Journal of Medical Systems (2018) 42: 235
https://doi.org/10.1007/s10916-018-1097-0

SYSTEMS-LEVEL QUALITY IMPROVEMENT

Information System Maturity Models in Healthcare

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Received: 25 October 2017 / Accepted: 9 October 2018 / Published online: 16 October 2018

Abstract

The use of information systems in healthcare (HIS) has been recognised as having crucial importance in improving the efficiency, cost-effectiveness, quality, and safety of medical care delivery. HIS has the potential to improve individuals' health and providers' performance by producing better quality, cost savings, and greater patient involvement in their own health. There have been two major drivers for the HIS investments in healthcare: The ever-increasing burden from chronic disease with costs growing significantly faster and the recognition of the need for greatly improved quality and safety in health delivery. Maturity models (MM) are based on the premises that people, organizations, functional areas and processes evolve through a process of development or growth towards a more advanced maturity, going through a distinct number of levels. Through a state-of-the-art review of HIS, focused on their maturity state, we identify and characterize a set of critical factors recognized as determinants in the context of HIS maturity. The article identifies a broad spectrum of MM applied to the health sector and its characteristics and reinforces the belief that the maturity of HIS can contribute to the quality of information and knowledge management in the sector.

Keywords Maturity models · Information Systems in Healthcare · Information Systems Investments in Healthcare · Information systems health maturity models

Introduction

In almost every industry, organisations rely on investments in Information Systems (IS) to realise benefits after their successful implementation [1]. Healthcare organisations face increasing pressure to improve their processes and to provide evidence of the quality and efficiency of their operations [2]. Despite the tremendous investments in IS, the studies present contradictory evidence as to the expected benefits [3, 4]. The relationship between investments in IS and organisational performance has been the subject of many discussions [5]. Although most of the research finds empirical evidence in favour of the operational and strategic relevance of IS/IT [6–8], the fundamental question lies in the causal relationship between IS investments and business value which is still partially inexplicable. Several empirical studies in the management information systems field have shown that the use of computer-based applications could have positive impacts on organizational performance, including the healthcare organisations [9, 10]. HIS have the potential to improve methods and processes that support the individual's health, promote better operational performance, and provide more and better quality, cost savings and patient involvement [11]. The health sector has found that the underlying reasons for a certain inadequacy in the management of health processes is directly related to the limitations of infrastructure and its inefficient management [12, 13]. The more comprehensive the technology, or the broader the extent of its implementation, the harder it seems to achieve success [14, 15]. Governments have decided to reform their health care system to improve transparency, quality, safety, patient satisfaction, and, above all, cost control. Hospitals have invested heavily in improving and managing their processes. Although there is no consensus on the capacities that hospitals need to acquire to become process-oriented organizations, nor a consensus on the sequence of steps I have followed for their development [16]. Health sector, stimulated by the successful implementations experienced in other industries, have developed some organisational models, such as, the

This article is part of the Topical Collection on *Systems-Level Quality Improvement*

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patient-focused hospital or clinical pathways to introduce process management into hospitals [17, 18]. Prior statistical research shows that process orientation significantly enhances hospital performance [19]. Overall, this paper intends to contribute towards a deeper understanding of the process management maturity in hospitals.

Maturity models for information systems in healthcare

Within the healthcare sector, several maturity models have been developed, although these models are still at an early stage of development [20]. The basic concept underlying maturity is that mature organizations do things systematically, while immature organizations achieve their outcomes because of the heroic efforts of individuals using approaches that they create and use spontaneously [21]. A hospital with a mature IS infrastructure can reflect higher degree of formalization of IS planning and control processes [22]. Governments have attempted to reduce costs and increase productivity by implementing enterprise resource planning systems or process management systems [21]. To identify and explore the strengths and weaknesses of the organizational designs, a wide range of MM have been developed by practitioners and academics over the past years [23]. MM have become an important topic in management research and are defined as conceptual multi-stage frameworks that describe typical patterns in the development of organizational capabilities [20]. MM are based on principle that people, processes, and organizations evolve to a higher level of capability following a process of development, which encompasses an evolutionary sequence of phases [24]. MM provide managers and organisations with an important framework for identifying the capability status of an IS, and to plan and implement actions that allow them to advance to a higher maturity stage and thus achieve the proposed objectives. MM are a means to support effective management and continuous improvement for initiatives that are complex and have multiple components [25, 26]. While current research is occupied with the specification of ever-more rigorous approaches for developing MM, there has been a general disregard of effectively implementing MM in complex organizational environments, such as hospitals [27]. Several models have been developed to help assess or describe the current level of IS adoption in the health sector [28]. These are useful benchmarks when looking at patient information systems. In the health sector, e-health services often involve multiple collaborating healthcare providers, individuals or organisations. Their ability to interoperate will significantly influence their capability to deliver safe, reliable, efficient and convenient healthcare services [29]. The capability of IS infrastructure is used as the basis for defining the sophistication of IS in organizations, supporting a wide variety of application systems in a hospital [10, 30, 31]. The completeness of the infrastructure is generally proportional to the maturity of IS/IT of the hospital [22]. Many studies in IS have indicated that system integration is another important challenge for the development of IS within healthcare organisations [30, 31]. Several standards have been developed to cope with the problem of integration for healthcare providers, particularly regarding the exchange of data between health organisations [22, 32]. The overall idea is that organizations will increasingly adopt maturity models to stimulate and guide the development of their IS capabilities.

Methodology

The methodology adopted for the literature review aims to conduct a wide and comprehensive documental review. The initial step is to provide the criteria to choose the approach and establish the strategies to be applied to the current project. Following the strategy proposed by [33], five steps were needed to a systematic of the literature review. (1) Defines terms, keywords and combinations to be used as criteria to be applied in the review (2). Identify relevant works that contain the keywords and terms defined above (3) Promoting an assessment of identified papers and select the works that meet the criteria; (4). Extracting the relevant information from the selected literature. (5) Finally, perform a synthesis of data (Table 1).

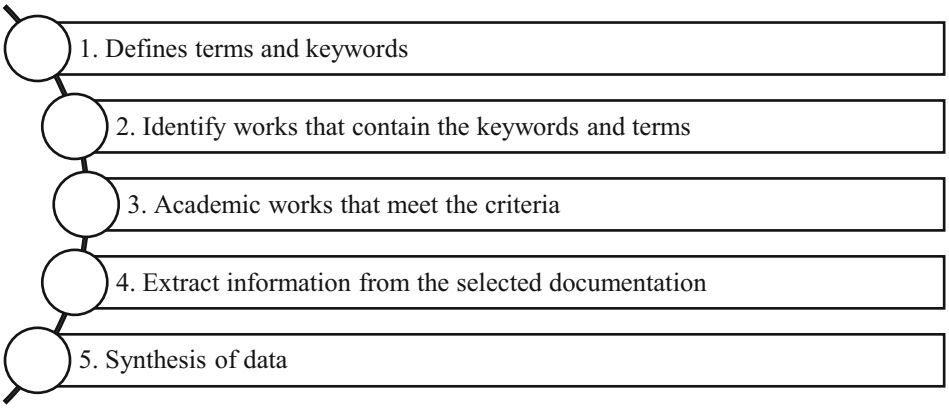
The research materials were collected initially across the platforms AIS Electronic Library, ISI Web of Knowledge, SCOPUS, Springer, Elsevier/Science Direct and IEEE Computer Society Digital Library. Afterwards we moved to a more extended search through the search engine Google Scholar and Google to ensure identification of other relevant work for the study. As a quality criterion it was established to gather all the studies where maturity models were mentioned, directly or indirectly, and that clearly identify the contextual factors, such as, motivation, goals, results, and benefits (Table 2).

The characterization of each model was done taking into account the description, scope, stages and their characteristics, size, influencing factors, methods adopted in the development and validation process. In the end, after processing of all cases, 26 models were selected, which are described below.

Maturity models approaches

In the literature review described in the previous section, we identified 26 /Maturity Models. These models were summary described on the present section and listed in Table 4. Each model is characterized by its focus and domain, a sequential identification, its name and/or initials, a reference for the paper where it is described, and a list of the source models on which it is based.

Table 1 Methodology



Capability maturity model integration for services (CMMI-SVC)

One of the most prominent MM is the Capability Maturity Model Integration (CMMI) with its roots in software engineering where it was found relatively helpful in guiding and monitoring the maturity of software development practices [34] and over the years it was extended to other domains. CMMI is a process level improvement training and appraisal program and introduces the concept of five maturity levels defined by special requirements that are cumulative and uses standardized question catalogues and evaluation criteria to assess an organizations product development process. CMMI includes a self-assessment that presents the organisation's best practices in key process areas and then shows how the organisation can redefine its capabilities as it evolves into a more mature state [34]. CMMI-SVC goals and practices are therefore potentially relevant to any organization concerned with the delivery of s health care services [34].

HIMSS analytics electronic medical record adoption model (EMRAM)

The EMRAM is an international standard to measure Electronic Medical Records (EMR) Adoption and is used by over 9000 hospitals across the globe. It incorporates a methodology and algorithms to automatically score hospitals around the world relative to their EMR capabilities. This eight-stage (0–7) model measures the adoption and utilization of the EMR functions [35], moving the organizations closer to achieving a near paperless environment that harnesses technology to support optimized patient care by completing each stage below. An EMR is a multifaceted, electronic patient records system and is often adopted in a model of hierarchical and increasingly complex stages [60]. Through EMRAM, patient records become electronic and accessible across inpatient and outpatient environments, and health care practitioners can document, monitor, and manage health care more effectively [61]. The results of the EMRAM assessment can be used to identify key opportunities for improvement, to drive an IT strategy and alignment with the overall business strategy of an organization.

Table 2 Search criteria

Search criteria
Maturity Model AND Health
Maturity Model AND Healthcare
Maturity Model AND Hospital
Maturity Model AND eHealth
Maturity Model AND HIS
Maturity Model AND Health Information System

Electronic Healthcare Maturity Model (eHMM)

In general, MM focuses mainly on the organisations, although eHMM incorporates all the services providers associated to the healthcare processes, adjustable to any specific provider at any maturity level and able to show different levels of maturity for different business processes [62]. The following process maturity levels provide a roadmap for organizations embarking on the journey of continuous process improvement. The eHMM proposes a 7-level maturity model to map how health processes can reach maturity. The model shows the evolution, improvement, and transformation of a business over time and captures its capabilities at each intermediate level. The maturity model is used in contemporary methodologies for setting goals and measuring progress. The eHMM illustrates a transformation of the healthcare enterprise electronic process from an immature to a national level. This is explained through entities, departments and infrastructure at a defined point in time. Each level has distinct characteristics that differentiate it from other levels.

IDC Maturityscapes

IDC MaturityScapes were created by IDC Health Insights to provide a detailed explanation of the stages from the simplest, unstructured ad hoc stage to the advanced, systematized optimized level, offering an opportunity for managers and their organisations to have a structured way to identify their current level of capability, or maturity, and find the gap between where they are and where they want to be to maintain competitive balance or achieve industry superiority. IDC MaturityScapes are designed to be used assuming change in the IT ecosystem — as a result of new technological advances, the maturation of existing technology use, or the integration of technologies, like social and mobile applications, that were previously considered to be separate platforms. These maturity models are particularly intended for enterprises making significant, business-transforming investments in the 3rd Platform [36]. IDC MaturityScapes can be used to enable managers to align business value goals with IT strategy, as a tool to identify where investments in people, process, and technology can be consistent with what the organization requires. This is an input to a variety of business-IT dashboards that monitor and measure IT capabilities against best practices and as a roadmap for overall improvement of IT processes, communications, and business integration [36]. IDC MaturityScapes dimensions are five and were often associated with issues that arise from having to implement change to people, technology, and processes (Intent: Strategy, sponsorship, and justification; Data: Relevance, quality, and availability; Technology: Adoption, performance, and functionality; People: Skills, culture, and organizational structure; Process: Tracking, analysis, and decisioning). Each of the five dimensions points to several sub-dimensions (data describing relevance, quality, and availability). These are the key factors that the model (in this case) uses to chart a course for data maturity — which in turn supports a more coherent overall Big Data strategy for the 3rd Platform.

IDC mobility maturity model (IDC-Mobility)

Healthcare is undergoing a mobile transformation because of the consumerization of technology and the digitization of patient health information [37]. Consumers want to use a mobile device to interact with their health plans and physicians and manage their health [37].

The Maturity Model for Mobile in Healthcare prescribe five stages of mobile maturity (ad hoc, opportunistic, repeatable, managed, optimized). IDC-Mobility for healthcare provides the *building blocks* for developing a roadmap for enterprise mobility. This framework is meant to enable healthcare organizations to [37]: (1) Assess mobility competency and maturity; (2) Use the baseline to define short- and long-term goals and plan for improvements; (3) Prioritize mobility technology, staffing, and other related investment decisions; (4) Uncover maturity gaps among business units or between business and IT groups; (Leverage mobile technology for significant long-term competitive advantage).

IDC healthcare IT maturity model – IT (HIT)

IDC (Health Industry Insights) developed a maturity model that describes the five developmental stages of hospitals IS (basic HIS, advanced HIS, clinical HIS, digital hospital and virtual hospital) [38]. Each step is supported by the capabilities of the previous stage. Healthcare IT (HIT) Maturity Model, has been used worldwide by IDC to assess the maturity of the hospitals IS (HIS) [38].

Healthcare information technology maturity model (HIT-MM)

HIMSS Analytics USA/Europe and Innovation Value Institute have come together to create an industry leading programme for hospitals to enhance their IT organisational capabilities towards achieving better eHealth outcomes [39].

The HIT-MM is aimed at CIOs and senior IT decision-makers responsible for delivering and running clinical eHealth systems as well as more traditional IT systems. The results of the programme provide a solid foundation to trigger senior level decisions within the hospital in relation to improving constrained IT organisational capabilities, which are considered essential for delivering and running better HIS and services [39]. The programme enables hospitals to map the maturity of their healthcare IT services and the maturity of the organisational capabilities to deliver and run those services within IT. This unified approach reveals dependencies that may constrain the strategizing, deployment and running of clinical IT services, through tracking levels of EMR adoption with underlying IT organisational capabilities (via the IT Capability Maturity Framework- IT-CMF identifies maturity of IT organisational capabilities from ad-hoc to optimising) [39].

The telemedicine service maturity model (TMSMM)

The conceptual telemedicine service maturity model TMSMM was developed by following an iterative process involving telemedicine practitioners from five different South African provincial departments of health (DoH). The TMSMM is developed in response to the need for a framework according to which the maturity of existing and proposed telemedicine projects can be measured with the purpose of supporting decision making towards sustained telemedicine services [40].

The TMSMM is designed along three dimensions: eReadiness Categories; Telemedicine Process Steps; and

Maturity Levels. The intercept of each pair of these dimensions form a matrix, each with a specific significance and function. This dimension includes all micro-level, meso-level and macro-level processes required to make this happen. The maturity scale of the TMSMM is based on the generic level indicators of the capability maturity model CMM [40]. According the TMSMM, the success determinants are organized as follows [63]: (1) Technology and maintenance - ICT availability, reliability, training, usability; (2) Policy and legislation - Governmental and institutional policies and procedures, standardization and security; (3) Individual users - Trust and willingness of users and decision makers, producing evidence, change in way of doing; (4) Organizational processes - Decision making processes, work procedures; (5) Planning and financial sustainability – Business models which will ensure continuation of the telemedicine endeavour; (6) Interaction and involvement with community. Telemedicine is per definition the delivery of healthcare service over a distance. This model can be used to measure, manage and optimize all the components of a telemedicine system, as well as the health system within which it is implemented [63].

Continuity of care maturity model (CCMM)

CCMM is a strategic framework created by HIMSS to guide continuity of care implementation. This model was created to help optimise outcomes for health system and patient alike. CCMM outlines the progressive capabilities healthcare organisations need to possess to seamlessly coordinate patient care across a continuum of care sites and providers. The CCMM is based on eight stages (0–7) and addresses the convergence of interoperability, information exchange, care coordination, patient engagement and analytics with the goal of individual and population health management [64]. Every organisation starts at Stage 0, moves into basic peer-to-peer data exchange progressing to using discrete and structured data in Stages 1–3. In Stages 4–6 the model looks for enhanced levels of coordinated care and expanding circles of care provider and patient engagement. In Stage 7 organisations optimise all parts of healthcare delivery with a focus on patient centred, dynamic, knowledge driven interconnected healthcare delivery [64].

Interoperability maturity model (IMM)

Individual health information must follow the patient as he receives services from various providers. This requires data interoperability which is the key to effective use of health information. The National Australian E-Health Transition Authority (NEHTA) has defined an Interoperability Maturity Model (IMM) [29] that identifies increasing capability for data interoperability. IMM defines an iterative process by which e-health organisations can assess and increase their ability to interoperate, internally or as part of a national e-health community [29]. Provides a set of guidelines for setting organisational process improvement goals in delivery of interoperable e-health solutions and a point of reference for appraising an e-health organisation's interoperability through the respective interoperability systems or work products [29].

Business process orientation maturity model (BPOMM)

The BPOMM was developed to measure the process orientation maturity of employees within a large hospital facility [41]. The BPOMM measurement tool provides hospitals with a means to evaluate their evolvement towards process orientation maturity. The model describes the different stages through which an organization must go to reach the goal of being fully process oriented (ad-hoc, defined, linked, integrated) [65]. The model benchmarks each health unit with competitors or other organizations, based on their relative position in the model. The measurement tool consists of 35 questions measuring seven dimensions, the seven dimensions can be further subdivided into two parts [41]: the BPO-Components and the BPO-Impacts. The BPO-components measure the process orientation and included three dimensions (Process View – 4 items, Process Jobs - 3 items, Process Management and Measurement – 4 items). The BPO-Impacts include the remaining four dimensions. They determine whether the BPO score results in improved organizational performance and long-term health.

Moreover, the MM can be further detailed by including the individual scores of each BPOMM component and their related impacts. Some of the benefits reported in the literature are: cost savings through a more efficient execution of work, reduced cycle times, improved customer focus, better integration across the organization, increased flexibility of the firm along with improved customer satisfaction, elimination of redundant and duplicated activities [66].

Process management maturity model (PMMM)

Technology usage is insufficient to evaluate the IT level of an organization. Other benchmarks, such as the attitude of staff towards new technologies, should also be incorporated into the assessment of organizational IT maturity, and Nolan's stage model is a well-known.

IT model fulfilling these requirements. A lack of consensus regarding the capabilities and development stages of hospitals required to become process-oriented. Successful process management within hospital settings require a much stronger focus on both cultural and structural capability areas than it does in other organisations, where the focus is rather on IT-support and process automation [21]. The conceptual basis for the PMMM consists of five capability dimensions, including: (1) Culture - Covering communication and leadership-

related practices; (2) Strategy - Covering principles that are prerequisite for a full development of process management; (3) Structure - Comprising the organisational dimensions; (4) Practices - Summarising work practices that are crucial for process management; (5) IT - Including items that capture in how far the employed hospital IT systems can support a smooth flow of complete patient care.

NHS infrastructure maturity model (NIMM)

The NIMM framework supports the National Health Service (NHS) IT organisations to carry out an objective assessment of their IT infrastructure and to identify infrastructure maturity improvement projects. The NIMM framework is divided into 13 categories, 74 capabilities, five perspectives and several KPIs, each of which is scored out of five [42]. Not all capabilities have to be completed at once. Review the capability list, decide the priorities for your IT organisation today and concentrate your efforts on completing this subset. Each category is further divided into many capabilities which are used to target the assessment to a specific area. A capability is then further organised into perspectives. Each perspective has several KPIs associated with it, against which the capability in question is assessed. Organising the metrics into perspectives provides the opportunity to review the capabilities and develop an overall view of the capability rather than just from a technology view point.

Informatics capability maturity model (ICMM)

The ICMM helps leaders to assess the role informatics play in their organisation to deliver business value. The ICMM assesses how well an organisation collects and manages and shares information, manages information and communications technology, implementation and change; manages data quality and governance; and uses health business intelligence to achieve multidisciplinary integrated care [27]. The ICM instrument categorises the following key informatics capability [43]: (1) Basic – Systems and processes not completely reliable or coordinated; (2) Controlled – Systems coordinated, manageable, performs consistently, but knowledge silos still exist; (3) Standardised – Standards used to support sharing and collaboration; (4) Optimised – Consolidated, efficient, accountable with good governance; (5) Innovative - Facilitates innovation with enterprise level engagement. The dimensions considered by the ICM are [43]: ICM1. Data collection, integration and management in HIS/HER; ICM2. Information sharing in the health neighbourhood; ICM3. Managing health information and communication technology implementation and change; ICM4. Data quality management and information governance; ICM5. Using health business intelligence to improve care and population health.

The ICMM aim is to encourage leaders to develop organisations to: (1) appreciate the potential role of informatics in providing business advantage; (2) treat informatics as a strategic resource; (3) make investments in informatics aligned with the business strategy; (4) deliver informatics enabled change effectively to optimise the business value.

PACS maturity model (PMM)

PACS has become an integrated component of today's healthcare delivery system and therefore can be considered as the fundamental infrastructure for digital diagnostic imaging and information management systems [44]. The PMM describes the process maturity of hospitals based on PACS. PMM is a descriptive and normative model developed as a guide for evaluation and strategic planning through five levels of maturity [67]. This model can help hospitals to gain insights into their strategic objectives for growth and maturity about PACS, the electronic patient record and other health information systems [67]. PMM combines three concepts [45]: (1) PACS maturity as the concept to define PACS and its elements; (2) PACS alignment as the concept to complement the organizational dimensions of PACS; (3) PACS performance as the added value of PACS within hospitals. Moreover, the proposed model can be applied as a valuable trool for organizational assessments, monitoring and benchmarking purposes.

Health information network maturity model (HIN)

The HIN is one of several tools that will enable HIN planners and operators to operationalize the leading practice findings and recommendations. It will allow HIN planners and operators to objectively assess themselves, and to develop plans for enhancing their operational capabilities, and the level of service and value they deliver [46]. The HIN has been synthetized into 10 capability domains (vision & engagement, governance, policy & legislation, skills & resources, financing, model practice, success metrics, clinical use cases, technology & apps, security & privacy). Five maturity levels have been identified for each capability domain (initial, anticipate, interoperate, collaborate, optimize). The HIN comprises a set of structured levels that describe the behaviours, practices, processes, capabilities and milestone achievements which a HIN will develop over time to reliably and sustainably deliver the infrastructure and services required to support health and health care related outcomes for a province or territory [46].

At a high level, the model comprises four components [46]: (1) Maturity Levels - A five-level maturity continuum where the uppermost level is a notional ideal state; (2) Domains - A domain or key process or capability area identifies a cluster of related activities or business capabilities that, when performed together or combined, achieve a set of goals considered

important to the success of one or more stakeholder groups; (3) Goals - The goals of a key process or capability area summarize the states that must exist for that key area to have been implemented in an effective and lasting way; (4) Characteristics - Common characteristics that implement and institutionalize a key process area or capability.

The healthcare analytics adoption model (HAAM)

The Health Catalyst announced in 2012 a framework to measure the adoption and meaningful use of data warehouses and analytics in healthcare in ways similar to the well-known HIMSS Analytics EMRAM model. The data-collection phase characterized by the urgent deployment of EMRs, will not have a significant impact on the quality or cost of healthcare [47]. The HAAM was designed to ensure that organizations establish a foundational understanding of analytic technology and organizational use of analytics in step-wise fashion before attempting the more complicated topics of the upper levels. Each level of adoption includes progressive expansion of analytic capability in four critical dimensions [47]: (1) New Data Sources - Data content expands as new sources of data are added to the healthcare ecosystem; (2) Complexity - Analytic algorithms and data binding become progressively more complex (3) Data Literacy - Organizational data literacy increases among employees, leading to an increasing ability to exploit data as an asset to organizational success, including new business and economic models; (4) Data Timeliness - Timeliness of data content increases which leads to a reduction in decision cycles and mean time to improvement. The HAAM prescribed 8 maturity levels [47]: Level 8 - Personalized Medicine & Prescriptive Analytics; Level 7 - Clinical Risk Intervention & Predictive Analytics; Level 6 - Population Health Management & Suggestive Analytics; Level 5 - Waste & Care Variability Reduction; Level 4 - Automated External Reporting; Level 3 - Automated Internal Reporting; Level 2 - Standardized Vocabulary & Patient Registries; Level 1 - Enterprise Data Warehouse; Level 0 - Fragmented Point Solutions. Current adoption rates of data warehousing and analytics stand at only 10% and just a small subset of those early adopters operates above Level 3 and none operates consistently above Level 5. Organisations consistently reports that operates between Levels 2 and 3, no higher [47].

Hospital information system maturity model (HISMM)

The HISMM was developed to address the complexity of HIS and offer a useful tool for the demanding role of HIS management. The HISMM displays a conventional Maturity Model structure, that is, a matrix comprised by different maturity stages and six influence factors (data analysis, strategy, people, electronic medical record, information security, systems and IT infrastructure) identified as the most relevant for healthcare IS [62]. These factors emerge as reference descriptors or variables that characterize each stage and determine the necessary criteria to reach a specific maturity stage. The HISMM architecture comprehends levels on an evolutionary scale with measurable transitions between levels. Each level is defined by a set of attributes, and when an HIS reveals such attributes, the corresponding level and the capabilities it embodies have been achieved. With measurable transition states between levels. The stages are: Adhocracy, Starting the foundations, Centralized dictatorship, Democratic cooperation Entrepreneurial opportunity and Integrated relationships. Hospitals can use this scale to: (1) define the current maturity stage; (2) determine the next achievable maturity stage; (3) identify the attributes that must be met to achieve a new maturity stage [68].

Healthcare usability maturity model (UMM)

Three accepted goals of usability are improved effectiveness, efficiency and user satisfaction. EHRs with poor usability can impact clinician productivity [51]. Organizations typically install EHRs to reduce errors. Incorporating usability into organizational processes could address these major detrimental impacts on clinicians. The authors co-led Usability Taskforce with HIMSS develop this Maturity Model [69]. The development of this model was based on the evaluation of the characteristics of three usability maturity models and how they could be adopted in healthcare [48–50]. The UMM identifies key elements and milestones involved in successfully integrating usability into a healthcare organization. Each phase allows organizations to identify their current level of usability and also includes guidance to move to the next stage. The five phases are the following [51]: (1) Unrecognized - Lack of awareness of usability; (2) Preliminary Sporadic inclusion of usability; (3) Implemented - Recognized value of usability; (4) Integrated - All benchmarks of usability implemented; (5) Strategic - Business benefit well understood, usability mandated, budget and people part of each year's budget, results used strategically throughout the organization.

Hospital cooperation maturity model (HCMM)

HCMM took the following design decisions to build the maturity model [52]:

> Opportunity - HCMM addresses an emerging phenomenon, i.e. intensified networking and cooperation in healthcare. HCMM is a completely new maturity model. But the structure is similar to a CMM-like model.
> Scope - HCMM covers a very specific area of interest. Focuses on intra-organizational as well as inter-organizational aspects relevant to optimizing cooperative

structures and processes in hospitals. HCMM is intended to primarily support decision making of hospital managers.

Design Model/Maturity Concept - HCMM uses a multi-dimensional approach to measure maturity, including items for strategic, organizational, and technical capabilities as well as "as-is" and the targeted "to-be" maturity.

Design activity/ Decision parameter - HCMM tries to identify challenges for cooperation and supports optimization of cooperation in a holistic manner, thus underlies multi-dimensional goals. HCMM measurement items are a combination of theory-driven and practitioner-based inputs.

Evaluate design/ Subject of evaluation - HCMM was evaluated in terms of form and content (design product), ex-ante (questionnaire) and in a naturalistic setting by means of the experiences of real users.

The HCMM is structured in three layers or dimensions [52]: (1) A strategic layer -Used to measure the ability of a hospital to cooperate with external partners; (2) Organizational layer – Used to measure the ability to cooperate within the hospital; (3) Information layer - Used to measure the technical capabilities of a hospital to provide the IT infrastructure needed for internal and external cooperation efficiently and effectively.

Business intelligence maturity model (BIMM)

Today's healthcare decisions makers are facing growing demands for both clinical and administrative information [70]. When evaluating Business Intelligence (BI) in the context of healthcare, it is important to understand the complexities and how BI needs may be impacted. Three key areas that make healthcare BI efforts particularly challenging, namely: (1) The need for integration of clinical and financial data; (2) The diverse types of data formats that may provide information for higher level analytics; (3) The demands and expectations of external data for clinical and financial decisions.

The requirements for a BI maturity model for healthcare were developed after a thorough literature review of existing BI maturity models, processes and complexities in healthcare information management, and critical success factors for BI success. The intended user of the BI maturity model would be management staff within a healthcare organization. Therefore, it is important that the requirements are very practical so that the organization understands its maturity level after the evaluation, namely [53]: (1) Providing a conceptual structure for managing the use of business intelligence in healthcare; (2) Focusing on the needs of operational/financial and clinical information; (3) Focusing on capturing key business intelligence processes and practices, taking into consideration specific processes within healthcare; (4) Incorporating key processes that include people, technology, and organizational processes; (5) Incorporating aspects of quality including system quality, information quality, and service quality; (6) Providing an understanding of relationship between the different levels and key processes involved in a maturity model by incorporating theoretical underpinnings.

The approach used for creating the requirements to include in a maturity model will be validated empirically to confirm accuracy and completeness in the healthcare environment. Gastaldi et al. [54] mapped BI considering dimensions and metrics in 4 maturity levels through the several functional areas.

The creation of a maturity model for BI in healthcare has great opportunity for contribution to information and knowledge management in healthcare. The overarching need for a maturity model for BI is to provide guidance to BI deployment initiatives and serve as a readiness assessment to move up each level in maturity. A maturity model can provide a readiness assessment and planning for a BI strategy by providing the insight to the critical steps and processes needed to reach a desired level in BI maturity.

"Meaningful use" (Forrester model)

A wide variety of systems, organizations, and processes are in place to manage medical records and surrounding work processes. Providers will take different paths at different speeds to meet these challenges. This diversity led to a three-phase maturity model that leverages content, collaboration, and workflow technologies as building blocks for transition. The Forrester model helps providers assess their content, collaboration, and workflow state, and more importantly, determine the road map required to get to the next phase. The three phases are [55]: Phase 1: Paper- or imaged-based patient records dominate. Most providers are in this mode, looking at patient information and a records or content management problem; Phase 2: Access to standalone repositories improves. Providers have more patient information contained in the electronic medical records system with less dependence on paper; Phase 3: Access to the complete digital medical record is role-based. Providers in Phase 3 exchange data electronically with other providers, patients, and administrative systems. Content is organized to support "results-based" analysis.

According to Clair [55], this three stages model includes four dimensions or influencing factors: access, interoperability, content features and planning and strategy.

Health game maturity model (HGMM)

Gaming can be seen as the next step in the application of information technology to healthcare. Gaming improves interaction and has a direct impact on human behaviour. The HGMM is developed to help healthcare organizations

Table 3 – Dimensions across the functional areas

Functional	Technological	Diffusional	Organisational
F_1- Goal definition	T_1- BI architecture	D_1- Accessing users	O1- BI strategy
F_2- Measurement	T_2- Reporting	D_2- System users	O2- BI budget
F_3- Gap analysis	T_3- Interface	D_3- Process coverage	O3- Organisation coverage
F_4 -Data quality	T_4- User profiling		O4- Key-user capabilities
F_5- Functional integration	T_5- Technological integration		O5- User capabilities
	T_6- Standards		O6- Competence improvement
	T_7- Data provisioning		O7- Partner/supplier coordination

introduce and improve their use of gaming. HGMM can help identify the position of a healthcare institution concerning gamification and help the organization identify steps to proceed to the next maturity level. For instance, gamification can be applied to make a task more fun for employees, without necessarily achieving benefits like behavioural change or learning. This would indicate a lower level of maturity in comparison to an organization that implemented gamification in its organization while achieving these benefits. In more mature organisations, gamification contributes to actual healthcare execution. HGMM distinguishes four perspectives, each with five maturity levels (based on the CMM approach) [56].

HGMM propose that organizations rank themselves on each of the four perspectives in order to assess the level of gamification and the contribution of gamification to their strategic goals.

The first perspective of the model is related to the value generated through gamification - Value: (1) Non-existent – No value seen in using games, or no gamification in place; (2) Pleasure – Using games for pleasure but not yet for results. Games have no real purpose; (3) Passion – Games promote flow and engagement and stimulate learning and healthcare simulation; (4) Purpose – The goal is to advance and innovate using games. Actual healthcare execution and treatments are done through gamified processes; (5) Healthcare profit – Quality of healthcare is increased, and costs are lowered due to use of gamification.

The second perspective of the HGMM is related to the process that is in place to support gamification - Process: (1) Ad hoc - Gamification processes are unpredictable, poorly controlled and reactive; (2) Repeatable - Processes are matched to projects and are often reactive; (3) Defined - Gamification processes are developed organization-wide and are proactive (4) Managed - The gamification process is measured and controlled; (5) Optimized - There is a focus on continuous monitoring and improvement.

The third perspective of the model is related to coverage, or the ways in which gamification and games are applied by organizations - Coverage: (1) None – No gamification in place; (2) Individual – Gamification is applied by individuals; (3) Entity – Gamification is applied within functional groups or healthcare departments; (4) Institution – Gamification is applied across the healthcare level; (5) Ecosystem – Gamification is applied in complete horizontal and vertical integration throughout the ecosystem of the users and providers of healthcare.

The fourth perspective of the model is related to the different types of games that are used by organizations - Type: (1) Off-line – Non-internet, non-network components, such as traditional board games, are used; (2) Single-player – Online single-player techniques are used; (3) Multi-player – Online multi-player techniques are used; (4) Group playing – Online group playing techniques are used; (5) MMO – Mass multi-player techniques are used.

Maturity model of hospital (MMH)

MMH summarizes the evaluation criteria performed by a hospital to evaluate the level of maturity using a Balanced Scorecard (BSC), which is used when stand a strategy, and the framework of CMMI, which is one of process maturity model. MMH can be considered as an indicator of the strategy for improving hospital and learning the degree of improvement that can be achieved at each stage [57]. The framework has the following structure: (1) A BSC is a framework that has been used well as a strategy in managed companies in recent years. It is used also for planning stage of a PDCA cycle. BSC consists of four perspectives (financial, customer, internal processes and learning and growth). Generally, learning & growth perspective is the foundation of a project, and it grows up with the internal process and the customer perspectives. Ideally it will be achieved in financial perspective.

The MM is a measure that shows how well the organization is managed (systematization). CMMI (Capability Maturity Model Integration) is one MM. Hospital Functional Evaluation criteria (HFE) is divided into 6 common domains and 2 peculiar domains. Moreover, the evaluation criteria are divided into large, middle, and small items in each domain. Some total numbers of common items of the three above are 72 items, 178 items, and 577 items respectively.

Table 4 Summary of maturity models for healthcare

	Model name	Lv	Health focus	Dimensions/ factors	Ref. model	Author
1	Capability Maturity Model Integration for Services (CMMI-SVC)	5	health care services	24 process areas	CMM/ CMMI	[34]
2	HIMSS Analytics Electronic Medical Record Adoption Model (EMRAM)	8	EMR	HIS application		[35]
3	Electronic Healthcare Maturity Model (eHMM)	7	General	Timeliness of process; Data access and accuracy of data; Process Effort; Cost effectiveness; Quality of process results; Utility or value to stakeholders:		[13]
4	IDC Maturity Scapes	5	3rd Platform technologies	Intent; Data; Technology; People; Processes	CMM/ CMMI	[36]
5	IDC Mobility Maturity Model (IDC-Mobility)	5	Mobility	Intent; technology; people; processes		[37]
6	IDC healthcare IT maturity model – IT (HIT)	5	General	HIS application		[38]
7	Healthcare Information Technology Maturity Model (HIT-MM)		General	HIS application		[39]
8	The Telemedicine Service Maturity Model (TMSMM)	5	Telemedicine	Man; Machine; Material; Method; Money	CMM/ CMMI	[40]
9	Continuity of Care Maturity Model (CCMM)	8	EMR	HIS application	EMRAM	[35]
10	Interoperability Maturity Model (IMM)	5	Interoperability	Organisation, Information, Technical	CMM/ CMMI	[29]
11	Business Process Orientation Maturity Model (BPOMM)	4	Process Orientation	Seven dimensions subdivided into two parts: the BPO-Components and the BPO-Impacts		[41]
12	Process management maturity model (PMMM)	5	Process management	Culture: Strategy; Structures; Practices; IT	Nolan's stage model	[21]
13	NHS Infrastructure Maturity Model (NIMM)	5	General	People & Organisation; Technology; Security & Information Governance; Alignment & Value	CMM/ CMMI	[42]
14	Informatics Capability Maturity Model (ICMM)	5	Infrastructure IT	Managing IS; Using BI; Using IT; (4) Aligning Business and Informatics; Managing Change.	NIMM	[43]
15	PACS Maturity Model (PMM)	5	PACS	Strategy & Policy; Organisation & Processes; Monitoring & Control; IT; People & Culture;	CMM/ CMMI	[44]
16	Health Information Network Maturity Model (HIN)	5	health information exchange	Vision & Engagement; Governance, Policy & Legislation; Skills & Resources; Financing; Model practice; Success metrics; Clinical use cases; Technology & Apps; Security & privacy.		[45]
17	The Healthcare Analytics Adoption Model (HAAM)	9	Data Warehouse & Analysis	New Data Sources; Complexity; Data Literacy; Data Timeliness	EMRAM	[46]
18	Hospital Information System Maturity Model (HISMM)	6	General	Data Analysis; Strategy; People, Electronic medical Record; Information security; Systems and IT infrastructure		[47]
19	Healthcare usability maturity model (UMM)	5	Usability	Focus on users; Management; Process & Infrastructure; Resources; Education	[48–50]	[51]
20	Hospital Cooperation Maturity Model (HCMM)	4	Networking /Cooperation	Strategic; Organisational, Information	CMM/ CMMI	[52]
21	Business Intelligence Maturity Model (BIMM)	4	Business Intelligence	Collaboration; Knowledge; Trust; Institutions; Governance		[53, 54]
22	"Meaningful Use" (Forrester Model)	3	EMR	Access; Interoperability; Content Features; Planning & Strategy		[55]
23	Health Game Maturity Model (HGMM)	3	Gamification	Value; Process; Coverage; Types	CMM/ CMMI	[56]
24	Maturity Model for Hospital (MMH)	5	Medical service improvement	Learning & Growth; Hospital's Process; Patients; Citizen	CMM/ CMMI	[57]
25	High Reliability Health Care Maturity Model (HRHCM)		High reliability health care	Leadership, Safety Culture; Robust Process Improvement.		[58]
26	Healthcare Data Quality Maturity Model (HDQM2)		Data quality	Accuracy/ Correctness; Completeness; Uniqueness; Duplicates	CMM/ CMMI	[59]

The strategy of MMH is the maintenance of a local medical system. This strategy considers what "a local resident is efficiently provided with when receiving high quality medical service."

MMH creates the domain rule with the four perspectives of BSC: (1) Learning & growth; (2) Hospital's Process (3) Patients; (4) Citizen.

The Maturity Levels of MMH are made into six stages, from L0 (stage which is not carried out) to L5 (optimized stage) based on CMMI. The Maturity Level rules of MMH follows 3 basic rules: (1) "mw" (Maturity model keyword) is the rule that transposes each requirement for a level of CMMI to the requirements for a medical system; (2) "mp" (Medical Priority) is the rule that carries out the level attached to the priority of a medical act; (3) "hfa" (Hospital function average) is based on the average of functional evaluation.

High reliability health care maturity model (HRHCM)

Despite serious and widespread efforts to improve the quality of health care, many patients still suffer preventable harm every day [58]. The lack of a tool for categorizing and differentiating hospitals according to their high reliability organization (HRO)–related characteristics has hindered progress toward implementing and sustaining evidence-based HRO practices. Hospitals would benefit both from an understanding of the organizational characteristics that support HRO practices and from knowledge about the steps necessary to achieve HRO status to reduce the risk of harm and improve outcomes [71]. The HRHCM is a model for health care organizations' achievement of high reliability with zero patient harm, incorporates three major domains critical for promoting HROs—Leadership, Safety Culture, and Robust Process Improvement.

Healthcare data quality maturity model ($HDQM^2$)

Data Quality (DQ) is a central issue within the development of Healthcare Systems, for both the delivery of the service as well as for the establishment of public policies [59]. There is an overwhelming amount of existing evidence that DQ in registered patients contains deviations and errors that should be evaluated and improved. If improvement does not happen, these problems could generate adversity in the provided health service. $HDQM^2$ was developed taking as basis models found within literature, considering the peculiarities of the Health Sector and the characteristics of the local context. $HDQM^2$ starts from the scenario that an information system is composed of basic and fundamental elements for its characterization. These are: People, Processes, Data and Technology. This model is formed by the following elements: Levels of Maturity, Practices, Process Areas and Value Creation. The principal dimensions were extracted from DQ literature (Accuracy/ Correctness, Completeness, Uniqueness and Duplicates). The Metamodel was represented by the following elements: Levels of Maturity, Practices, Process Areas and Value Creation. For areas of process of the Maturity Model the phases of data life cycle were considered.

Discussion

The literature review identified a set of MM with different focus and characteristics applied to healthcare. Some are more generalist and have a broader focus on HIS, namely, eHMM, CCMM or IT (HIT), others, such as the EMRAM and Meaningful Use models are examples of EMR applications. Besides, there are MM that assess different aspects of HIS, namely: PACS (e.g. PMM); usability (e.g. UMM); interoperability (IMM); platform mobility and devices (e.g. IDC Mobility); cooperation & networking (HCMM); business intelligence (e.g. BIMM); warehousing and data analysis (e.g. HAAS); telemedicine (e.g. TMSMM); gaming (HGMM) and medical service (MMH). We found also some national health services that developed their own maturity models, namely the UK National Service with the NHS Infrastructure Mature Model (NIMM) focus on the assessment on their IT infrastructure and the National E-health Transition Authority of Australia with the NeTHA model focus on the interoperability.

Most of the MM has their roots in the CMM/CMMI and the documentation describes their characteristics and specificity. Regarding the number of maturity stages, there are models from 3 stages as the "Meaningful Use" model [55] up to 9 stages of HAAM [47] and not all the identified MM with various dimensions or influencing factors have explicitly broken down the characteristics for each stage of maturity. The study also shows a wide range of generic and domain-specific MM that have been developed to improve organizational design and learning of healthcare organizations. Following we summarize the main features of the MM approaches (Tables 3 and 4).

Conclusions

Many hospitals and health systems are adopting delivery system reform with the goal of better aligning provider incentives to improving the patient experience of care, improving the health of populations, and reducing the per capita cost of health care. Every day it becomes clearer the importance of HIS in-health organizations, which deal with a multitude of administrative and medical data of many patients. More than having access to these data, the important thing is to transform them into intelligent information that allows for further analysis that makes management more efficient and contributes to

the improvement of the quality of care and provides financial benefits to the organization. Having a clear strategy, an adequate governance system, optimized processes and a qualified team makes it possible to take advantage of the full potential offered by the available technology. MM are no longer directed exclusively at the evaluation of software vendors or software development processes. They are now commonly used as a means of benchmarking, self-assessment, change management, and organisational learning. Increasing maturity of these processes and protocols in hospital management improves the organisation's profitability by making them more efficient. Additionally, very demanding and exogenous regulations can also benefit from the existence of MM at the level of organizational processes and the supporting HIS. CMM served as inspiration for dozens of MM. Some MM are developed by health national and supranational organizations, mainly corporations, who are dedicated to technological developments, such as IDC Health Insights and HIMSS or even by national health organizations as the NHS or NEHTA.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Human and animal rights and informed consent This article does not contain any studies with human participants or animals performed by any of the authors. For this type of study formal consent is not required.

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