<sup>13</sup> Accessible on: <https://www.hfma.org/content/dam/hfma/document/trends/Docs/52108.docx>

- **Capability: Internal and external information sharing / Question: C2.1 / ML: 1 / Importance: 4**

This question is related with the existence of several repositories of information which by being non-interoperable potentiate duplicated or overlaid data. Considerations on H3 are also applicable to H5.

## **F. Hospital 6 (H6)**

- **Capability: Intra e inter-hospital coordination / Question: F3.1 / ML: 2 / Importance: 4**

This question is concerned with collaborative relationships with stakeholders (suppliers, other public and private hospitals, civil society organizations, etc.), which, based on the provided answer it is not nourished. It is important for emergency managers to enhance collaboration among stakeholders in order to ensure effective integration of efforts. Face-to-face dialogue, participative decision-making, trust building, reaching consensus, establishing team spirit, flexibility, and improving mutual understanding via effective communication are indispensable parameters (Kapucu et al., 2010).

- **Capability: Logistics and management of clinical and non-clinical supplies / Question: E3.3 / ML: 2 / Importance: 3**

This question is related to the existence of alternative suppliers' contacts in a portfolio in case of urgent requests for supplies or medicines. The answer provided reveals that there are not. The organization should seek and establish contact not only with back-up suppliers in the medical area, but also think outside the box and look for companies that can provide materials transversal to other industries, according to the existing and future potential bottlenecks. As an example, during the COVID-19 outbreak, H1 bought provisions destined to the chemical and agricultural industry (masks, suits, and visors) to face the disruption of PPEs' suppliers, that, despite not being ideal, served the purpose. Additionally, in a more advanced stage, the hospital should have a solid grasp of what rights it has to use an alternative supply source, the steps it will need to take – both legally and commercially – to obtain an alternative supply source, and the amount of time it is likely to take to implement that strategy.

- **Capability: Fatality management / Question: G3.1 / ML: 2 / Importance: 2**

This question is related to the existence of a well-defined mass casualties management plan, which, according to the answer provided, the hospital does not possess. This can lead to inconsistent acting during treatment, transportation, and storage phases at the time of disaster. In this case, it might be highly useful to incur in a deep analysis of the guide written by the Los Angeles County Emergency Medical Services Agency (2013), to then try to adapt it to the context in question. This document is organized into two primary components: A base guide, providing step-by-step direction for plan development, activation, operations, and demobilization; Appendices, with supplemental resources to aid in plan development. The New York City Office of Chief Medical Examiner (2020) also presents a good example of a fatality surge toolkit to look at, in need of a more succinct document, which includes pertinent lessons learned during past emergencies related to this subject matter.

- **Capability: Volunteer management and NGOs / Question: H3.1 / ML: 2 / Importance: 2**

This question is related to the collection of volunteers' information through standardized sheets at the moment of application. The answer provided reveals that this method is not used, which can hinder the information management of potential candidates and, ultimately, the identification of congruences between the needs of volunteers and those of the organization. VOAHR (2016, pp. 70–72) gives examples of application sheets that can function as a starting point for H6.

- **Capability: Volunteer management and NGOs / Question: H3.2 / ML: 2 / Importance: 2**

This question is related to the evaluation of volunteers at the end of the volunteer period. The answer provided shows that the organization does not have a process for it, not even performing an informal evaluation. Failing to evaluate the volunteers gives the clear impression that the institution does not care much about the quality of the work that is being developed and leaves volunteers with a sense of personal devaluation. VOAHR (2016, pp. 55–57) presents interesting considerations to conduct an evaluation session, focused on reviewing their performance, suggestions on changes of working style, which is also an opportunity for both the volunteer and the organization to examine and improve their relationship, potentiating another future enrollment of the volunteer. This can be the first step before proceeding to a more formal evaluation through forms, which are also suggested in the same document (VOAHR, 2016, pp. 75–76).

## **G. Hospital 7 (H7)**

- **Capability: Hospital preparedness / Question: A2.2 / ML: 1 / Importance: 5**

This question is related to the *a priori* delegation and formalization of members to manage the response to emergencies, which, based on the provided answer, H7 does not do. If the organization does not possess a full-time “Emergency Office”, it is important that it determines and registers *a priori* the relocation of managers for the authority/leadership positions during emergencies (as for an emergency manager, field operations' responsible, operational oversight, technical and operational support, etc.) and correspondent hierarchies, as well as the transition of duties that will come associated with the new roles.

- **Capability: Internal and external information sharing / Question: C2.1 / ML: 1 / Importance: 5**

This question is related to the existence of several repositories of information which by being non-interoperable potentiate duplicated or overlaid data. Considerations on H3 are also applicable to H7.

## **H. Hospital 8 (H8)**

- **Capability: Hospital preparedness / Question: A2.2 / ML: 1 / Importance: 4**

This question is related to the *a priori* delegation and formalization of members to manage the response to emergencies. The answer provided shows that it exists a vague idea of who it might take on these roles, but it does not exist a formal document on it. The organization should follow the proposals on H7 for the same question, so it can achieve level 2 on this capability, since it is the only criterion restraining this transition.

## I. Hospital 9 (H9)

- **Capability: Hospital preparedness / Question: A2.2 / ML: 1 / Importance: 4**

This question is related to the *a priori* delegation and formalization of members to manage the response to emergencies. The answer provided shows that it exists a vague idea of who it might take on these roles, but it does not exist a formal document on it. Proposals on H7 for this question are also applicable to H9.

- **Capability: Internal and external information sharing / Question: C2.1 / ML: 1 / Importance: 5**

This question is related to the existence of several repositories of information which by being non-interoperable potentiate duplicated or overlaid data. Considerations on H3 are also applicable to H9.

## J. Hospital 10 (H10)

- **Capability: Hospital preparedness / Question: A2.2 / ML: 1 / Importance: 5**

This question is related to the *a priori* delegation and formalization of members to manage the response to emergencies. The answer provided shows that it exists a vague idea of who it might take on these roles, but it does not exist a formal document on it. This negative response is the only one holding this capability to level 1. Also, since the criteria of the next level are all fulfilled, by improving this weak point, H10 manages to escalate the hospital preparedness capability from level 1 to 3.

## K. Hospital 11 (H11)

- **Capability: Internal and external information sharing / Question: C2.2 / ML: 1 / Importance: 5**

This question addresses the training of PIO and senior emergency managers for emergency risk communication, which, in the case of H11 is inexistent. Courses indicated for H2 are also valid for H11. Furthermore, the accomplishment of this criterion will lead capability C to attain level 3, as the institution meets all the requirements on that level.

## L. Hospital 12 (H12)

- **Capability: Fatality management / Question: G2.2 / ML: 1 / Importance: 2**

This question is related to hospitals' respect for the cultural and religious needs of deceased and survivors on the population they serve, during and after catastrophes. Proposals on H1 are also applicable to H12. Additionally, this is the only question for this level of the fatality management capability that has a negative response, inhibiting this organization from achieving the maturity level 2 and, as such, it should be addressed.

## 5.4 Chapter Conclusion

This Chapter describes the data collection and analysis process, demonstrating the practical functionality of the newly developed model, meeting this way the last secondary research question (SRQ5) that leads to the accomplishment of the last two goals of this dissertation (number five and six) raised in Section 1.2.



The Chapter organizes the hospital assessment process according to the proposed practices by ISO/IEC 33030 and SCAMPI, concentrating on the transfer and evaluation of the maturity model, the last three stages (R4, R7, R3) of the maturity model development method by Becker et al. (2009) portrayed in Figure 2.

In total, 12 hospitals across all Portuguese regions showed a willingness to collaborate in our study, with H1 and H2 being receptive to performing face-to-face interviews and guided tours through their facilities. The identification of all hospitals and all 18 relevant participants involved was made, as well as their roles in the correspondent organizations.

An evaluation plan describing all the activities to be performed, including the adopted strategy to effectively collect, review, validate and document all the data in each stage, was developed and briefly summarized in a scheme, presented in Figure 9.

This Chapter also marked the end of the 1<sup>st</sup>. iteration, moving from the model development phase to the data collection one, which first took place in H1 and then continued in the 2<sup>nd</sup>. iteration in the remaining hospitals, after the necessary enhancements are made. These enhancements were mainly related to: revisions in the gathering of participants' personal data, due to anonymity policies; specific language adjustments, both from the management scope that was not being understood by the respondents, or from the medical scope that was inaccurate; questions that aggregated too much information and should be separated. The strategy and techniques for the selection, collection, and analysis of data were explicitly explained along the way.

A set of ratings that measure the achievement degree of the capabilities' group was determined and weak points corresponded to unmet criteria identified. A pattern related to the underperformance of any specific capability across organizations was not detected. However, it was verified that none of the institutions had the "Hospital recovery" capability (I) among the least developed ones. An overall maturity level for each hospital was also set to be seen as an indicator for decision-makers to have consciousness of the general disaster preparedness level of their hospital. Predominantly, hospitals were classified as of level 3 or 4, except for H2, which was classified with level 2.

Data validation was also conducted through synthetic scenarios to ensure the correct functioning of the developed Excel tool.

The Chapter ends with a proposal of improvements to address the lowest-rated capabilities. These could not be performed following the ISO/IEC 33014 proposed steps as it would imply a larger-scale study, but they provide further directions for deeper analysis.

# 6 Conclusions

This Chapter provides a critical reflection on the research outcomes presented in the dissertation. In Section 6.1, a summary of the findings and achievements is made confirming the accomplishment of all the dissertation's goals. Section 6.2 addresses some difficulties faced and discusses the limitations of the model. Finally, this Chapter closes with Section 6.3, with pointers regarding future research opportunities resulting from this work.

## 6.1 Overview and achievements

Generally, the research aim of this study was to develop a maturity tool that would help the Portuguese SNS to prepare and perform better at the time of emergency, by following a methodical and continuous path that would lead to a progressive evolution of the necessary capabilities to do so. This model was developed in line with the methodological procedures for creating maturity models, with a view to guarantee its recognition, solidity, and relevance, both in the academic field and in society as a whole. The results of this investigation have been encouraging, while revealing a high level of acceptance among the interviewees. To accomplish this, our approach went by pursuing the research questions indicated in Section 2.2 that led us to attain the following goals:

**(G1) To intensively describe and contextualize the problem at hand and the goal of the project:**

This dissertation started by making a characterization of SNS to the present year and of relevant factors in Portugal that affect care delivery, focusing on the lack of expenditure on public health, the shortage in numbers of health professionals working on the public system, and recalling certain events of the last emergency that hit the country, the COVID-19 pandemic, as well as some of the actions taken to face it.

With this recent event highlighting the importance of disaster management as an ongoing activity inherent to the SNS governance, tools that allow hospitals to prioritize related areas of improvement for a good redirection of future investments in the health sector that might be made are valuable. Here, maturity models can come in as a simple-to-understand tool that, additionally through benchmarking, can establish a path for gradual progress for the several Portuguese hospitals.

**(G2) To elaborate a literature review, including an overview of the existing maturity models' background and history and the clarification of the key concepts and essential principles to follow during the development of a maturity model:**

The literature review started by dating back to maturity models' first appearance in 1973, from which they have had a constant evolution, achieving its pinnacle of popularity at the time of the CMMI and ISOs emergence. With the discipline of DSR continuing to be the major foundation for the construction of new maturity models, it was imperative to revise papers from authors that have devised design and development techniques based on this ontology.

On a general note, it is recommended that the development process presents a clear identification of the problem and its relevance to the market, and goes through several iterations underlying the design of the model (that can be presented as descriptive, prescriptive or comparative), its evaluation, and proposals for

improvement until no more significant changes are suggested. Periodic review and adaptation of the model in face of new constraints are also encouraged to prevent it from turning to a simple snapshot in time.

Assessment methods as a way to determine the organizations' as-is situation before starting the improvement path are pointed out by experts – self-assessment, third-party assisted, and certified professionals – as well as others, suggested by renowned institutions, with very specific guidelines, such as ISO/IEC 33030 and SCAMPI.

Regarding improvement methods, the ISO institute also suggests a framework to follow, the ISO/IEC 33014, focusing on strategic, tactical, and operational components.

**(G3) To elaborate the state-of-art and critical analysis of maturity models that target hospital units' management:** 13 models under the healthcare topic were compared, leading us to the conclusion that, not only no maturity models are targeting directly hospitals services' readiness to respond to disaster and emergency situations, but also that many of the capabilities we found essential to incorporate in this model were not even addressed in any of the reviewed models (except for the information sharing, human resources, logistics and coordination ones).

This emphasized this thesis' importance and sets a note for the future work to be performed. Considering all the benefits adjacent to maturity models, there is a need for the introduction of this tool in the health system, to re-organize hospitals and improve the effectiveness of interventions in a scenario of a sudden increase in demand. This allows to maintain the services' quality, reconciling the treatment of emergency-caused patients with the remaining clinical activity, and avoiding last-minute decisions that result in long waiting lists, unnecessary waste of resources, and, ultimately, helping save lives.

**(G4) To develop a maturity model that accounts for objective and subjective criteria for each set of evaluation's dimension and maturity levels, considering the hospital context:** A new five-stage maturity model for public healthcare was then developed. The maturity model provides a framework to assess both where an organization is "today" on emergency preparedness maturity scale and how it can progress towards more advanced maturity levels by addressing nine capabilities considered key success factors for disaster preparedness and response. They are: hospital preparedness, impact assessment and surveillance, internal and external information sharing, human resources management, logistics and management of clinical and non-clinical supplies, intra and inter-hospital coordination, fatality management, volunteer management and NGOs, and hospital recovery.

Each stage of the maturity model represents enhanced emergency capabilities in the development process, and an organization can only progress from one stage to another by building on practices that have been solidly established in preceding stages, and, therefore, upon achieving all capabilities' criteria in those stages.

**(G5) To perform a relevant data collection within three Portuguese organizations, to be evaluated using the developed maturity model:** The data collection for this maturity model followed a two-iteration process. The purpose of it was to enable a better understanding and refinement of the maturity model and assessment tool through semi-structured interviews with subject-matter respondents. Recurring to the elaborated questionnaire comprising fundamental questions based on the maturity table criteria, in total we

managed to collect data not only from three, but twelve Portuguese organizations: two of them by performing in-person interviews (four in each) and the other ten through Google Forms filling. All the assessment process was conducted in accordance with the proposed practices by ISO/IEC 33030 and SCAMPI, comprising the phases of initiation, planning, briefing, data collection and validation, and results reporting.

**(G6) To implement the model, to discuss the results of the assessment, and to establish improvement plans accordingly:** After implementing the model, the first stage of analysis aimed at running through each hospital identifying the least mature emergency capabilities that have a high impact on the organization and require low effort to implement/sustain. A pattern related to the underperformance of any specific capability across organizations was not detected. However, it was verified that none of the institutions had the “Hospital recovery” capability (I) among the least developed ones. Subsequently interventions were planned to address the weak points on these capabilities, which ultimately will lead to the improvement of the organization’s global capability. Here, hospitals were predominantly classified as of level 3 or 4, except for H2, which was classified with level 2, with none standing out as having an exceptionally good or bad overall capability. It was not evidenced a difference in services’ preparedness levels between the interior and coastal regions of the country.

In conclusion, this tool serves as a quick assessment, allowing us to identify and prioritize the most critical areas to address and present simple ideas for improvements since the capabilities represent a wide range of areas of knowledge. This study contributes to the extent that not only indicates to managers about which processes to review and which document or standard to follow, but also provides an overall level to be seen as an indicator for decision-makers to take consciousness of the general disaster preparedness level of their hospital.

## 6.2 Limitations

Like any other study, this one has also limitations. Disaster management applied to maturity models is a relatively (or entirely) new approach and, for this reason there is little published data in this field. The present work aims to take the first steps to analyze emergency management from an end-to-end within an organization, as well as on a posterior alignment and integration of all direct partners (suppliers, government, and other hospitals) in the path towards excellence in the field of emergency preparedness.

It was also a very difficult process to get ethical clearance to do the interviews in the hospitals. Although the process of contacting the institutions started promptly, we realized early on that it would not be possible to conduct face-to-face interviews in all hospitals as it was initially planned. Hence the Google Forms filling was an alternative solution we came up with. This brought up some issues because, while on the face-to-face interviews the chosen method went quite well, since people made comments as they answered the questions, allowing us to clearly understand at what level each hospital was in, in the online interviews that did not happen. Despite being asked for it, with justifications of optional character, none of the participants bothered explaining or giving evidence on their answers. The bias for this approach is on the assumption that all respondents interpret key terms similarly when they answer a question in a questionnaire. As many

of the capabilities differ in small details from one level to another, a potential lack of attention from the participants or a wrong understanding of the question could lead to an erratic evaluation and, therefore, some deviation from reality is admitted.

Moreover, the existence of an additional iteration including the validation of the maturity table and, specially, of the assessment questionnaire by subject matter experts on the maturity models field, besides the one already conducted by hospital administrators participating in this research, should not be overruled and could be included in future tasks when constructing an improved version of the present model, since all the following work will be based on these components.

However, we believe that both these limitations are not overly substantial and the approaches taken to bypass them the best as possible were effective and, therefore, we can rely on the feasibility of the study.

### 6.3 Future Work

The study presented provides a basis for future research that complements and extends the research presented in this work. Therefore, from the foundation presented in this document, the following research directions can be taken:

**To apply the solution artifacts to new case studies:** This will allow to exploring further limitations of the approach. The study of the utility of the proposed solution artifacts can be collected through the gathering of statistical data on the usage and satisfaction of users.

**To study relationships between capabilities:** That is, to ascertain how the dimensions interlock and amplify each other, or if improving any of the capabilities will positively impact any of the others (leading others to also perform better and achieve a superior level), which can be a factor at the time of prioritizing which weak points to address.

**To perform an after-implementation of improvements study:** Although this study established a concept of disaster preparedness in the Portuguese hospitals, it has not tested in practice the benefits of its application on the organizational capability, by conducting an after-implementation study. Future research could present data on the levels achieved by following the proposed improvements, including statistics on the results such as variance, standard deviation, and confidence intervals.

**To refine the assessment questionnaire:** This newer version could be available online and developed as a self-assessment with an immediate result questionnaire, so that organizations that wanted to assess their current disaster management practices can freely assess it, fill the answers and get a detailed reports on their current maturity level for disaster preparedness.

**To combine the model with computer analysis and other quantitative techniques:** It might be useful to use computational inference combined with other quantitative analyses to support and automate maturity assessment methods. For instance, combining cost estimation techniques with the maturity assessment results and the organization's maturity goals to produce a detailed and prioritized improvement plan can be a possibility.

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# Appendix

## A Correspondence of ISO/IEC 15504 to ISO/IEC 330xx family

Table A.1 - Correspondence of ISO/IEC 15504 to ISO/IEC 330xx family (adapted from ISO/IEC (2015a))

ISO/IEC 15504	ISO/IEC 330xx
Part 1 – Concepts and vocabulary (2004)	33001 – Concepts and terminology (2015)
Part 2 – Performing an assessment (2003)	33002 – Requirements for performing process assessment (2015) 33003 – Requirements for process measurement framework (2015) 33004 – Requirements for process reference, process assessment, and maturity models (2015) 33020 – Process measurement framework for assessment of process capability (2015)
Part 3 – Guidance on performing an assessment (2004)	33010 – Guide for performing process assessment
Part 4 – Guidance on use for process improvement and process capability determination (2004)	33010 – Guide for performing process assessment 33014 – Guide for process improvement (2013)
Part 5 – An exemplar process assessment model (2012)	33061 – Process capability assessment model for software life cycle processes
Part 6 – An exemplar system life cycle process assessment model	33060 – Process capability assessment model for system life cycle process
Part 7 – Assessment of organizational maturity (2008)	33001 – Concepts and terminology 33002 – Requirements for performing process assessment (2015) 33003 – Requirements for process measurement framework (2015) 33004 – Requirements for process reference, process assessment and maturity models (2015) 33010 – Guide for performing process assessment 33014 – Guide for process improvement
Part 8 – An exemplar process assessment model for IT service management (2012)	33062
Part 9 – Target process profiles	33010 – Guide for performing process assessment
Part 10 – Safety extension	33064 – Process assessment model for safety extensions

The correspondence between the ISO/IEC 15504 parts and the ISO/IEC 330xx family is summarized in the following Table A.1.

# B Structure of the ISO/IEC 330xx family's set of standards

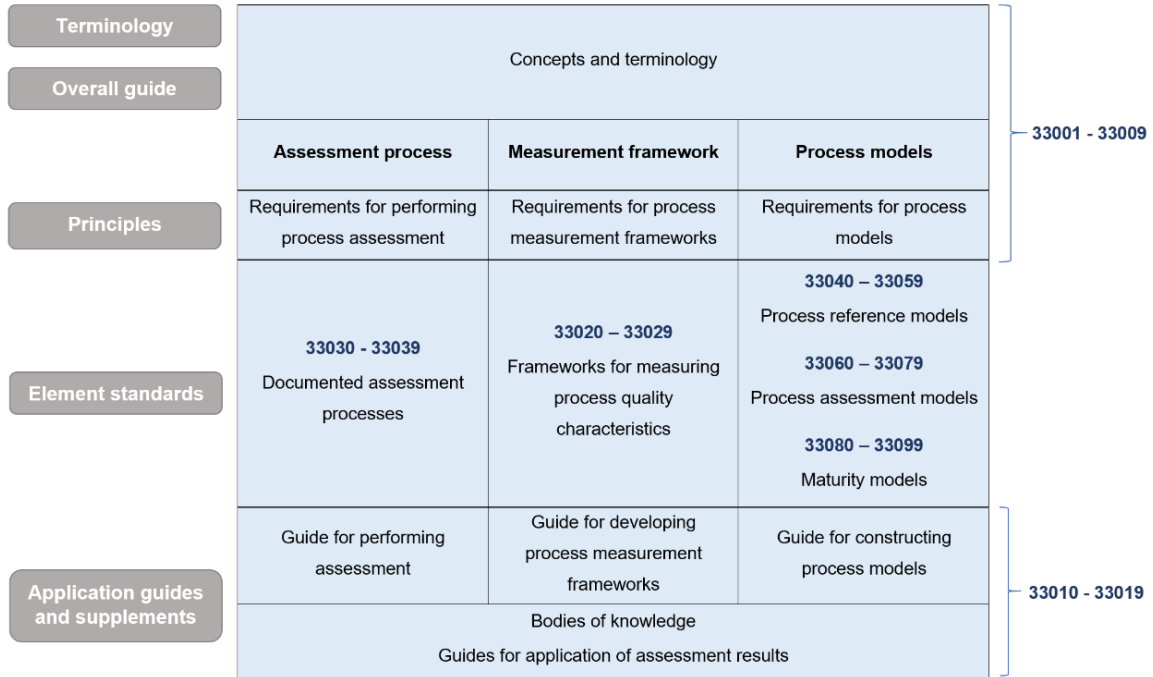


Figure B.1 - Structure of the ISO/IEC 330xx family's set of standards (adapted from ISO/IEC (2015a))



# C Decision parameters and its characteristics during maturity model development

Table C.1 - Decision parameters and its characteristics during maturity model development (adapted from Mettler (2014))

Phase	Decision Parameter	Characteristic			
Define scope	Focus / Breadth	General issue		Specific issue	
	Level of analysis/depth	Group decision-making	Organizational considerations	Inter-org. considerations	Global & societal considerations
	Novelty	Emerging	Pacing	Disruptive	Mature
	Audience	Management-oriented	Technology-oriented	Both	
	Dissemination	Open		Exclusive	
Design model	Maturity definition	Process-focused	Object-focused	People-focused	Combination
	Goal function	One-dimensional		Multi-dimensional	
	Design process	Theory-driven	Practitioner-based	Combination	
	Design product	Textual description of form	Textual description of form and functioning	Instantiation (assessment pool)	
	Application method	Self-assessment	Third-party assisted	Certified professionals	
	Respondents	Management	Staff	Business partners	Combination
Evaluate design	Subject of evaluation	Design process	Design product	Both	
	Time-frame	Ex-ante	Ex-post	Both	
	Evaluation method	Naturalistic		Artificial	
Reflect evolution	Subject of change	None	Form	Functioning	Form and functioning
	Frequency	Non-recurring		Continuous	
	Structure of change	External / Open		Internal / Exclusive	

## D Phases and decision points to develop new and evaluate existing maturity grids

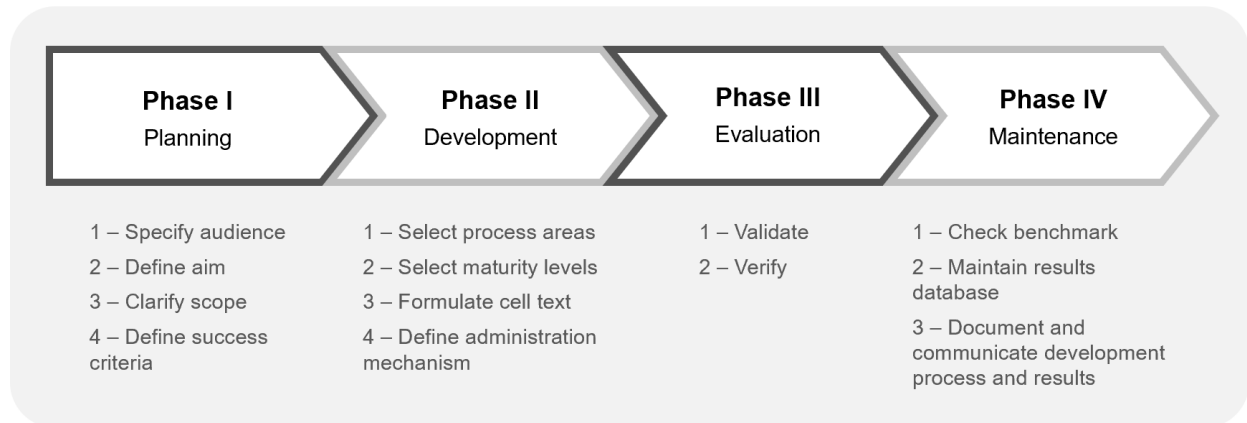


Figure D.1 - Phases and decision points to develop new and evaluate existing maturity grids (adapted from Maier et al. (2012))

# E Activities' scheduling

To facilitate this thesis planning and scheduling, the following Gantt chart in Figure E.1 lists by order the tasks to be completed until the end date of October 31<sup>st</sup>.

		2020	2021									
STAGES		DEC	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEPT	OCT
	Literature review.											
	Dissertation project writing.											
	Choose and establish contact with the organizations to be assessed.											
1 <sup>st</sup> Iteration	Design, develop and demonstrate maturity model.											
	Evaluate and compare hospital performance, and collection of model improvement points.											
2 <sup>nd</sup> Iteration	Maturity model's refinement.											
	Evaluate and compare hospital performance, and collection of model improvement points.											
	Present results, paper writing and thesis submission.											

Figure E.1 – Activities' scheduling Gantt Chart

# F Additional elements

Due to the space restrictions imposed for the structure of the thesis concerning the total number of 100 pages (counting appendices and references), plus the length of some of the components developed in this dissertation, the elements mentioned in the following Sections are available for consultation in a Google Drive's shared folder, from links below mentioned.

## F.A Maturity Table

This Section details the developed maturity table, which consists of a table that crosses maturity levels with the maturity dimensions (in our case capabilities) and characterizes each dimension in each level.

Link: [https://drive.google.com/file/d/1r-Ng2kAbJWpthKUfQ0j87\\_LX\\_HxEJtWQ/view?usp=sharing](https://drive.google.com/file/d/1r-Ng2kAbJWpthKUfQ0j87_LX_HxEJtWQ/view?usp=sharing)

## F.B Assessment Tool (Questionnaire)

This Section details the self-assessment questionnaire to assess the organizational scenario. The questionnaire is comprised of five main sections with a set of questions in each one.

Link: <https://drive.google.com/file/d/1H5kewUAfkgQksBxDYBdp4WFFJ0xK8qT/view?usp=sharing>

## F.C Excel

This Section details the developed Excel tool, with all the calculi performed during this dissertation. It is composed by five sheets: "Interviews", "Capabilities' level", "Overall level", "Overall level smaller scale test", and "Comparisons".

Interviewees' justifications/notes present on "Interviews" sheet are displaced in Portuguese as it was the participants' native language and the one spoken during the interview process.

The answers from participants in "Capabilities' level" can be edited and if changed produce modifications in the level calculations as well, since several sheets are interlinked through formulas.

There is also another Excel file containing a synthetic scenario, which was used to validate the accuracy of the Excel tool.

Link Excel tool: [https://docs.google.com/spreadsheets/d/1950O6\\_aHEy7u10LluaUaNckv\\_gsMp-BQ/edit?usp=sharing&oid=107088908725921746523&rtpof=true&sd=true](https://docs.google.com/spreadsheets/d/1950O6_aHEy7u10LluaUaNckv_gsMp-BQ/edit?usp=sharing&oid=107088908725921746523&rtpof=true&sd=true)

Link Excel tool with synthetic scenario: [https://docs.google.com/spreadsheets/d/1UyaF76RgTH\\_vdoc-3rDIQzaeNRN-6D9V/edit?usp=sharing&oid=107088908725921746523&rtpof=true&sd=true](https://docs.google.com/spreadsheets/d/1UyaF76RgTH_vdoc-3rDIQzaeNRN-6D9V/edit?usp=sharing&oid=107088908725921746523&rtpof=true&sd=true)