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

Rita Mendes[1], Diogo Proença[1] and José Rui Figueira[1]

[1] Departamento de Engenharia e Gestão, Instituto Superior Técnico, Lisboa, Portugal

E-mail: ritamendes98@hotmail.com (Rita Mendes), diogo.proenca@tecnico.ulisboa.pt (Diogo Proença), figueira@tecnico.ulisboa.pt (José Rui Figueira)

Received xxxxxx
Accepted for publication xxxxxx
Published xxxxxx

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 and 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 in 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 applying it to a set of Portuguese hospitals, assessing their current status over nine key domains on this area. Results achieved 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

1. Introduction

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 (Serviço Nacional de Saúde, 2021).

As a large and complex governmental unit, composed of a diverse set of hospitals and health care centers, 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.

The emergency situation recently generated by the current pandemic aggravated and exposed the weaknesses of a system that became critically overloaded under such pressure. In the face of this blatant muddle of resources, it is necessary to concentrate our attention on good management and coordination. With expected investments in the upcoming years, it will be necessary to design plans for prioritizing improvement measures to enhance the readiness to respond to similar emergency situations. For this purpose, and once 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 multicriteria methods and statistical analysis, and qualitative, such as Lean techniques and others – can bring measurable benefits.

2. Problem and Research Goals

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). These had to do either with extreme temperatures, wildfires, floods, or more recently COVID-19 and, apart from the latter, are all still classified as of high national exposure. Considering their unpredictability, such events can trigger life-threatening situations to which hospitals must be prepared to respond and, therefore, must be an area addressed in risk management.

This is an especially important matter in Portugal given its demography. With 22% of its population over 65 years (PORDATA, 2020), the country is ranked as third among the most aged in the world, thus holding a population particularly vulnerable to these incidents, which might cause difficult-to-manage demands to health care providers at the time of an emergency.

With such demographic trends, it would be expected large investments in this area, however, 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. Regardless, the Portuguese NHS is still ranked among the best in the world.

The existing soft spots were put to a test in 2020 upon the surge of the pandemic. If on a first instance the time lag between the first case detected in China (December 1st. 2019) and the first case in Portugal (March 2nd. 2020), might have acted as a buffer for the initial impact, the difficulties in responding during the first quarter of 2021 made everyone in the SNS fear the worst.

Considering 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.

The present thesis aims to develop a maturity model to measure and improve Portuguese healthcare units' preparation and provision of services during disaster

and emergency situations. To accomplish the purpose of this research, the following goals were delineated: (G1) To intensively describe and contextualize the problem at hand and the goal of the project; (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; (G3) To elaborate the state-of-art and critical analysis of maturity models that target hospital units' management; (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; (G5) To perform a relevant data collection within three Portuguese organizations, to be evaluated using the developed maturity model; (G6) To implement the model, to discuss the results of the assessment and, to establish improvement plans accordingly.

3. Literature Review

3.1 The Emergence of Maturity Models and Assessment Techniques

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).

The popularity of maturity models was especially intensified with the presentation of a modified version of the Capability Maturity Model (CMM) in 1991, 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). Now, almost thirty years since the Software Engineering Institute (SEI) has launched the CMM, which was eventually surpassed by the CMMI in 2000 (CMMI Institute, 2021), 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.

Aligned with the evolution of maturity models, there was also the emergence of approaches for its appraisal. With good results stemming from the launch of the first standard in 1987, the ISO 9000, innumerous other initiatives within the software engineering community also appliable to commercially-sensitive areas continued to emerge. 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.

3.2 Fundamental Concepts

The structure of the maturity model as it is known is composed of 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.

3.3 Design Principles and Development Methods

Despite the constant evolution of maturity models and the broadening of the "maturity" concept, the proposed characteristics for design and development remain considerably within the same standards, with their frameworks continuing to be based on the discipline of Design Science Research (DSR).

For the design, models can be presented as descriptive (if only intended to evaluate the as-is situation of a company), prescriptive (if additionally identifies desired maturity levels and appropriate measures to attain them), or comparative (if it also allows for both internal and external benchmarks), and should fulfill an increasing number of requirements, the broader their nature, as de Bruin et al. (2005) and Röglinger and Pöppelbuß (2011) describe.

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 obsolete. Researches by Becker et al. (2009) or Mettler (2014) should be a reference for this stage.

3.4 Assessment Methods

Being an inherent component of maturity models, assessment methods represent an essential part of the evaluation stage, as a way to determine the organizations' as-is situation before starting the improvement path. According to Mettler (2014), three possible assessment methods can be distinguished – 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.

Briefly, ISO/IEC 33030 (2017) decomposes the process in seven main steps – initiation, planning, briefing, data collection, data validation, results determination and assessment reporting – while SCAMPI goes into more detail, dividing the assessment process in three main sections – plan and prepare for assessment, conduct appraisal, and report results – to then detail each one. Despite this different division, their underlying principles are similar.

3.5 Improvement Methods

With globalization leading to increasing amounts of informed and demanding consumers, 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), led to the recognition of continuous improvement as a vital element for business excellence.

Accordingly, many methods emerged during the last years to address this topic, being the ISO/IEC 33014 (2013) one of them, providing a cyclical framework that deals with continual improvement on three levels – strategic, tactical, and operational – which should be followed when carrying on a relevant project in the organization, and we believe that it would be worthwhile to complement with Lean methodologies.

3.6 Maturity Models for Hospital Unit's Management

To further converge the current state of the art analysis, after performing a systematic literature review based on Kitchenham et al. (2009) methodology to select relevant documents, 13 maturity models under the healthcare topic were compared against a set of fields proposed by Proença and Borbinha (2016): the number of maturity levels, attributes' quantity and name, the concept of maturity, practicality, assessment methods, strong and weak points identification, continuous assessment, and improvement opportunities prioritization.

The main conclusion was that, although the scope of maturity models has been widening over the years, it is confirmed the embryonic stage at which their development is in the health field, with many still lacking on following practices considered fundamental and continuing to be heavily influenced by the IT theme. None was found directly tackling strategies of improving hospitals' effectiveness and efficiency in emergency situations, confirming our research importance.

3.7 Research Method

Following guidelines of Design Science Research Methodology (DSRM) adopted by Becker et al. (2009) and Peffers et al. (2007), our research method was defined, encompassing the steps of problem identification, the definition of goals to be achieved, iterative design and development, demonstration, evaluation, and communication.

4. Model Development

The developed maturity model comprises a conventional structure, that is, a matrix composed of nine key-factors, identified as the most relevant for the emergency preparedness and management area, and five maturity levels, similarly to CMMI. Each stage is defined by a set of criteria and when a hospital reveals such criteria, the corresponding stage and the attributes it embodies have been achieved. With measurable transition states between levels, hospitals can use this scale to (1) define the current maturity level in a given capability, (2) determine the next achievable maturity level, and (3) identify the criteria that must be met to reach a new maturity level.

Completed the maturity table, we proceeded to select the criteria we considered as the minimum set of questions to determine whether the organization meets a certain level for a given capability or not, which were addressed during the assessment process.

4.1 Capabilities

4.1.1 A - Hospital preparedness. Represents the ability to prepare for and withstand public health incidents both in the short and long term.

4.1.2 B - Impact assessment and surveillance. Represents the ability to keep track of the ongoing situation and related consequences, to provide all decision-makers with relevant information concerning the nature and extent of the hazard, vulnerable elements, and resources required. (NSW Government, 2020).

4.1.3 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.

4.1.4 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.

4.1.5 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.

4.1.6 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) in operations inherent to the emergency.

4.1.7 G - Fatality management. Represents 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).

4.1.8 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).

4.1.9 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, as well as the revision of the taken course of action during the disaster and comparison with former mitigation plans to adjust them, according to the learned lessons.

4.2 Maturity Levels

4.2.1 Level 1 - Initial. The organization has 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. With tasks poorly defined or not defined at all, planning is reactive instead of preventive, which results in unpredicted schedules, budgets, and response quality.

4.2.2 Level 2 - Managed. Actions end up being influenced by the repetition of elementary emergency operating conducts that have worked in the past instead of formal processes since these are not precisely defined. Also, the organization lacks uniformization, denoting significantly different approaches across departments to tackle similar problems.

4.2.3 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.

4.2.4 Level 4 – Quantitatively managed. The organization would be expected to quantitatively collect, analyze, and manage targets for its performance to every capability throughout the life of projects, using statistical and other quantitative techniques, translating into predictability, and allowing to forecast and adapt preparedness plans to each particular emergency.

4.2.5 Level 5 - Optimizing. Level 5 is characterized by a closed loop of improvement according to past experiences' performances or new emerging knowledge, based on the conjunction of measurable processes with a quantitative understanding of business objectives and performance needs.

5. Hospital Assessment

To evaluate the "utility, quality, and efficacy of the design artifact" (Hevner & Chatterjee, 2010), twelve institutions were assessed in conformity with the ISO/IEC 33030 and SCAMPI steps.

5.1 Plan and Prepare

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.

We aimed at involving several hospital Groups (from B to F (SNS, 2017)), to obtain a sample comprising establishments of different sizes and regions, which would allow to secure a bigger variety of work environments, come across different practices, and, consequently, solutions for a change that might be pertinent to replicate among hospitals. Hospitals from Coimbra (H1), Aveiro (H2), Leiria (H3), Évora (H4), Porto (H5), Faro (H6), Lisboa (H7), Braga (H8), Setúbal (H9), Viseu (H10), Santarém (H11), and Castelo Branco (12) shown willingness to collaborate in the study, with H1 and H2 having even being opened to receive us to perform face-to-face interviews and guided tours through their facilities. In the same train of thought, professionals from different hierarchical levels in each individual department in the covered areas were contacted, to guarantee an organization-wide view. Participants were identified by their role in the respective organizations.

A semi-structured interview mode was prepared, guided by a previously elaborated questionnaire comprising a set of questions to be explored. This method enabled, not only to gather more general information about the organization, participants, and their future 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.

The questionnaire’s composition can be summarized as follows: (1) Respondent’s background, about basic information concerning the targeted group; (2) Future expectations, of both the organization as a whole and the interviewees’ current department; (3) Capabilities’ ranking, in a 5-point scale, according to the respondents’ perception on the importance of each dimension to the global level of maturity in the hospital emergency preparedness’ context; (4) Open questions, of YES, NO, or DON’T KNOW and correspondent justification, which served to infer the level at which each hospital is ranked; (5) Post-questionnaire feedback, regarding the usefulness of the model and asking for suggestions for model improvement.

5.2 Conduct Appraisal

In total, the data collection took place over 10 weeks, during July, August, September, and October. The appraisal correspondent to the 1st. iteration took place only in H1, comprising four meetings with an average span of 02h:16min.

Then, based on the preliminary findings, the data collection method was revised, weaknesses on it identified and corrective actions taken as needed. 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 2nd. iteration comprises a presential phase on H2, where also four meetings were performed with an average time of 01h:10min 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.

5.3 Report Results

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. All necessary calculi were done recurring to Excel.

5.3.1 Capabilities' maturity level. Capabilities' maturity level was determined by analyzing the answers provided by each pilot in the open questions. If a question was answered as Y, it meant that the organization fulfilled the criterion, if answered otherwise it was considered that it did not and, therefore, it was not in a position to be classified with the question's correspondent maturity level.

While from H3 to H12 there was only an interviewee, making it easy to obtain the levels through an Excel formula, for hospitals H1 and H2, since in some cases there was not a consensus on the answer, it was necessary to run through each of the questions to check justifications and consider the most plausible ones.

5.3.2 Overall maturity level. To calculate a final value, it was decided to take into account the importance perceived by the participants regarding each capability for the overall level of maturity of the institution. The perceived importance was firstly transposed to a new scale ranging from 0 to 20, which kept the relative importance from the original scale ranging from 1 to 5. This transposition was necessary to avoid erroneous data coming from the lack of detail of a minimal scale. 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 this does not happen for all participants, the maximum achievable score (in ∑ of Table 1, at the end of this document) 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.

For H1 and H2, the highest degree of importance amongst the four participants 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 2 - *Number of questions per level in each capability*

		Number of questions per Level								
Level	Threshold (0-20)	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
	Total	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 1, at the end of this document) by the total number of questions in that capability (Table 2), determining the points per question for each capability. These were multiplied by the number of questions awarded with Y for each level and each capability. This process was repeated to all levels and capabilities, which summed all together corresponded to a value between 0 and 180 and, therefore, to a maturity level as described above (Table 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 3 (Table 3). 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 organization's overall maturity level.

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, which allowed us to identify minor formulation errors in the functions, which were immediately corrected.

Table 3 - *Hospitals' overall maturity level*

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

5.3.3 Comparison. From Figure 1 to Figure 6, 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.

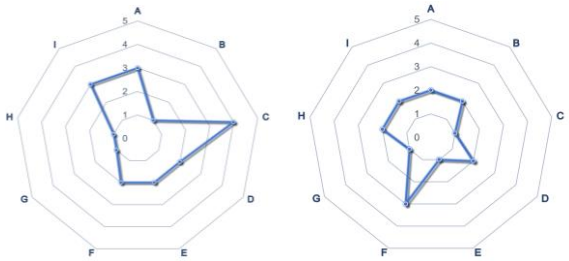

Figure 1 - *Capabilities' maturity level in H1 and H2, respectively*

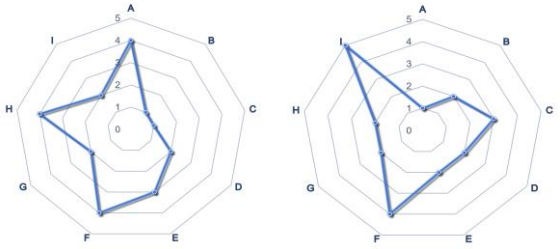

Figure 2 - *Capabilities' maturity level in H3 and H4, respectively*

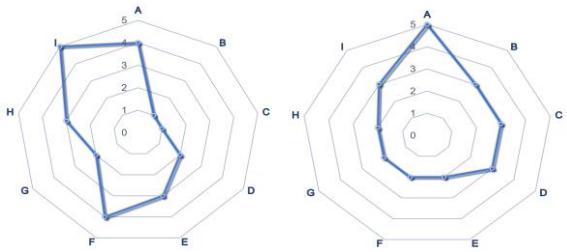

Figure 3 - *Capabilities' maturity level in H5 and H6, respectively*

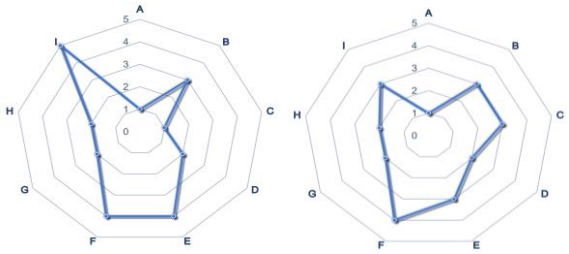

Figure 4 - *Capabilities' maturity level in H7 and H8, respectively*

Does not seem to exist a pattern in terms of underperformance of a specific capability. Otherwise, concerning 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 2), 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.

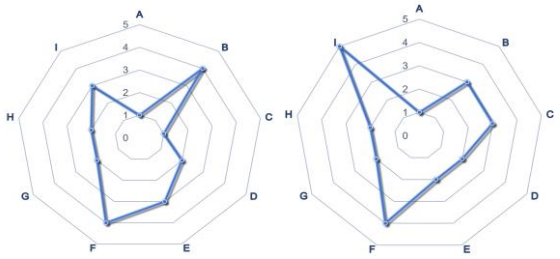

Figure 5 - *Capabilities' maturity level in H9 and H10, respectively*

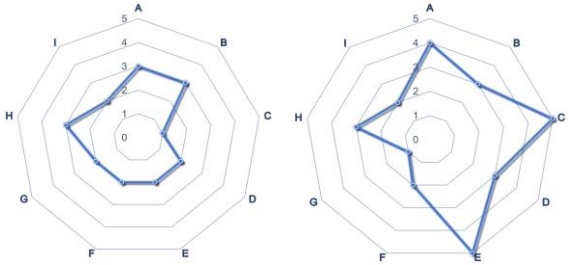

Figure 6 - *Capabilities' maturity level in H11 and H12, respectively*

Table 4 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 regarding the general maturity, that were mostly 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.

Table 4 - *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). All hospitals (except H8 and H12) have the highest percentage of their capabilities rated as level 2 or share the level 2 highest percentage with another level (H3, H5, and H6). These should be addressed as soon as possible to reach at least maturity level 3.

5.3.4 Improvements. The last stage of the dissertation consisted in identifying the weak points in the underperforming capabilities found during the assessment in each hospital and proposing general measures which the organization should look at with closer attention and analyze their viability. 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. Suggestions were made to address the following questions: (H1) B2.2, G2.2, and H2.3; (H2) C2.2, E2.1, and G2.2; (H3) B2.3 and C2.1; (H4) A2.1; (H5) B2.2 and C2.1; (H6) F3.1, E3.3, G3.1, H3.1, and H3.2; (H7) A2.2 and C2.1; (H8) A2.2; (H9) A2.2 and C2.1; (H10) A2.2; (H11) C2.2; (H12) G2.2.

6 Conclusions

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. All the research goals were met, and this model was developed in line with the methodological procedures for creating maturity models, 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, setting a note for future work to be performed.

It was 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. Despite being asked for it, through this method, none of the participants explained or gave evidence on their answers. 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. However, we believe that these will not be too considerable and, therefore, we can rely on the feasibility of the study.

From the foundation presented in this document, the following research directions can be taken: (1) To apply the solution artifacts to new case studies; (2) To study relationships between capabilities; (3) To perform an after-implementation of improvements study; (4) To refine the assessment questionnaire; (5) To combine the model with computer analysis and other quantitative techniques.

Table 1 - *Perceived importance by participant*

	Perceived importance by participant (New scale)																		
	H1				H2				H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	
C#	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	Count
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
Σ	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	

Acknowledgements

This research is a closing of a cycle in this eternal learning life.

First of all, I would like to thank Prof. Diogo Proença and Prof. José Rui Figueira for sharing their knowledge to make this dissertation possible and taking their time to challenge me to do and be better.

Also, I would like to thank Carolina Motta who, even though she had no commitment to me, readily shared her wisdom in the area of scientific writing, showing herself available to exchange countless e-mails and phone calls with me, always accompanied by her characteristic and uplifting humor.

A big thank you to all the employees of the hospitals under study, for their kindness and availability in answering the questionnaire during long interviews, without whose participation this dissertation would not have been possible.

Then, I would like to thank my group of friends from my bachelor's degree in Coimbra, which made the Mechanical Engineering Department feel like home to me and that helped me to grow as an adult, bringing, at the same time the funniest moments, parties and joy. You helped me realize that it is possible and, most of all, advisable to reconcile many long-lasting nocturnal coffees until the next-day morning with many long-lasting nights of study and work.

To the friends I made during these two years of my master's degree at Instituto Superior Técnico, who readily welcomed me and helped me get to know the campus and the city, even in such an atypical year marked by a hybrid course. Without them, I would not have been able to continue my university student life in a new city full of challenges and adapt so well. António, Chica, Tomás, Tiago e Vera.

To all the others who were forced to take study sessions with me and helped me keep my mental sanity in times of despair, Laura, Mafalda, and Leonor, thank you so much for your company.

Finally, and most important, I would like to thank my parents and the remaining members of my family, the ones that supported me the most through all my life, making everything that I accomplish special.

References

Albliwi, S. A., Antony, J., & Arshed, N. (2014). Critical literature review on maturity models for business process excellence. *2014 IEEE International Conference on Industrial Engineering and Engineering Management*, *2015-Janua*, 79–83. https://doi.org/10.1109/IEEM.2014.7058604

Becker, J., Knackstedt, R., & Pöppelbuß, J. (2009). Developing Maturity Models for IT Management - A Procedure Model and its Application. *Business & Information Systems Engineering*, *1*(3), 213–222. https://doi.org/10.1007/s12599-009-0044-5

Caralli, R., Knight, M., & Montgomery, A. (2012). *Maturity Models 101: A Primer for Applying Maturity Models to Smart Grid Security, Resilience, and Interoperability* (Issue November). https://doi.org/10.21236/ADA610461

CDC. (2019). *Public Health Preparedness and Response Capabilities: National Standards for State, Local, Tribal, and Territorial Public Health*. *January*, 1–168. http://ajph.aphapublications.org/doi/10.2105/9780875532806appE

CMMI Institute. (2021). *History of CMMI*. https://cmmiinstitute.zendesk.com/hc/en-us/articles/360025569473-History-of-CMMI

de Bruin, T., Rosemann, M., Freeze, R., & Kulkarni, U. (2005). Understanding the main phases of developing a maturity assessment model. *ACIS 2005 Proceedings - 16th Australasian Conference on Information Systems*.

European Union, & Civil Protection. (2019). *Peer*

review – report Portugal 2019.

Finegan, O., Fonseca, S., Guyomarc'h, P., Morcillo Mendez, M. D., Rodriguez Gonzalez, J., Tidball-Binz, M., & Winter, K. A. (2020). International Committee of the Red Cross (ICRC): General guidance for the management of the dead related to COVID-19. *Forensic Science International: Synergy*, *2*, 17. https://doi.org/10.1016/j.fsisyn.2020.03.007

Hevner, A., & Chatterjee, S. (2010). Design Research in Information Systems. In R. Sharda & S. Voß (Eds.), *Springer* (Vol. 22). Springer US. https://doi.org/10.1007/978-1-4419-5653-8

ISO/IEC. (2013). *Information technology Process assessment - Guide for process improvement*. *1*, 1–48.

ISO/IEC. (2017). *Information technology - Process assessment - An exemplar documented assessment process*. *1*, 1–40.

Kitchenham, B., Pearl Brereton, O., Budgen, D., Turner, M., Bailey, J., & Linkman, S. (2009). Systematic literature reviews in software engineering – A systematic literature review. *Information and Software Technology*, *51*(1), 7–15. https://doi.org/10.1016/j.infsof.2008.09.009

Mettler, T. (2014). *A Design Science Research Perspective on Maturity Models in Information Systems*. *41*(0), 1–14.

NSW Government. (2020). *A Capability Development Framework for NSW Emergency Management Sector*. 1–25.

Oliveira, R. C., & Ferreira, J. S. (2014). *Investigação operacional em ação: casos de aplicação* (R. Oliveira & J. Ferreira (eds.)). Imprensa da Universidade de Coimbra. https://doi.org/10.14195/978-989-26-0738-2

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A Design Science Research Methodology for Information Systems Research. *Journal of Management Information Systems*, *24*(3), 45–77. https://doi.org/10.2753/MIS0742-1222240302

PORDATA. (2020). *Retrato de Portugal* (2020th ed.). https://www.pordata.pt/ebooks/PT2020v20200710/mobile/index.html

Proença, D., & Borbinha, J. (2016). Maturity Models for Information Systems - A State of the Art. *Procedia Computer Science*, *100*, 1–8. https://doi.org/10.1016/j.procs.2016.09.279

Röglinger, M., & Pöppelbuß, J. (2011). What makes a useful maturity model? A framework of general design principles for maturity models and its demonstration in business process management. *19th European Conference on Information Systems, ECIS 2011*, 1–13. https://aisel.aisnet.org/ecis2011/28/?utm_source=aisel.aisnet.org%2Fecis2011%2F28&utm_medium=PDF&utm_campaign=PDFCoverPages

Rout, T. P., El Emam, K., Fusani, M., Goldenson, D., & Jung, H.-W. (2007). SPICE in retrospect: Developing a standard for process assessment. *Journal of Systems and Software*, *80*(9), 1483–1493. https://doi.org/10.1016/j.jss.2007.01.045

Sanchez, L., & Blanco, B. (2014). Three decades of continuous improvement. *Total Quality Management & Business Excellence*, *25*(9–10), 986–1001. https://doi.org/10.1080/14783363.2013.856547

Serviço Nacional de Saúde. (2021, May 3). *História do SNS*. https://www.sns.gov.pt/sns/servico-nacional-de-saude/historia-do-sns/

SNS. (2017). *Benchmarking Hospitais - Grupos e Instituições*. https://benchmarking-acss.min-saude.pt/BH_Enquadramento/GrupoInstituicoes

Varanda, J., Gonçalves, L., & Craveiro, I. (2020). The Unlikely Saviour: Portugal's National Health System and the Initial Impact of the COVID-19 Pandemic? *Development*, *63*(2–4), 291–297.

https://doi.org/10.1057/s41301-020-00268-8