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A health data analytics maturity model for hospitals information systems

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ABSTRACT

In the last five decades, maturity models have been introduced as reference frameworks for Information System (IS) management in organizations within different industries. In the healthcare domain, maturity models have also been used to address a wide variety of challenges and the high demand for hospital IS (HIS) implementations. The increasing volume of data, is exceeded the ability of health organizations to process it for improving clinical and financial efficiencies and quality of care. It is believed that careful and attentive use of Data Analytics in healthcare can transform data into knowledge that can improve patient outcomes and operational efficiency. A maturity model in this conjuncture, is a way of identifying strengths and weaknesses of the HIS maturity and thus, find a way for improvement and evolution. This paper presents a proposal to measure Hospitals Information Systems maturity with regard to Data Analytics. The outcome of this paper is a maturity model, which includes six stages of HIS growth and maturity progression.

1. Introduction

The health industry is undergoing enormous transformations with the pressure to reduce costs and improve the quality and efficiency of healthcare services (Wu, Kao, & Sambamurthy, 2016). The exponential growth of health data, the pressures to make continuous investments and the necessity to provide integrated care services meeting the healthcare needs of patients, are all good reasons for Hospital Information Systems adopt Data Analytics (DA) and thus, ensure reliable and efficient services. This situation becomes even more demanding because this enormous volume of health data does not only come from traditional interviews, hospitalizations, and medical tests in a hospital or outpatient clinic, but it involves data that patients collect themselves using wearables for telemonitoring and data that healthy people collect using a wide variety of health and wellbeing apps (Roesems-Kerremans, 2016). In addition, the emergence of new technologies followed by genetic information, has contributed to the increase of clinical data collected. Process and analyse all this information, allows to identify health patterns that can contribute to cure and prevention of diseases, besides improving patient safety and quality of life. In short, improving the efficiency, quality and savings of health systems. Therefore, new opportunities are emerging based on the rapid evolution of Big Data technologies and the enormous availability of data that organizations can capture (Raguseo, 2018).

Data management and Analytics is critical in health information systems. Data management includes processes and technologies to acquire, store, prepare and retrieve data for analysis. Analytics, refers to techniques used to analyse and acquire intelligence from Big Data (Gandomi & Haider, 2015).

The investigation suggests that organizations using DA, when managing decision-making processes, are more productive and profitable than those who do not (Mathews, 2015). However, it is not clear at the moment, to what extent organizations are already implementing Analytics, as there are still many challenges in this area (Lismont, Vanthienen, Baesens, & Lemahieu, 2017). In this sense, organizations that intend to increase the use of DA to optimize costs, profitability, productivity and quality should consider strategic investments in this field. Healthcare organizations are clearly no exception to this rule. Within the healthcare field, Hospitals have followed three stages of data computerization and management, namely: data collection, data sharing and (more recently and gradually) data analysis (Sanders, Burton, & Protti, 2013). The collection, storage and analysis of health data have been, are and will remain, fundamental procedures to providing efficient healthcare services, and their importance is increasing in line with the growing amount of health data collected every day (Roesems-Kerremans, 2016).

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In this article, we will initially present maturity models in IS field, its importance, usefulness and evolution. Subsequently, it will be presented the state of the art of maturity models in Health Data Analytics domain. Then, a maturity model will be proposed to evaluate the DA maturity of HIS. Finally, we will make the discussion of this issue, and finish with some conclusions, limitations and further work.

It should be noted that this article, is an extension of a recently published article (Carvalho, Rocha, Vasconcelos, & Abreu, 2018). This article presents in more detail, the entire methodological process of development of the proposed maturity model. In addition, this article presents the state of the art of the Maturity Models in IS health domain, identifying gaps and limitations of those models in the specific area of Data Analytics in Health Information Systems.

2. Maturity models

2.1. Maturity models in information systems

The concept of maturity models is increasingly applied in the IS field, both as an approach needed for continuous improvement (Paulk, Curtis, Chrissis, & Weber, 1993) as for its evaluation (Fraser, Moultrie, & Gregory, 2002). Since its initial conception in the early 1970s (Gibson & Nolan, 1974; Nolan, 1973), a multitude of different instances have been developed in science and practice. However, as organizations face constant pressures to achieve and maintain competitive advantage by inventing and reinventing new products and services, reduce costs and time to market, and at the same time improve the quality, there is a continuing need for development of new maturity models, since they help the decision makers to achieve these goals (T. Mettler, 2009). On the other hand, through the incorporation of formalism in the improvement of activities, decision makers within organizations can determine if the potential benefits are being achieved or not.

During the last five decades, several maturity models have been proposed, differing in number of stages, maturity-influencing factors and intervention fields (Rocha, 2011). Each one of these constituent factors, identifies the characteristics that typify the focus of these maturity stages, that is to say, are factors which act as descriptors or variables of reference for the characterization of each stage and that provide the necessary criteria to achieve a specific maturity level (Becker, Knackstedt, & Pöppelbuß, 2009). In other words, the maturity models offer an orientation through an evolutionary process, incorporating the procedures for improving activities (Mettler & Rohner, 2009).

The maturity models are available to respond to many different challenges. These models provide information for organizations to address the problems and challenges in a structured way, providing both a reference point to assess the capabilities as a roadmap for improving (Caralli & Knight, 2012).

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. These models mainly differ in terms of a number of stages, variables of evolution and focus areas (Mettler & Rohner, 2009; Rocha, 2011). Each of these models identifies certain characteristics that specifically define the objectives of the next stage of growth. These types of models can be applied situationally within healthcare in order to strategically planning for Information Systems and Technologies (IST) maturation, based on the degree of alignment between the hospital strategy and the selected growth path, as well as associated investments and improvement activities (van de Wetering, Batenburg, & Lederman, 2010, 2011).

In Analytics and Business Intelligence (BI) domain, several Maturity Models are known, i.e., Data ware-housing stages of growth (Watson, Ariyachandra, & Matyska, 2001), the HP BIMM (Hewlett-Packard, 2009), the Gartner's MM For BI and PM (Rayner & Schlegel, 2008), EBIMM (Chuah, 2010), AMR research's BI/PM MM (Hagerty, 2006), and TDWI's BI MM (Eckerson, 2009), among others. These models are adopted in different contexts and in different sectors of activity, however, they do not present specific characteristics that represent the specificity of the IS in the health area.

2.2. Maturity models in health IST

Within the healthcare domain, several maturity models have been proposed, although these models are still at an early stage of development (Mettler & Rohner, 2009; Rocha, 2011). Based on a systematic literature review conducted by Carvalho, Rocha, and Abreu (2016) in 2016, it was possible to identify and characterize a broad set of maturity models that address the most diverse areas of health IST. It was also found that, there are two main approaches: in one hand, the highly specialized models that have resulted in a health subsystem and in the other hand, the more comprehensive models, i.e. models representing the HIS as a whole. Also it was found, that most of the analysed maturity models does not disclose the design process nor the research options for development and validation (ISO9241-11), thereby compromising, the researcher´s work with regard to its analysis and explanation.

In the literature review mentioned above, the following maturity models were identified in the health IS domain: HIMSS Maturity Model for Electronic Medical Record (EMRAM) that is a model for the identification of various stages of maturity in the area of Electronic Medical Record (EMR) of hospitals (HIMSS, 2008); The HIMSS Continuity of Care Maturity Model (CCMM) goes beyond Stage 7 of EMRAM, because was created to help the optimization of results in health systems and patient satisfaction (Etin, 2014); The Quintegra Maturity Model for electronic Healthcare (eHMM) is a model that incorporates all service providers associated with the health process. It is adaptable to any provider at any level of maturity (Sharma, 2008); Within the EMR, there is also the Electronic Patient Record Maturity Model (EPRMM) (Priestman, 2007) and Patient Records/Content Management Maturity Model (Forrester Model) (Clair, 2010); The Healthcare Usability Maturity Model helps healthcare professional to assess the usability stages of IST of organizations and how they can advance to the next stage (HIMSS, 2011); A Maturity Model for Interoperability in eHealth (Velsen, Hermens, & d'Hollosy, 2016) aids eHealth developers to determine what level of interoperability they should strive for, and that allows researchers to benchmark interoperable eHealth infrastructures in terms of maturity; The NHS Infrastructure Maturity Model (NIMM) aims to provide a coherent framework for healthcare organizations. The organization will be able to measure its own current technological infrastructure capabilities in specific areas and consequently, to identify and prioritize activities that enhance these capabilities (NHS, 2011); Hospital Cooperation Maturity Model (HCMM) aims to conceptualize an evolutionary path for improving cooperation within hospital and between hospitals (T. Mettler & Blondiau, 2012); The PACS maturity model (PMM) describes the process maturity of hospitals based on PACS (R. van de Wetering & Batenburg, 2009); Telemedicine Service Maturity Model (TMSMM) can be implemented to measure and manage the health system capability to provide clinical health care at a distance (van Dick & Schutte, 2013); IDC Health Insights, proposed a maturity model for health care organizations. It consists of stages, measures, results and actions to advance along the path of maturity in the context of mobility toward a mobile culture (Dunbrack & Hand, 2013). IDC Health Insights, proposed also, a maturity model for Healthcare Provider IT Strategies (HIT) (Holland, Dunbrack, & Piai, 2008).

In the extant literature, it is verified that there are very few maturity models focused exclusively in the Health Analytics domain. Although some of the characteristics associated to DA are incorporated in more comprehensive maturity models such as the EMRAM (HIMSS, 2008), HIT (Holland et al., 2008), eHMM (Sharma, 2008) or EPRMM (Priestman, 2007), in the literature review mentioned above, only the following maturity models were identified in the Health DA domain: The Healthcare Analytics Adoption Model (HAAM) (Sanders et al.,

2013) is a proposed framework to measure the adoption and meaningful use of data warehouses and analytics in healthcare; The Healthcare Data Quality Maturity, focuses on the knowledge of the level of data quality within a hospital (Pinto-Valverde, Pérez-Guardado, Gomez-Martinez, Corrales-Estrada, & Lavariega-Jarquín, 2013); There is another model in this context, such as the Business Intelligence Maturity Model for Healthcare, which contributes to information and knowledge management in this area (Brooks, El-Gayar, & Sarnikar, 2013). All the mentioned models are still in an early development stage and in premature phase of affirmation and consolidation, being proposed by their authors through exploratory studies. In fact, none of the identified models are adopted in Hospitals on a large scale, nor are significantly referenced by the academic community. Additionally, these models are not sufficiently explicit in the way they were developed and validated and especially because they are poorly detailed, do not provide tools to determine the maturity stage nor structure the characteristics of maturity stages.

For these reasons, it is opportune to develop a maturity model which addresses the gaps of the actual maturity models in this area, and thus contribute as a valid option that HIS managers can adopt in their difficult and complex task. Based on the description of the problem, the following research question was formulated:

► Is there a maturity model in Data Analytics domain, which consists of maturity stages, that can be applied to HIS?

3. Health data analytics in the HISMM

As an alternative to the existing maturity models in the Health Information Systems domain, Carvalho, Rocha, and Abreu (2016), Carvalho, Rocha, van de Watering and Abreu (2017) developed in 2016 a comprehensive model composed of 6 dimensions or maturity-influencing factors. This multidimensional maturity model HISMM (Hospital Information System Maturity Model), was empirically validated and presents Data Analytics in one of its dimensions (hereafter referred to as HISMM-DA). Taking advantage of the work carried out in this project, it is possible to isolate Data Analytics and based on its nature, transforming this dimension into an autonomous maturity model.

3.1. Research methodology

For the development of the HISMM and consequently HISMM-DA, the authors decided to choose an approach with the inclusion of the following methods: a systematic literature review and design science research (DSR). In this project, the aim of the literature review was to identify and discuss a set of concepts and key aspects related to IS maturity models in general, as well as gather, analyze and systematize a set of contributions regarding IS maturity models in the health field in particular. In addition, different ways to develop a conceptual maturity model in the IS field were also analyzed and summarized. At the end of the systematic literature review, one of the most important results, in addition to a description of the state of the art concerning IS maturity models in the health field, was the identification of an initial set of maturity-influencing factors associated with different maturity stages.

In relation to the other adopted method, this work used DSR methodology in line with the guidelines from Hevner, March, Park, and Ram (2004) and the methodology for the development of maturity models, as proposed by Mettler, (2010b), which is consistent with these guidelines. Under the DSR method, the maturity-influencing factors of different maturity models in the health field, as identified in the literature review, were characterized. Subsequently, these factors were prioritized (Carvalho, Rocha, Abreu et al., 2017), based on a questionnaire that was sent to a community of health professionals (mainly HIS managers). Following identification of the main maturity-influencing factors, their characterization at different stages of the model was determined, giving rise to the first version of the new model. The validity of this model was tested via contributions by a restricted set of specialists in the health field and those with whom interviews were conducted. It should be noted that the development of the new model as a result of a DSR process, is framed in one of the three types of artifacts, as defined by March and Smith (1995).

3.2. Methodology for the development of the maturity model

Considering the methodological approaches adopted in the development of Maturity Models and herein under analysis, and after a thorough reflection, we selected the Mettler, (2010b) methodology for the development of the HISMM-DA. This choice was made based on a set of assumptions, including:

- This methodology results from a comparative study and a systematization carried out by its author, among some of the most referenced methodologies in this area.
- The methodology (or mental model) presented by this author is consistent with the DSR guidelines.
- This methodology respects the iterative nature of the Maturity Model development process.
- This methodology takes into account the need to combine theoretical and empirical research as recommended by other Maturity Models researchers (de Bruin, Freeze, Kulkarni, & Rosemann, 2005; Mettler, 2011; Von Wangenheim et al., 2010).
- This methodology is consistent with the type of Maturity Model intended for this project.

Mettler carried out a comparative study between three Maturity Model development methodologies (Becker et al., 2009; de Bruin et al., 2005; Mettler, 2010a). As a result, a new approach emerged, introducing the so-called "decision parameter" elements (Fig. 1). This approach is based on an interactive design process, which consists of five steps or design activities (white boxes). Within each, several decisions must be made (black lozenges), that is, at each stage of the model-building process the designer must choose a number of elements before proceeding with the process.

Table 1 presents the decisions (identified) made when developing the HISMM-DA design.

3.2.1. Identify need or new opportunity

In the “identify need or new opportunity” step, two parameters are considered. On the one hand, the novelty of the topic covered by the Maturity Model plays an important role, since it determines if there is a need that this model will fill. In fact, the development of a new model (*emerging*) is justified by the fact that the existing Maturity Models in this field present weak points, both in their affirmation and adoption by the HIS, as mentioned in 2.2. On the other hand, innovation is another parameter of decision to be considered, before beginning the development of a Maturity Model. Where the HISMM-DA is concerned, we consider that it is completely new (*new*), despite having a structure that is similar to the model developed by Galliers and Sutherland (Galliers & Sutherland, 1991). In fact, the structure of this model has the same number of stages and the same form of maturity progression of Galliers and Sutherland stages of growth model, although obviously, presents different characteristics.

3.2.2. Define scope

In the second step, the first decision involves defining the magnitude of the phenomenon to be studied, i.e., we must decide if the model addresses a generic or a more specific topic. In the case of the HISMM-DA, the model is applied to hospital organizations only, and for this reason the choice is "*specific issue*". Still in this step, the Maturity Model detail conditions must be considered. The HISMM-DA model focuses on *intra-organizational* as well as *inter-organizational* aspects. In fact, this model incorporates aspects relating to internal processes of

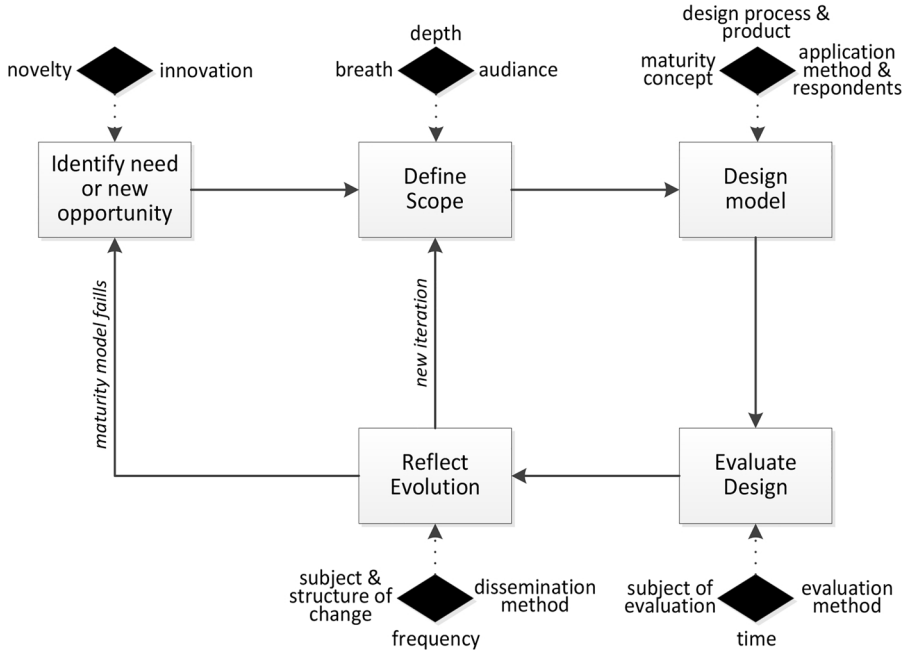

Fig. 1. Mettler Methodology Decision Parameters (Mettler, 2010b).

organizations, but also aspects representing processes of cooperation with external organizations. Finally, considering one of the DSR guidelines (Hevner et al., 2004), the potential "*audience*" of the Maturity Model must be pondered. In the case of the HISMM-DA, the target audience includes managers of health organizations who have decision making authority. These can either be CEOs and department directors with responsibilities in the management field, such as CIOs, or directors of the Information Systems and Technologies (IST) area of health organizations. In this case, the choice of "*audience*" parameter falls under the option "*both*".

3.2.3. Design model

In the "design model" stage, the construction of the model itself begins. Here, one of the major decisions involves the definition of "maturity" in the context of the intended model. Mettler (2010b) resorts to literature to justify the emergence of three different maturity concepts, as they focus more on the process, the object or the people. The HISMM-DA presents a multi-faceted approach (*combination*) to measure maturity in order to increase the efficiency of the HIS (*process-oriented*) and the satisfaction of people using the HIS (*people-oriented*). In addition, the HISMM-DA assesses analytical capabilities, both organizational and technical.

A Maturity Model can have multiple goals, as is the case with the HISMM-DA. Therefore, another important decision relates to the maturity level: one-dimensional (that is, focusing on one measure as an efficiency target) or multidimensional (i.e., focusing on several, sometimes divergent, objectives). In fact, in the case of the HISMM-DA, only the DA maturity is measured (*unidimensional*). Subsequently, the nature

Table 1
Decisions made when developing the HISMM-DA (Adapted from Mettler, 2010b).

Design activity	Decision parameter	Characteristic			
1. Identify need or new opportunity	Novelty	Emerging	Pacing	Disruptive	Mature
	Innovation	New	Variant	Version	
2. Define scope	Breadth	General issue		Specific issue	
	Depth	Individual/Group	Organization	Inter-organizational	Global/Society
	Audience	Management oriented	Technology oriented	Both	
3. Design model	Maturity concept	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 (software)	Combination
	Application method	Self-assessment	Third-party assisted	Certified professionals	
	Respondents	Management	Staff	Business partners	Combination
4. Evaluate design	Subject of evaluation	Design process	Design product	Both	
	Point of time	Ex-ante	Ex-post	Both	
	Evaluation method	Naturalistic	Artificial	Combination	
5. Reflect evolution	Subject of change	None	Form	Functioning	Form and functioning
	Frequency	Non-recurring		Continuous	
	Structure of change	External/open		Internal/exclusive	
	Dissemination	Open		Exclusive	

of the design process (e.g., *theory-driven* vs *practitioner-based* or a combination of both) has to be determined in order to identify the knowledge base concerning maturity levels, metrics, and the corresponding improvement recommendations. The HISMM-DA model adopts a *combination* of both.

Another important decision parameter concerns the model format. Here too, there is a combination of two options, namely the "*instantiation software*", considering that a tool to evaluate the HIS maturity will be developed, and the "t*extual description of form*", as the HISMM-DA will be available in text format, with a description of its applicability. This decision certainly affects the selection of the application method (i.e. whether data collection is based on self-assessment or third-party assessment such as outsourcing by certified professionals). It is our understanding that this model is to be fundamentally implemented by managers of the health units whose maturity is to be assessed (*self-assessment*), since they are the ones who know the reality of their organization better.

Finally, in the data collection process for HIS maturity assessment, it is important to define the actors (*respondents*) of this collection. In the HISMM-DA model, data collection can be diversified, and it is fundamentally carried out by managers, but also by different Health and IS professionals. Thus, the "*combination*" option is the most suited for this last parameter of the "*design model*".

3.2.4. Evaluate design

The "*evaluate design*" stage concerns the verification and validation of the developed Maturity Model. Regarding the HISMM-DA, two parameters ("*design process*" and "*design product*") are initially considered in the context of the object to be evaluated (*subject of evaluation*). The HISMM-DA has been evaluated in terms of form and content, so the choice lies with "*design product*". On the other hand, this new model was evaluated before being implemented, that is, in the "*point of time*" option, the choice falls to "*ex-ante*". Finally, the evaluation method was "*naturalistic*", since the evaluation of the HISMM-DA was made by real users, based on their experience and reflection. In fact, semi-structured interviews were conducted with a diverse group of Portuguese HIS managers to validate the HISMM-DA. We took care to guarantee that they had significant experience in HIS management and that different types of hospitals were represented, whether private or public. In addition, the representation of hospitals took into account different criteria that categorize the SNS[1] services and facilities, according to the nature of their responsibilities, the framework of valences exercised and their positioning in the hospital network. Based on these assumptions, five specialists were chosen, two of them noted for being awarded by CIOnet[2] Portugal, as CIOs of the Year in 2014 and 2015. Their contribution was essential for the confirmation and validation of the characteristics of each stage. Given the characteristics proposed in the first version of the model (drawn from the literature), the experts suggested new characteristics, moving others between stages and changing denominations of others.

3.2.5. Reflect evolution

In the last "*reflect evolution*" step, the designer has to decide on the mutability of the Maturity Model over time. In the context of this research project, this step was not carried out due to temporal constraints. However, in the near future we intend to implement this model in several hospitals, as well as the procedures associated with this last stage of the Maturity Model development.

4. Hospital information system maturity model - data analytics

HISMM-DA is a dimension of the comprehensive maturity model HISMM. The HISMM comprises a conventional maturity model structure, which is, a matrix composed of six different maturity stages and six different maturity-influencing factors, identified as the most relevant for a healthcare IS (Carvalho, Rocha, Abreu et al., 2017). With HISMM, 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 to reach a specific maturity stage. In other words, the HISMM architecture comprehends stages on an evolutionary scale with measurable transitions between them. Each stage is defined by a set of attributes and, when a HIS reveals such attributes, the corresponding stage and the capabilities it embodies have been achieved. With measurable transition states between stages, hospitals can use this scale to define the current maturity stage, determine the next achievable maturity stage and identify the attributes that must be met to reach a new maturity stage. The HISMM was developed to address HIS complexity and propose a useful tool for the demanding role of HIS management. This model was developed in line with the methodological procedures for creating maturity models, with a view to guaranteeing its recognition, solidity and relevance, both in the academic field and in society as a whole (Carvalho et al., 2016a).

As previously mentioned, this model has several maturity dimensions or influence factors, one of which is Data Analytics. Next, a description of each of the six stages of Data Analytics maturity-influencing factor included in the HISMM is presented, as well as the respective characteristics (Table 2).

4.1. Stage I - adhocracy

Initial stage where Hospitals have not yet formally approached Data Analytics. Hospitals have analytically limited data sets. Although the need for data and information processing exists, it is fundamentally realized through spreadsheets and PC-based databases. There are limited resources in the organization to develop and maintain local spreadsheets and databases. Due to the lack of BI capabilities and Analytics technologies, most analyses are done reactively to respond to problems. The standard reports for Enterprise Resource Planning (ERP) and accounting (patient-related) modules are the main sources for the data.

4.2. Stage II - starting the foundations

Hospitals where BI and *Data Warehousing*[3] solutions have recently been implemented fit into this stage. BI is available for several functional zones, although the focus at this stage may be only one or two functions (e.g. department productivity). Solutions are implemented based on the needs and priorities of the activity associated with health services. Users now have the ability to look at the historical trends of the last few months or years. The use of BI is still at a very embryonic stage and can be limited to an exclusive set of users. The critical success factors for moving an organization from this stage to the next entails strong patronage of top management, quality data maintenance, and support technology.

4.3. Stage III - centralized dictatorship

At this stage, dissemination of the use of BI by other exclusive users, such as department managers and other knowledge professionals, is a reality. These users take advantage of parameterized reports and dashboards that contain key performance indicators (KPIs) for their areas. Department managers monitor daily productivity results on their

[1] Serviço Nacional de Saúde de Portugal – National Health Service.
[2] CIOnet - The biggest community of IT executives worldwide.
[3] *Data Warehousing* **- Is a subject-oriented, integrated, time-variant and non-volatile collection of data in support of management's decision making process.**

Table 2
HISMM-DA: Data Analytics Maturity Model.

Stage	Characteristics
I Adhocracy	• 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
II Starting the Foundations	• 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
III Centralized Dictatorship	• 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
IV Democratic Cooperation	• 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
V Entrepreneurial Opportunity	• 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
VI Integrated Relationships	• 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

dashboards. At this stage, performance can already be measured based on goals. The focus is on the operational performance of certain business units (i.e., patient financial services, emergencies, etc.). Operational decision making is improved on the basis of virtually real-time information.

4.4. Stage IV - democratic cooperation

Hospitals at this stage, already use BI to drive operational performance and Analytics to execute their business strategy. The operational decision has improved, contributing to better strategic decision-making. High-level corporate scorecards define performance indicators that span multiple pillars of the business. Financial results and clinical patient data form a competitive advantage to increase profit. Patient care is adjusted, based on metrics and final users have started to incorporate analytical patient data, including big data, in operations and daily tasks.

4.5. Stage V - entrepreneurial opportunity

The availability of robust data makes it possible to implement robust strategies for increasing patient profitability and for improving quality and reducing costs. Organizational processes for intervention are supported by predictive risk model. Clinical and operational indicators are now available to all services leaders. Data are often used for financial modelling and predictive analytics. In this stage, Hospitals implement clinical alarm management and/or clinical data intelligence. Existence of an Analytics Ecosystem that supports innovation and data exploitation.

4.6. Stage VI - integrated relationships

In this last stage, Hospitals clearly and demonstrably have Data Analytics as one of their competitive advantages. Top managers are highly committed to the advancement of Analytics across the organization. Analytics is applied not only to meet operational and strategic needs, but also to create new ways of using data to create new opportunities. Health organizations continually develop new applications to meet the needs of various functions throughout the organization. Analytics is applied in order to identify health patterns that can contribute to cure and prevention of diseases, besides improving patient safety and quality of life.

5. Discussion

There are many barriers to DA adoption in HIS. Barriers such a isolation of data stores, system users' resistance, low data quality, no information integration, lack focus on BI, are recurrent in this area. Using a maturity model, can help the health managers to evaluate its HIS in order to determine in which maturity level it resides and how it can continually improve to a higher maturity.

Maturity models, which support decision makers in the process of improving health systems and facilitate major organizational, procedural and clinical transformation, are very valuable in this field. However, the extant literature on empirically validated IST maturity models is limited, particularly concerning models in the healthcare Analytics. In this paper, we present a Maturity Model based in one dimension (or influencing-factor) of HISMM. HISMM is based on a mixed methods approach and informed by the IST maturity model literature, along with associated evolutionary stage characteristics.

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 a HIS and the individual maturity of its different dimensions. This extends the currently available literature on health ISTs.

The HISMM-DA, as a dimension of HISMM, also represents a

practical application for decision makers in the process of situationally setting goals and systematically enabling a HIS to evolve toward higher maturity levels. This process can now be supported by the HISMM-DA architecture, which includes various comprehensible evolutionary stages with associated measurable indicators. The HISMM-DA can be applied to a wide variety of conditions and circumstances, i.e., hospital decision makers can now use the maturity model to (1) define the current maturity stage, (2) determine the next achievable maturity stage and, finally, (3) identify the attributes that must be met in order to reach a new maturity stage and meet the respective hospital's ambitions and goals.

Stage-based maturity models are often criticized for being overly simplistic in nature (King & Kraemer, 1984). In principle, this model provides all the necessary means by which to evolve through the different maturity levels and understand what the considerations are at each level. HIS implementations can also be evaluated, while their different stages of maturity can be determined by taking into account their characteristics. As such, the HISMM-DA allows for situational routes and improvement road maps, 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 ISTs. It is within this process that they should manage the implementation, adoption and acceptance of the exponential growth of health data within the hospital enterprise. The HIMSS-DA model is, therefore, a promising route by which to address the many challenges that hospitals face with regard to the processing and analysis of data.

6. Conclusions and further work

Healthcare is a very complex, knowledge-driven industry that created massive amounts of clinical and financial data. It is believed that careful and attentive use of Analytics in healthcare can transform data into knowledge that can improve patient outcomes and operational efficiency. Maturity Models in Health Analytics are a way of identifying strengths and weaknesses of HIS information maturity.

The present paper has presented a proposal to measure Data Analytics Hospitals Information Systems maturity. The Maturity Model was developed to address HIS complexity and propose a useful tool for the demanding role of HIS management. This model was developed in line with the methodological procedures for creating maturity models, with a view to guaranteeing its recognition and relevance, both in the academic field and in society as a whole. That is, it uses a development methodology recognized by the scientific community, drawing in a systematic way, the whole development process, validation and consolidation of a Maturity Model.

Despite its contributions, this proposal includes a number of limitations, some of which should prompt further research. First, the model was not yet implemented in hospitals, and for this reason, we did not specifically measure hospitals' HIS maturity nor identify improvement opportunities (because it was not possible to carry out the procedures described in the last stage of the model development). For that matter, we also did not relate such a maturity measurement to hospital performance or IST performance within the hospital. This would be a valuable research opportunity, as HIS maturity could be conditioned by certain contextual and organizational aspects.

Another future piece of work could involve the development of an automatic tool for assessing HIS maturity. This tool should be built, based on the principles established in relation to our Data Analytics Maturity Model, and should be made available on the Internet, enabling managers to perform HIS maturity assessments and simultaneously make comparisons with their competitors, as well as understand the evolution of their maturity over time.

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