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SYSTEMS-LEVEL QUALITY IMPROVEMENT

Maturity Assessment Methodology for HISMM - Hospital Information System Maturity Model

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Abstract

Maturity models have been adopted in organizations from different sectors of activity, as guides and references for information system (IS) management. In the healthcare field, maturity models have also been used to deal with the enormous complexity and demands of hospital information systems (HIS). This article presents a research project that aimed to develop a new comprehensive model of maturity for a health area. HISMM (hospital information system maturity model) was developed to address the complexity of HIS and intends to offer a useful tool to meet the demands of its management. The HISMM has the peculiarity of combining a set of key maturity influence factors and their respective characteristics, enabling not only the assessment of the global maturity of an HIS but also of the individual maturities of its various dimensions. In this article, we present a methodology for the application and implementation of this model in HIS, thus contributing to its widespread practical application and acceptance.

Keywords Stages of growth · Maturity models · Hospital information systems · Management · eHealth

Introduction

The technological revolution we are currently experiencing results from a combination of increased computer acceleration capabilities, the reach and expansion of the Internet and the growing ability to capture and leverage knowledge in a digital format. This technological revolution naturally impacts on healthcare services, changing the relationship between patients and healthcare professionals, that is, providing significant opportunities for healthcare professionals to deliver technology-effective healthcare services to their customers and offering the latter ways to access all the information they need. However, healthcare systems all over the world are under considerable pressure to reduce continuously rising costs, while simultaneously maintaining, or even improving, the quality of healthcare services [1]. Collateral factors, such as demographic changes, the lack of qualified healthcare professionals, and the expectations of, and demands from, patients, local administrators and health insurance companies, hinder the attainment of this goal [2]. It is strongly expected that a broader adoption of information systems and technologies (IST) in the healthcare field will contribute decisively to reducing costs and improving quality [3]. However, evidence shows that implementing IST without considering the underlying strategic and organizational structures and processes, will not necessarily produce the expected benefits [4]. Indeed, IST are generally perceived as having enormous potential to improve healthcare systems, and several examples from around the world prove this point. Unfortunately, some cases have also led to disappointment and scepticism [5]. Several studies highlight the importance of finding suitable models that improve, measure and assess the success rate of healthcare systems-related projects [5]. Maturity models are a perfect match to achieve these goals.

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Maturity models are available to respond to many different challenges. These models provide information to assist organizations in addressing problems and challenges in a structured way, providing both a reference point to assess capabilities and a roadmap for improving [6]. In other words, maturity models offer orientation through an evolutionary process, incorporating procedures for improving activities [7].

Various maturity models have been proposed over time, both for the development of individuals and for the general evolution of organizations or the particular evolution of the IS management function. However, as organizations face constant pressures to achieve and maintain competitive advantage by inventing and reinventing new products and services, to reduce costs and time to market and at the same time to improve quality, there is a continuing need for development of new maturity models, since they help decision-makers to achieve these goals [4]. In health, the volatility of systems, services, applications and products over time, justifies the appearance of new maturity models, or at least, the rectification of existing ones.

The present paper introduces a maturity model called HISMM and explains how it should be applied in HIS. In the next section, the opportunity to develop a new maturity model for HIS is presented and justified, based on the limitations of the existing models. In the following section, HISMM will be explained, as well as the activities that supported its development. Finally, the section preceding the discussion and the conclusion explains the methodology for the application and implementation of this model in HIS.

HIS maturity model: Necessity vs opportunity

Healthcare and governmental organizations are starting to realize that a certain inability to properly manage health processes is directly connected to limitations in technological infrastructures and to the ineffectiveness of their management [8, 9]. Considering the healthcare context, the weight and significance of technological transition-related problems becomes clear [9]. Moreover, the complexity of IT operations has grown to meet the demands of this sector. This increase in complexity has led to the introduction of multiple new business integration systems, processes and approaches, as well as the emergence of new companies offering their services in the field. Consequently, immature products and services are being implemented by HIS, which are undergoing changes and demanding, more than ever, a level of performance and effectiveness that answers their actual needs. In this context, it is difficult to know whether a good job is being done in managing these changes and monitoring progress on an ongoing basis. Furthermore, managing interactions between systems and processes that are constantly evolving is a difficult task, as is managing the impacts of low interoperability, safety, reliability, efficiency and effectiveness processes. The benefits of modern technologies in the healthcare field, sustained by improved methods and tools, cannot be harvested through undisciplined and chaotic processes [10]. That is why we believe HIS management must be supported by the implementation of maturity models.

As in most IS fields, several maturity models have been proposed for the healthcare field. However, although the specificities of these models set them apart from those used in other fields, they remain at an early stage of development [11, 12]. In the course of our investigation we observed that healthcare models are insufficiently detailed, fail to offer maturity assessment tools and do not structure their maturity stages according to influencing factors. Moreover, in our literature review [13], as well as in complementary studies, we noticed the absence, as far as we could tell, of a tolerably all-encompassing healthcare model which assesses the maturity of the different dimensions of an HIS. Indeed, a thorough analysis of scientific papers, manuals, reports and websites addressing healthcare-related maturity models, revealed an absence of maturity models whose dimensions or influencing factors are taken into account with different relative weights, according to relevance. Faced with these limitations, we identified the opportunity to develop a sufficiently all-encompassing maturity model incorporating the main HIS influencing factors.

The proposed HISMM - hospital information system maturity model

In order to develop a new HIS maturity model, we defined a set of activities in compliance with the established research methodologies that are considered most suitable for this type of project (see Fig. 1). Based on our literature review [13], the activities included a review of key concepts and aspects of maturity models, i.e., a state-of-the-art review on healthcare IS maturity models, as well as the identification and definition of influencing factors adopted in these models. The design science research (DSR) methodology, in its turn, supported the activities connected with the identification of the main influencing factors and the subsequent proposal and validation of the new model. Based on a survey carried out via a questionnaire given to 46 HIS experts, we identified the main influencing factors and developed the first version of our HISMM [14]. Subsequently, the DSR supported our model validation through a series of interviews carried out with a selected group of HIS managers.

To support our decision regarding the methodology to be applied, we conducted another literature review, in order to find the state of the art on methodologies to apply in the conception of maturity models. The approach proposed by Mettler [7] was in our option due to its characteristics, which we consider that are appropriated for our model.

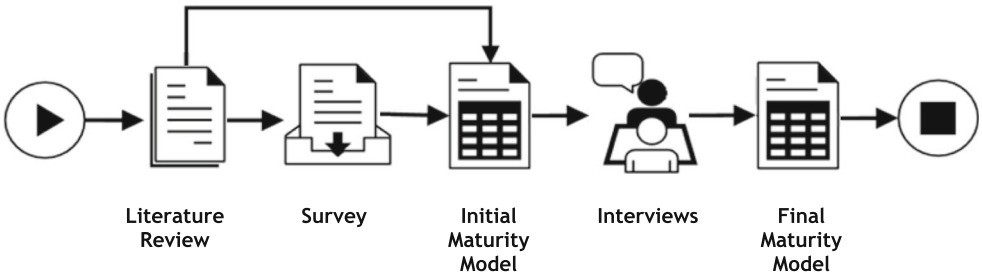

Fig. 1 Activities carried out in the development of the HISMM

The HISMM [15, 16] was inspired by the revised model of maturity stages of Galliers and Sutherland [17], and it displays a conventional maturity-model structure, that is, a matrix comprising different maturity stages and the six influencing factors identified as the most relevant for healthcare IS [14]. As seen in Table 1, where our HISMM is described, each factor identifies the features that typify the focus of each maturity stage. These factors emerge as reference descriptors or variables that characterize each stage and determine the necessary criteria for reaching a specific maturity stage. It should be noted that these influencing factors present different percentages due to their relative importance, as initially established by the 46 experts who participated in the survey and then validated by the interviewees.

In other words, the HISMM architecture comprehends the "levels" (or stages) on an evolutionary scale, with measurable transitions between levels. With measurable transition states between levels, hospitals can use this scale to: (1) define the current maturity stage, (2) determine the next achievable maturity stage and (3) identify the attributes that must be met to achieve a new maturity stage.

As previously mentioned, HISMM presents 6 dimensions or influence factors that were considered the most important in HIS. These influence factors will be briefly described in the next sections.

Data analysis

Organizations that intend to increase the use of Data Analysis to optimize costs, profitability, productivity and quality should consider strategic investments in this field. Healthcare organizations are clearly no exception to this rule. The collection, storage and analysis of health data have been, are and will remain some of the fundamentals in providing efficient healthcare services and their importance is increasing in line with the growing amount of health data collected every day [18].

Strategy

The ability to develop a strategic plan and effectively implement it, is fundamental to the sustainable growth of any organization, including hospitals. HIS maturity is often measured, based on the ability to adapt to strategic changes or new opportunities. In a time of fast-paced changes and tight IT budgets, the ability to concentrate efforts on matters, which are of strategic importance to each department, sector or health organization as a whole, becomes increasingly critical.

People

People play a central role in health organizations and are, more than ever, becoming a differentiating factor, assuming an increasingly relevant position in their growth and development strategies. Depending on how services are configured, health processes may include patients, health professionals (such as medical specialists, nurses and radiologists) and IST professionals, amongst others.

Electronic medical record

The adoption of an electronic medical record system is a primary goal of modern health organizations, as it is mainly intended to improve their effectiveness when treating patient information and making it available in a timely and accurate form at the point of service [19]. This system works as the main source of all information relating to the patient, offering a complete medical record that should be available both *online* and when in human contact with the patient.

Information security

The main goals of data security are confidentiality, integrity and availability. However, safeguarding these goals does not translate automatically into security measures for health organizations. Security is achieved by simultaneously preventing attacks against IST and guaranteeing that the mission of the organization is fulfilled, despite attacks and accidents [20].

Systems and IT infrastructure

System connected with the health care process are a set of activities, methods, practices that people use to provide healthcare services and maintain the environment that supports the service providers. [9]. As in other activity sector, hospitals must resort to IST and their IT infrastructure to support all their activities, both inside the hospital environment and where different health field partners are involved [21].

Table 1 HISMM Maturity Model

	STAGE I Adhocracy	STAGE II Starting the Foundations	STAGE III Centralized Dictatorship	STAGE IV Democratic Cooperation	STAGE V Entrepreneurial Opportunity	STAGE VI Integrated Relationships
DATA ANALYSIS	• Isolated and fragmented data analysis solutions • Heavy and complex production of internal and external reports • Data integrity issues • Inability to handle large volumes and variety of data • Problems when collecting data from different systems • Lack of analytical and IT resources • Use of spreadsheets and local database	• Key data collection and integration • Centralized data repositories • Automated production of internal reports • Automated production of daily metrics available on BI platforms • Daily productivity is automatically estimated and delivered to managers • Ability to drill down from a summary to the particular conditions of the patient	• Efficient and consistent report production and adaptability to changing requirements • Decreased variability in healthcare processes and increased focus on internal optimization and waste reduction • Senior managers monitor productivity in terms of staff and combination of skills • Department managers monitor daily productivity results on their dashboards	• Patient care is adjusted, based on metrics • Final users have started to incorporate analytical patient data, including big data, in operations and daily tasks • Costs and quality are monitored via organizational performance dashboards • Financial results and clinical patient data form a competitive advantage to increase profit	• Organizational processes for intervention are supported by predictive risk models • Clinical risk intervention, modelling and predictive analysis • Full integration of service line data in the strategic planning process • Existence of an Analytics Ecosystem that supports innovation and data exploitation • Clinical outcomes screened with data warehouses and big data sources • Alarm management or clinical data intelligence production	• Adoption of personalized medicine and prospective analyses • Patient care adjustment based on population results and genetic data • All valuable data are available for analysis and exploration • Real-time data are used in critical activities, such as patient care • Internal and external data sources to improve and optimize costs and quality • Permanent data analysis mentality and culture
STRATEGY	• There is no global strategy for IS/IT • There is no formal strategy • Ad hoc strategies adopted by different IS sub-areas to answer isolated problems and needs • IT governance processes are not enforced and the organization does not recognize their need	• Development plans in silos and static structures • Lack of understanding of how to achieve success • The impact of high-level strategies and goals is not mapped • Strategic planning has little impact on day-to-day operations, budgets and resources • Individuals are left on their own to interpret goals, strategies and priorities • IT governance processes are casual and uncoordinated	• Plans are shared between silos • Different plans with a shared impact are aligned • Low prioritization between groups for high-level projects, goals and plans • There is a measuring tool (although minimal) to assess success and/or impacts • A formal strategy with a technology-centric tendency • IT governance processes follow a regular path	• Strategic plans share a common format • Strategic plans are shared with other strategic initiatives • Available metrics measure the impact of high-level goals in each programme • Projects are prioritized based on impact and alignment with established goals • Increasingly inclusive planning for all groups, plans and strategies • IT governance processes are documented and reported	• A specific group reviews goals and measures progress • Strategic goals become managed programmes • The strategy is regularly reviewed and updated • Funding processes are aligned to support strategic goals • Faster and more efficient planning and impact analyses • Evolution strategies based on new opportunities and developments in the sector • IT governance processes are monitored and measured	• Plans are agile and interactive • Plans to change impacts are understood and shared with other plans • Projects and costs are measured against strategic goals • Metrics support decision-making processes connected with goals and forms of achieving success • A strategic review involves all stakeholders for more comprehensive initiatives • Best IT governance practices are followed and automated
PEOPLE	• Inconsistency when performing existing practices • Lack of responsibility and capacity of managers/staff • Practices based on customs and habits • Teams lack emotional involvement	• Enforcement of a basic set of people management practices • Adoption of communication and coordination procedures • Introduction of performance management • People receive training • Existence of continuing training plans by type of user	• The development of an infrastructure to increase workforce capacity • Analysis and development of skills • Human resource planning • Recognition of the usability value • Internal awareness programmes on usability	• Previously implemented work practices are now standardized and adjusted • Development of careers, work groups and practices, based on skills • Participatory culture • Integration of skills at work	• Autonomous work groups • Quantitative management of performance and measured practices • Management of organizational capability • Guidance and counselling • All usability benchmarks are implemented, including the	• Continuous improvement in individual and work group skills • Work groups are aligned with organizational capability/performance • Continuous human resource innovation • Business benefits are understood, usability is

Table 1 (continued)

	• Lack of awareness about the relevance of usability • No initial training plan according to the type of user • Individualist attitude among ICT professionals	• The IS/IT team may receive some training in usability, although this is provided during work, rather than as a formal process		• A small team with usability-related responsibilities • Formal training to expand usability skills • Sharing expert staff with other health units	existence of a team focused on user experience • Staff are trained and know how to apply best practices when developing assessment systems for internal and external use • Healthcare professionals must participate in the definition/design of their clinical pathways	completely acknowledged, and the results are strategically used by the organization • Ongoing integrated development training for teams • Users are trained/encouraged to learn new skills
ELECTRONIC MEDICAL RECORD	• Patient clinical data are administrative only • Independent client management and departmental systems • Primary records and clinical images in microfilm or paper formats • Requires access to paper-based systems because not all repositories are electronic • Relies on statistical formats • Content is kept in separate repositories • There is no master patient Index system	• Integrated clinical diagnosis and treatment support • Integrated use of master patient index with departmental systems to organize content • Early PACS and ERP integration • DICOM images are accessed via separate repositories • Basic scanning of medical records in selected areas only • Record management for physical content only • Electronic integration with administrative systems • Administrative capabilities in resource management, electronic discharge submission, treatment schedule and electronic claims/payment processing	• Clinical activity support • Clinical documentation includes electronic clinical order, report results, prescriptions, multi-professional care • PACS available outside radiology • Medical record recovery (EMR, ECM, DICOM) through portals • Limited EMR and DICOM integration with heavy reliance on unstructured content • Limited electronic record management • EMR with limited interoperability • CIS, LIS, RIS, PACS and medication/pharmacy management systems are implemented	• Adoption of clinical knowledge and decision-making support • Electronic access to guidelines, rules alerts and support systems • Closed-circuit medication administration • Large-scale PACS dissemination and communication • Internal portals used to access repositories with relevant contents, such as EMR and PACS • EMR connection with automated ID, barcodes and OCR for image captioning • Static forms replaced by e-forms • Integrated CPOE with billing system	• Medical documents based on structured templates • Outpatient and inpatient regimes • PACS process innovation • Complete PACS and patient medical record integration • Integration of specialized medical modules	• Fully electronic medical records for all areas • Complete recovery of medical records through an EMR-based portal • Adoption of mobile telemedicine and wireless access to clinical data • Patient records become a collaborative tool • Complete point-of-care data (tablet, voice or workstation) • Management of audit requests, incidents and investigations • Content organized to support results-based analyses • Use of BPM for cross-functional processes • Medical record use by several healthcare providers
INFORMATION SECURITY	• Absence of policies to ensure IT/IS security • Investment in security systems is not a priority • The impact of vulnerabilities is not evaluated	• Early stage of conformity • Lack of policies and procedures defined to protect the organization • No contingency plan in crisis situations • Reactive and unplanned security control • Goals change in response to attacks with the implementation of some type of protection	• Applications and network security are implemented • Changes are not managed in a centralized way and security requests are performed ad hoc • Goals focus on business activities of the organization and the protection of central systems • Systems are falsely perceived as being protected • Unique credentials for portal access	• Security awareness programmes are adopted only for key resources • IT security procedures are formally defined • Responsibility for IT security is assigned, but execution is inconsistent • Ability to perform some penetration and detection tests • Closely monitored and mandatory access controls	• Centralized management of security-related issues and policies • Users are reliable, although system interaction is perceived as a vulnerability • No ad hoc changes • Implementation of central configuration models, from which all settings are derived • Security policies and procedures are in force • Identity management of in/out professionals	• Formal policies and procedures to prevent, detect and correct security problems • Corporate governance aligned with security needs • Internal audit policies with published results and implemented actions • Identification of security issues/ incidents is systematically monitored • Notification system for security incidents • Email filters and intrusion detection systems are used

Table 1 (continued)

SYSTEMS AND IT INFRASTRUCTURE	• Uncoordinated and unconnected systems with limited applications • LAN infrastructure • Key financial and administrative systems are implemented • Infrastructural management is manual, unarticulated and ad hoc • At this level, IT focuses on downtime avoidance • Lack of monitoring causes reactive and ad hoc procedures • Unpredictable service performance • Lack of interoperability awareness and supporting processes • Usability focuses on products and processes, rather than on people	• Internet-based infrastructure with HIPAA • Manual, yet coordinated, infrastructure management • Knowledge storage in silos • Services are managed and predictable • The organization is focused on obtaining infrastructural control • Interoperability solutions are firstly applied in clinical/ administrative areas • Product and service usability focused on users • Sporadic incursion in usability practices with limited resources	• Communication infrastructure based on Secure HL7 • Infrastructure for collaboration and knowledge-sharing • • Reactive, yet becoming proactive • Stable IT infrastructure • The organization recognizes the importance of adopting norms and best practices	• Cooperative infrastructure involving medical communities • Adoption of electronic prescriptions • Implementation of international coding of diseases, alerts/ contraindications for educational purposes • Incorporated nursing documentation system • Management of the emergency and cardiology departments • Interoperability guidelines defined for healthcare norms, services, policies, processes and legal compliance	• Fully connected and paper-free infrastructure (SaaS model) • Physician portal and patient portal • Wireless infrastructure • Available processing data tools for research purposes • Consolidated infrastructure level with OaaS model and RaaS model • Knowledge-sharing and collaboration inside the team • Proactive infrastructure and continuous service improvement • Interoperability assessment processes	• Infrastructure in a regional/ national network connecting all service providers • Aggregate data from all hospitals and regions enable governmental healthcare planning initiatives • Remote patient monitoring and telemedicine • Continuously improving interoperability capability based on monitored process feedback • Focused on becoming a catalyst for innovation • Infrastructure for knowledge-sharing and business collaborations, both internal and external • IT/IS and healthcare stakeholders work as a team

Maturity assessment methodology for HISMM

After presenting HISMM, it is necessary to discuss the methodology associated with its application. In fact, the correct application of the HISMM within the HIS is revealed as fundamental, from the perspective of clarifying the positioning of each hospital at the level of their IS and the perspective of identifying the aspects of their IS which should be given greater attention by management.

The HISMM follows a staged structure and has two major components: maturity stages and influencing factors. Each maturity stage is determined by an equal number of influencing factors for all stages. Each influencing factor is defined by a variable number of characteristics that specify the key practices/systems which, when performed, can help HIS meet the objectives of a particular maturity level. These characteristics become indicators, which, when measured, determine the maturity stage. The HISMM defines six maturity stages and proposes that the HIS under study should ascend from one stage of maturity to the next without skipping any intermediate stages. In practice, HIS can accomplish specific practices in the upper stages. However, this does not mean that stages can be skipped, since optimum results are unlikely if practices in the lower stages remain unfulfilled. To move from one maturity stage to a more advanced stage, the hospital needs to develop suitable strategies leading the hospital to achieve the characteristics of the next stage.

Assumptions for HISMM application

In the context of HISMM application, it will be necessary to consider the following set of assumptions.

- It is unlikely that an HIS will, at any given moment, be in a single stage of maturity for all dimensions/influencing factors. On the contrary, it is most likely that an HIS will present characteristics in several stages, making it difficult to identify its overall stage.
- There are several characteristics of the initial stages that must be achieved, in order that the characteristics associated with greater maturity to be achieved as well. For example, in order that electronic records for all areas (stage 6) to be achieved, the electronic integration with administrative systems (stage 2) feature must be concluded.
- In the implementation of a new HIS, managers who want to adopt this maturity model should plan the HIS according to the defined strategies, without needing to fulfil all the characteristics from the first stages of maturity. In fact, some of the characteristics of the initial stages are automatically achieved by practising procedures associated with the more advanced stages.
- In the process of progression between stages, HIS managers should preferably consolidate the characteristics of the stages already fulfilled. That is, all the characteristics must be satisfied in order to move smoothly to the next stage. Only then should the priorities be defined according to the strategic options of each HIS, in order to reach the next stage.
- HIS does not always evolve automatically into higher stages. There may be situations that force HIS to retreat into the previous maturity stage in a given dimension. In fact, if a specialized HIS professional leaves, changes in people management can lead to a regression of HIS maturity. The same can happen if the implementation of a system does not have the expected success.
- Concerning the determination of the stage of maturity, an HIS to be in a certain stage does not have to have all characteristics materialized. If all the characteristics of a certain stage are fulfilled, the HIS has this stage completed and is in the next maturity stage.

Maturity determination

As previously mentioned, HISMM has a two-dimensional structure to which a hierarchy of levels can be assigned (Fig. 2). The first hierarchical level is HISMM itself, which measures the overall maturity of HIS between 1 and 6. The second level is represented by domains called influencing factors (IF). These domains must be measurable and controllable and are related to a third hierarchical level called "critical variables" (CV) or characteristics. Each IF can be measured according to its positioning associated with the maturity stage (between stage 1 and stage 6), which can be determined by the existence or non-existence of CV (i.e. CV are Boolean type). It should also be noted that the calculation of the general maturity of the HIS will take into account the different weights associated with the FI. In fact, there are IF that present themselves as more influential, according to a study by Carvalho et al. [14].

Therefore, the maturity stage of each HIS studied is measured by assessing progress for each influencing factor, indicated by an analysis of the respective CV. To qualify for a specific maturity stage, the HIS under study, at least must perform most of the key practices of the previous stages successfully. Firstly, for each maturity influencing factor, the percentage of characteristics (% CV) achieved in each stage will be calculated. For each maturity influencing factor, the hospital is at the stage of the corresponding numerical value, which can be calculated using the following formulas:

$$Maturity\ Level\ IF1 = 1 + INT\ [\%CV\ (stage1) + \%CV\ (stage2) + \ldots. + \%CV\ (stage6)] \quad (1)$$

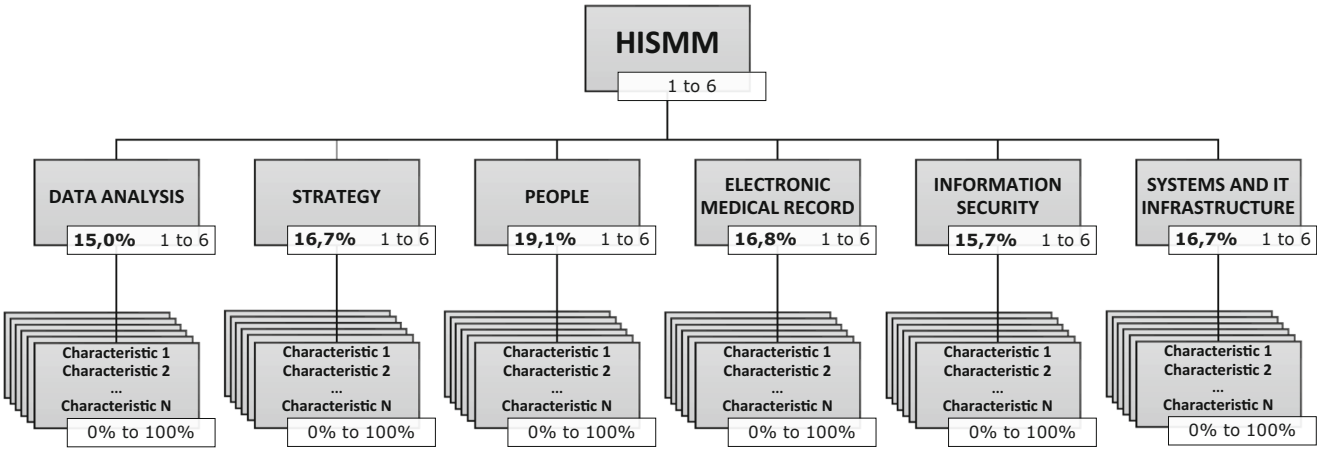

Fig. 2 Hierarchy of levels for maturity determination with HISMM

$$Maturity\ Level\ IF2 = 1 + INT\ [\%CV\ (stage1) + \%CV\ (stage2) + \ldots. + \%CV\ (stage6)] \quad (2)$$

$$Maturity\ Level\ IF6 = 1 + INT\ [\%CV\ (stage1) + \%CV\ (stage2) + \ldots. + \%CV\ (stage6)] \quad (3)$$

After calculating the stage of each IF, it will be possible to calculate the overall maturity of the HIS. To calculate the overall HIS maturity, taking into account all influencing factors and their respective weights, the following formula should be used:

$$HIS\ Maturity = Maturity\ Level\ IF1^{*}\ 15\% + Maturity\ Level\ IF2^{*}\ 16.7\% + Maturity\ Level\ IF3^{*}\ 19.1\% + Maturity\ Level\ IF4^{*}\ 16.8\% + Maturity\ Level\ IF5^{*}\ 15.7\% + Maturity\ Level\ IF6^{*}\ 16.7\% \quad (4)$$

Conduct of survey

A protocol (Fig. 3) will be developed to ensure consistency of data gathering when conducting the HIS maturity evaluation process. Following an initial meeting at which the model and its origins are presented, a survey will be used to gather data during the evaluation process. An extensive survey will be conducted to apply the model to a hospital whose HIS will be evaluated.

When we design the survey, one of the difficulties was to define the right questions in terms of quality and quantity, in order to obtain relevant and useful information for a meaningful analysis. The final maturity survey contained over 220 questions categorized by influencing factor, coverage and proficiency. The questions result in verifications of the existence or inexistence of a certain characteristic or CV. Table 2 presents three examples of survey questions arising from the HISMM characteristics.

In an effort to increase user acceptability, the survey will be developed to enable completion either by different people for

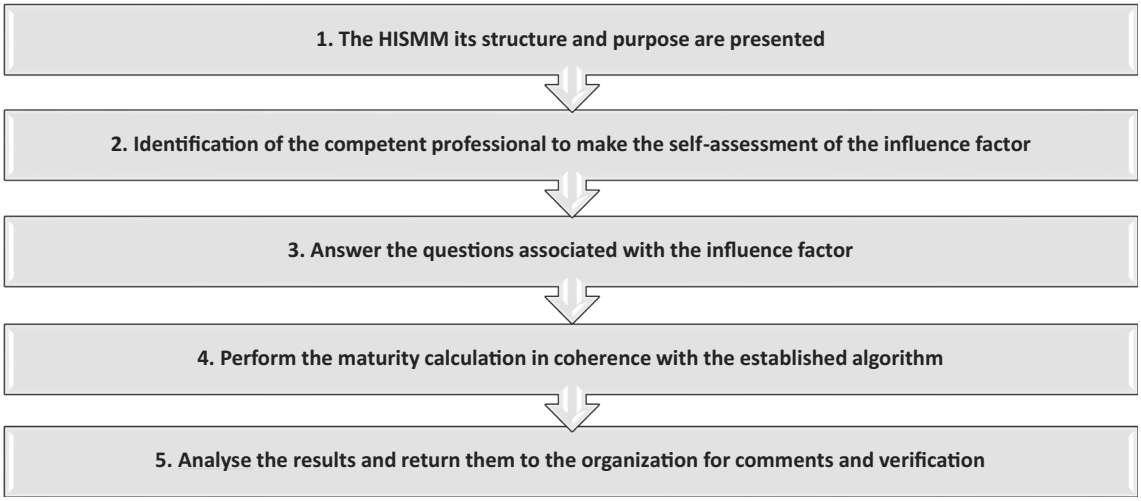

Fig. 3 Protocol to conduct the survey for HIS evaluation

Table 2 Some examples of survey questions

HISMM characteristic	Survey questions	
• Ability to drill down from a summary to the particular conditions of the patient	In the context of data analytics, the system has the ability to drill down from a summary to the particular conditions of the patient?	Yes ☒ No ☐
• Analysis and development of skills	Are there any procedures for analysing and developing people's skills?	Yes ☒ No ☐
• Interoperability assessment processes	Are interoperability assessment processes in place?	Yes ☒ No ☐

each influencing factor or by a single individual (CIO or another HIS professional) who has a deep knowledge of all HIS. In this context, the organization (hospital) should be able to identify specialists for each influence factor. The results of the survey will be analysed and fed back to the organization for comment and verification.

Maturity assessment tool

As part of this project, an assessment tool was designed (designated electronic HISMM or eHISMM) along with the maturity model that allows a practical application of the model. This assessment instrument is based on the questions used in the survey referred above. Thus, to evaluate the HIS maturity using the eHISMM and the measurement instruments that will be proposed, it is necessary to obtain a set of data from the responses to the questionnaire based on the indicators (CV) that define the influencing factors of our maturity model.

The eHISMM will be an online platform available 24/7, which will serve not only to assess the overall maturity of HIS but also the maturity of its different influencing factors. This automatic tool presents other features that complement the entire HIS characterization process as follows.

- Detailed characterization of HIS under study.
- Summary information on HISMM and the entire evaluation process.
- Comparison between HIS maturities of different hospitals.
- HIS positioning in relation to the average maturity of the category in which the hospital stands.
- Evolution over time of HIS maturity.
- Feedback on success cases with initiatives that have improved HIS maturity.
- Diversified graphical presentation of HIS maturity results.
- Identification of the characteristics that must be reached to improve HIS maturity.
- Semi-annual reports on the general maturity of national (and international) hospitals.

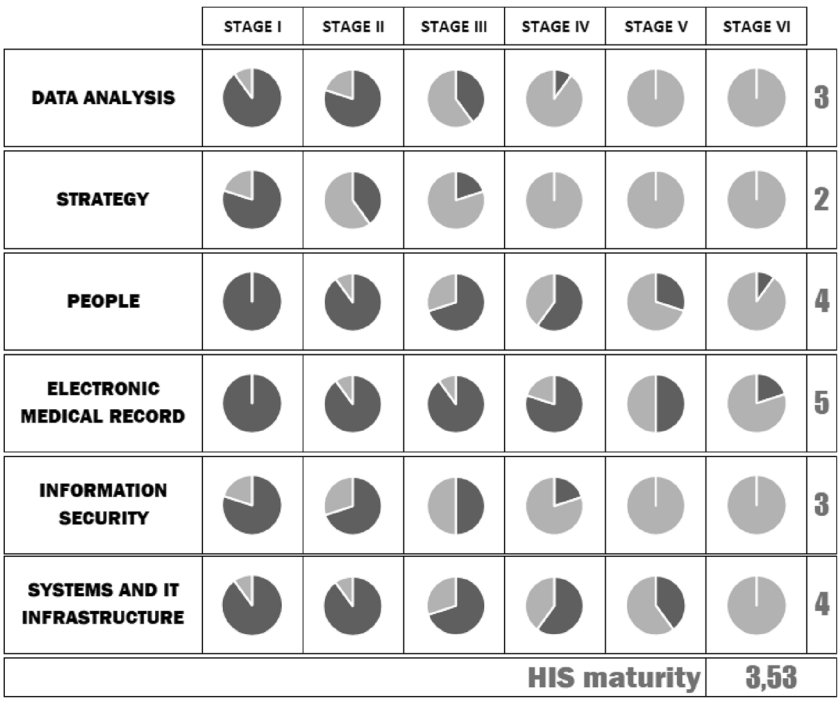

Fig. 4 Example of application, calculation and presentation of HIS maturity

- Input and analysis of new characteristics for HISMM, based on recommendations introduced by participants.

As an example of the HISMM application, we present the hypothetical results of an HIS that obtains a general maturity of 3,53 after calculating formula *(4)*, although it has different maturities for the 6 influence factors. For example, in the case of Data Analysis, this HIS has 90% of the characteristics materialized for the 1st stage, 80% for the 2nd stage, 40% for the 3rd stage, 10% for the 4th stage and 0% for the 5th and 6th stages. Thus, formula (1) would result in value 3 for this IF. In the following Fig. 4, is presented the table described the maturity for this HIS.

Discussion

The outcomes of this work suggest that the designed and empirically validated HISMM, which includes six stages of HIS growth and maturity progression, enables both the assessment of the global maturity of an HIS and the individual maturity of its various weighted dimensions. The HISMM, as an artefact, also represents a practical application for decision-makers in the process of situationally setting goals and systematically enabling the HIS to evolve toward higher maturity levels. This process can now be supported by the HISMM architecture, which includes various comprehensible evolutionary stages with associated measurable indicators. The HISMM can be applied to a wide variety of conditions and circumstances, and through the systematic application methodology presented here, will be easier to implement and use for managers who want a simple and versatile tool for the maturity evaluation of their HIS.

Stage-based maturity models are often criticized for being overly simplistic in nature [22]. In principle, this current empirically validated model provides all the necessary means for evolving through the different stages of maturity and simultaneously presents distinctive characteristics associated with each of the main sub-areas of HIS. HIS implementations can also be evaluated, taking into account that their different stages of maturity can be determined by the weights of their different sub-areas. Therefore, the HISMM allows for situational routes and improvement roadmaps, thereby avoiding the linearity pitfall of most stage-based models, in order to achieve the strategic direction of the hospital. Currently, hospital decision-makers are under pressure to reduce operational costs, while simultaneously improving their hospital's efficiency and effectiveness using costly IST. It is within this process that they should manage the implementation, adoption and acceptance of new digital technologies and systems within the hospital enterprise. Our HIMSS model is, therefore, a promising route by which to address the many challenges that hospitals face.

Conclusion

The current article concerns a research project whose objective is the development and implementation of a comprehensive maturity model for the HIS area. Comprehensive model of maturity, in order to include several dimensions associated with the information system, especially in identifying ways to optimize it. As far as we know, none of the identified maturity models in the literature has a sufficiently focused on the capability of the IS support complex, diversified, interoperable and dynamic organizational processes of HIS. In this perspective, there is an opportunity for proposing a new model to fill the gap.

The results of this investigation have been both encouraging and promising, revealing a high level of acceptance among the interviewed managers, as well as several additional requests for information that we have been received from managers and health professionals from various parts of the world. This good level of acceptance has encouraged us to clarify how this model should be applied.

Following the conclusion of the model development and validation phase, the effort focuses on the methodology for HISMM application in hospital organizations. In fact, the practical application of HISMM is fundamental, in order to provide the manager with the identification of the HIS maturity level. In addition, with the HISMM application, it is possible to identify: the aspects that should be given maximum attention in order to progress to a higher maturity, the evolution over time of the HIS maturity and the HIS positioning in relation to the average maturity of the hospital category, among other features.

As future work, we intend to conclude the design and construction of the eHISMM automatic tool presented in this article. In addition, it is planned to implement this methodology in several hospitals, in order to concretize the associated procedures for the consolidation of this methodology. These two goals are very important for the success of such maturity model in terms of recognition, strength and relevance, in both the health sector and in the society in general.

Compliance with Ethical Standards

Conflict of Interest João Vidal Carvalho declares that has no conflict of interest. Álvaro Rocha declares that has no conflict of interest. António Abreu declares that has no conflict of interest.

This article does not contain any studies with animals performed by any of the authors.

Informed Consent Informed consent was obtained from all individual participants included in the study.

References

1. Fitterer, R., and Rohner, P., Towards assessing the networkability of health care providers: a maturity model approach. *Inf. Syst. E-bus Mana.* 8:309–333, 2010.
2. Ahtonen, A., *Healthy and active ageing: turning the 'silver' economy into gold.* European Policy Centre, Europe's Political Economy - Coalition for Health, Ethics and Society (CHES), 2012.
3. Khoumbati, K., Themistocleous, M., and Irani, Z., Evaluating the adoption of enterprise application integration in health-care organizations. *J. Manag. Inform. Syst.* 22(4):69–108, 2006.
4. Mettler, T., Maturity assessment models: a design science research approach. *Int. J. Soc. Syst. Sci.* 3, Nr. 1–2, 2011: p. 81–98.
5. Van Dyk, L. and Schutte, C.S.L., The telemedicine service maturity Model: A framework for the measurement and improvement of telemedicine services. *Intech: Open Science/open Minds Telemed.* (Chapter 10), 2013.
6. Caralli, R. and Knight, M., Maturity models 101: a primer for applying maturity models to smart grid security, resilience, and interoperability. Software engineering institute, Carnegie Mellon University, 2012.
7. Mettler, T., Thinking in terms of design decisions when developing maturity models. *Int. J. Strat. Decision Sci. (IJSDS)*, 2010. 1(4): p. 76–87.
8. Freixo, J., and Rocha, Á., Arquitetura de Informação de Suporte à Gestão da Qualidade em Unidades Hospitalares. *RISTI - Revista Ibérica de Sistemas e Tecnologias de Informação* 14:1–18, 2014.
9. Sharma, B., Electronic healthcare maturity Model (eHMM): A white paper. Quintegra Solutions Limited, 2008.
10. Gonçalves, J., and Rocha, Á., A decision support system for quality of life in head and neck oncology patients. *Head Neck Oncol.* 4(3): 1–9, 2012.
11. Mettler, T., A design science research perspective on maturity models in information systems. St. Gallen: University of St. Gallen, 2009.
12. Rocha, Á., Evolution of information systems and technologies maturity in healthcare. *Int. J. Healthcare Inform. Syst. Inform.* 6(2):28–36, 2011.
13. Carvalho, J. V., Rocha, Á., and Abreu, A., Maturity models of healthcare information systems and technologies: a literature review. *J. Med. Syst.* 40(6):1–10, 2016.
14. Carvalho, J.V., Rocha, A., and Abreu, A., Maturity of hospital information systems: Most important influencing factors. *Health Inform. J.* 1460458217720054, 2017.
15. Carvalho, J. V., Rocha, Á., and Abreu, A., HISMM - hospital information system maturity model: a synthesis. *Int Conf Softw Process Improve.* 537:189–200, 2016.
16. Carvalho, J. V. et al., A maturity model for hospital information systems. *J. Bus. Res.* 94(1):388–399, 2019.
17. Galliers, R. D., and Sutherland, A. R., Information systems management and strategy formulation: The 'stages of growth' model revised. *J. Inform. Syst.* 1(2):89–114, 1991.
18. Roesems-Kerremans, G., Big data in healthcare. *J. Healthcare Comm.* 1(4:33), 2016.
19. Priestman, W., ICT Strategy 2007–2011 for The Royal Liverpool and Broadgreen University Hospitals NHS Trust. Trust Board Meeting 6th November 2007. Document Number: V1.4, 2007.
20. Saleh, M. F., Information security maturity model. *Int. J. Comput. Sci. Sec. (IJCSS)* 5(3):316–337, 2011.
21. Mikalef, P. and Batenburg, R., Determinants of IT adoption in hospitals - IT Maturity surveyed in an European Context. Proceedings of the International Conference on Health Informatics, Italy., 2011.
22. King, J., and Kraemer, K., Evolution and organizational information systems: an assessment of Nolan's stage model. *Comm. ACM* 27(5):466–475, 1984.