Analysis of the Growth of Medical Information Systems

Álvaro Rocha
University Fernando Pessoa - GIMED
Porto
Portugal
amrocha@ufp.edu.pt

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ABSTRACT: *Information Systems and Technologies (IST) in healthcare have evolved gradually, and theories about adopting and maturing information systems and technologies are sufficiently established in organisational management literature. In this paper, we approach the evolution of IST in healthcare, introducing the concepts associated with maturity models, addressing the generic maturity model for IST management, and explicitly presenting the main maturity models focusing on the management of IST in healthcare. Relatively to the last ones, we conclude that there is still a way to go in having widespread and detailed maturity models available.*

Subject Categories and Descriptors: [J.3 LIFE AND MEDICAL SCIENCES]; Medical information systems: [H. Information Systems]; MODELS AND PRINCIPLES: [H.3.3] Information Search and Retrieval

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1. Introduction

Information Systems and Technologies (IST) in healthcare has gradually evolved. It is a vast field, including advances like, for example, computerized diagnostic, decision support systems for medicine based on evidence, Electronic Health Records (EHR), inter-regional, national and international units of healthcare providers, medical imaging technology, for example, Picture Archiving and Communication Systems (PACS), and images to guide surgery and therapy [Mullner & Chung 2006, Wetering & Batenberg 2009].

Since the seventies of the last century, theories about the adoption and maturity of information systems and technologies have been sufficiently established in the literature of management. The concept of the hypothesis of maturity/growth stages in the field of information systems and technologies was introduced by Nolan [Nolan 1973].

The maturity models of Nolan (1973, 1979) for information systems and technologies management instigated extensive discussion, with many researchers conducting studies to validate it, which led to several extensions of the model and even new models [e.g., King & Kramer 1984, Earl 1989, Galliers & Sutherland 1991, Mutsaers et al. 1997, Khandelwal & Ferguson 1999]. Although more recent in the field of IST in healthcare, there are also some maturity models, from specific focus models [e.g., Wetering & Batenburg 2009] to generic focus models [e.g., Sharma 2008].

A maturity model shows the transformation and improvement of an organization over time. Maturity models are used in contemporary methodologies to establish goals for achieving and measuring progress. Overall, the maturity models focus on information systems and technologies and provide an overview of the structure of elements

that represent the effectiveness of management processes of the information systems and technologies in organizations.

With this paper, we intend to make a progress report on the maturity models' situation, focusing on IST management in healthcare. We also aim to verify the opportunities and strategies for developing better models.

Therefore, we discuss the evolution of IST in healthcare, introducing the concepts associated with maturity models, addressing the generic maturity model for IST management and presenting the main maturity models focusing on IST management in healthcare. We conclude by identifying its major gaps and pointing out future work to mitigate them.

2. Evolution of Information Systems and Technologies in Healthcare

The Information Systems and Technologies in healthcare are relatively recent. Probably not even five decades, but they were, from the beginning, enormous progress in healthcare and information technology. Haux (2006) identified several progress lines:

• Moving to a generalized treatment and storage-based computer, as well as an increase in data processing;

• Change of local architecture of information systems to a global architecture;

• Use of data not only for administrative purposes and provision of healthcare but also for healthcare planning and clinical research;

• Shift focus from technical problems particularly, to change management problems as well as issues concerning the strategic management of information;

• Shift from predominantly alpha-numeric data for clinic pictures and molecular data;

• And a constant rise of new technologies to be included to allow a continuous monitoring of patients health status.

Lines of similar developments can be found in other author's works. For example, Voguel (2003) presents different levels of investment in information systems and technologies in healthcare. In each subsequent stage, the expectations rise, producing more complex systems environments. Consequently, information systems and technologies are expected to provide better performance for healthcare organizations.

3. Maturity Models

The maturity models are based on the premise that entities (people, organizations, functional areas, processes, etc.) evolve through a process of growth or development towards a more advanced maturity across several distinct stages. These models have been used in various

Factors	Stage 1	Stage 2	Stage …	Stage N
Factor 1	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*
Factor 2	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*
Factor 3	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*
Factor …	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*
Factor N	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*	*Characteristic 1* *Characteristic ...* *Characteristic N*

Table 1. A maturity model structure

areas and to describe various phenomena [King and Teo 1997].

Maturity models assume that there are predicated patterns, conceptualized in terms of stages, on entity development [Rocha 2000]. Typically, the stages are: (1) by nature, sequential and cumulative; (2) occur as a hierarchical progression that is not easily reversible; and (3) involve a wide range of structures and human and organizational activities.

Various maturity models have been proposed over time [e.g., CMMI 2006]. These models differ mainly in the number of stages, variables/factors of evolution and focus fields. Each of these models identifies certain characteristics that typify the target at different stages of maturity (Table 1).

4. Maturity Models for Management of Information Systems and Technologies

The concept of maturity of information systems and technologies is well known in management literature, dating back to the seventies of the last century. Richard Nolan is considered the principal mentor of the IST maturity perspective. After research into the use of IST in large United States organizations, he proposed an evolutionary model initially containing four stages of maturity [Nolan 1973]. He later added two more stages to the initial model [Nolan 1979].

IST maturity models of Nolan (1973, 1979) generated considerable discussion within the scientific community, with many researchers developing further investigations to validate it, which led to some extensions to the model and even new models [e.g., King & Kramer 1984, Earl 1989, Galliers & Sutherland 1991].

The Revised Model of Maturity Stages of Galliers and Sutherland (1991) is the most comprehensive, detailed and consensus because it presents seven maturity influence factors with equal importance. This model assumes that an organization may find itself at different maturity stages under different influence factors, presenting characteristics of stages aligned with the modern organizations networking and also having a tool for collecting data to assess the maturity [Rocha 2000]. This model consists of six maturity stages (Table 2).

More recently, other models have been proposed, including a new model of Nolan with nine maturity stages [Nolan and Koot 1992, Mutsaers et al. 1997], justified by the progress in IST and management methods. In this latter case, an example is the model with nine maturity stages, which combines the stages theory with critical success factors [Khandelwal and Ferguson 1999].

Defining development and growth stages continues to be fully extended and applied in organizations. Several examples of maturity models focus on different organizational and IST fields. For example, the maturity model for the implementation of Intranets of Damsgaard & Scheepers (2000); the maturity model for ERP systems of Holland & Light (2001); the CMMI maturity model for software development process [SEI 2006], and the maturity model for PACS of Wetering & Batenburg (2009).

5. Maturity Models for Management of IST in Healthcare

The exponential increase of computer capability, the extension of the reach of the Internet and the increasing ability to capture and publish knowledge in a digital form are primarily responsible for conducting electronic healthcare today. IST are providing significant opportunities for health care providers, supplying health care services as well as ways to access to information that consumers need.

Healthcare institutions and governmental organizations are beginning to realize that their fundamental problem is the lack of technological infrastructure and an inability to manage the processes of healthcare properly. An analysis of the current healthcare context shows clearly the extent and importance of the transition problem of technology [Sharma 2008]. The benefits of modern technology, better methods, and better tools in healthcare cannot be achieved in the vortex of undisciplined, often chaotic processes.

These are good reasons for managing IST in healthcare organizations based on maturity models. Thus, in the following sections, we present the maturity models we consider that have significant scope and mainstreaming in the IST management in healthcare, knowing that there are more than a few other models, but focusing on very specific sub-domains, such as PACS.

To identify the current maturity models focusing on IST management in healthcare, we resort to our knowledge and the major digital libraries in the area of IST, as well as the Google search engine.

5.1. Quintegra Maturity Model for Electronic Healthcare

The maturity models are generally focused on individual organizations. However, Quintegra [Sharma 2008] developed a maturity model that incorporates all service providers associated with the health process, adaptable to any provider at any level of maturity.

The Maturity Model for Electronic Healthcare proposed by Quintegra illustrates a transformation of the health electronic process from an immature stage to a national one. This is explained through entities, services and infrastructures at a defined point in time. Each stage has its own characteristics that differentiate it from other stages. Table 3 shows how the progression in maturity levels improves the ability/maturity of a service provider. The base stage of "0" is considered a stage with no infor-

mation technology, and all processes are paper-based.

The maturity stages of this model provide a roadmap for healthcare organizations to embark on continuous improvement of the health process.

Factors	Stage I "Ad hocracy"	Stage II Foundations	Stage III Centralized	Stage IV Cooperation	Stage V Entrepreneurial	Stage VI Harmonious
Strategy	Acquisition of hardware, software, etc.	IT audit; Find out and meet user needs (reactive)	Top-down IS planning.	Integration, coordination and control.	Environmental scanning and opportunity seeking.	Maintain comparative strategic advantage; Monitor futures; Interactive planning.
Structure	None.	IS often subordinate to accounting or finance.	Data processing department; Centralized DP shop; End-users running free at Stage 1.	Information centers, library records, etc. in same unit; Information services.	SBU coalition(s) (many but separate).	Centrally coordinated coalitions (corporate and SBU views concurrently)
Systems	Ad hoc unconnected; Operational; Manual and computerized IS; Uncoordinated; Concentration in financial systems; Little maintenance.	Many applications; Many gaps; Overlapping systems; Centralized; Operational; Mainly financial systems; Many areas unsatisfied; Large backlog; Heavy maintenance load.	Still mostly centralized; Uncontrolled enduser computing; Most major business activities covered; Database systems.	Decentralized approach with some controls, but mostly lack of coordination; Some DSS-ad hoc; Integrated Office technology systems.	Decentralized systems but central control and coordination; Added value systems (more marketing oriented); More DSS-internal, less ad hoc; Some strategic systems; (using external data); Lack of external and internal data integration of communications technologies with computing.	Inter-organizational systems (supplier, customer, government links); New IS-based products; External-internal data integration.
Staff	Programmers/ contractors.	Systems analysts; DP Manager.	IS planners; IS Manager; Data Base; Administrator; Data Administrator; Data analysts.	Business analysts; Information Resources Manager (Chief Information Officer).	Corporate/business/IS planners (one role).	IS Director/member of board of directors.
Style	Unaware.	Don't bother me (I'm too busy).	Abrogation/ Delegation.	Democratic dialectic.	Individualistic (product champion)	Business team.
Skills	Technical (very low level), individual expertise.	Systems development methodology.	IS believes it knows what the business needs; Project management.	Organizational integration; IS knows how the business works; Users know how IS works (for their area); Business management (for IS staff).	IS Manager – member of senior executive team; Knowledgeable users in some IS areas; Entrepreneurial marketing skills.	All senior management understand IS and its potentialities.
Superordinate goals	Obfuscation	Confusion	Senior management concerned DP defensive.	Cooperation	Opportunistic; Entrepreneurial; Intrapreneurial.	Interactive planning.

Table 2. Revised Model of Maturity Stages of Galliers and Sutherland (1991)

	Factors of Influence		
Stages	**Entities**	**Department**	**Infrastructure**
1. Hospital Administration	Hospital	• Patient Administration • Billing • Wards management • Diagnostics Management • MIS	LAN
2. *Hospital Enterprise*	Set of hospitals in enterprise	Stage 1 + • finance • materials management • HR management • electronic claims & payments processing	Internet based Access with HIPAA
3. *EMR Basic*	Hospital + Lab + Pharmacy	Stage 2 + • Laboratory Information System • Radiology Information System • PACS • Pharmacy	Secure HL7 based communication
4. *Clinical Decision Support*	Hospitals + Labs + Pharmacies + Medical Colleges	Stage 3 + • Computerized Provider Order Entry • International codification of diseases • Alerts / Contraindications • Used for educational purposes	Fully connected and paperless – SaaS Model
5. *Clinical Research*	Stage 4 + Pharma Companies	• Clinical Trials • Clinical Data Research based on drug prescriptions and reactions	OaaS2 (Operations as a Service) Model + RaaS3 (Research as a Service) Model
6. *Regional*	Primary Healthcare Centers + Epidemiological centers + Regional Government	• Telemedicine • Aggregation of data from various hospitals at the regional level	Regional network connecting all hospitals with PHC's and Epidemiological centers
7. *National*	Federal Government	• Data from all regions aggregated • Enables healthcare planning and government initiatives towards healthcare	National network connecting all associated service providers in the healthcare process

Table 3. Quintegra Maturity Model for Electronic Healthcare

5.2. HIMSS Maturity Model for Electronic Medical Record

Understanding the level of capability of the Electronic Medical Record (EMR) in hospitals is a challenge in the context of healthcare in modern times. The HIMSS (Healthcare Information and Management Systems Society) created a model of adoption that identifies the different EMR maturity stages, from limited auxiliary departmental systems to EMR paperless environments (Table 4). This maturity model has eight stages [Garets & Davis 2006, HIMSS 2009].

5.3. IDC Maturity Model for IST in Hospitals

IDC (Health Industry Insights) developed a maturity model to describe the five stages of IST development in hospitals. Each step builds on the previous stage regarding capacity (Table 5).

This maturity model has been used worldwide by the IDC, whether to assess the maturity of IST in hospitals or to compare maturity differences average between regions and countries of different continents [e.g., Marc Holland et al. 2008].

Stages	Cumulative capabilities
Stage 0	The organization has not installed all of the key ancillary department systems (e.g. laboratory, pharmacy, radiology).
Stage 1	Major ancillary clinical systems are installed (i.e., pharmacy, laboratory, radiology).
Stage 2	Major ancillary clinical systems feed data to a clinical data repository (CDR) that provides physician access for retrieving and reviewing results. The CDR contains a controlled medical vocabulary, and the clinical decision support/rules engine (CDS) for rudimentary conflict checking. Information from document imaging systems may be linked to the CDR at this stage. The hospital is health information exchange (HIE) capable at this stage and can share whatever information it has in the CDR with other patient care stakeholders.
Stage 3	Nursing/clinical documentation (e.g. vital signs, flow sheets) is required; nursing notes, care plan charting, and/or the electronic medication administration record (eMAR) system are scored with extra points, and are implemented and integrated with the CDR for at least one service in the hospital. The first level of clinical decision support is implemented to conduct error checking with order entry (i.e., drug/drug, drug/ food, drug/lab conflict checking normally found in the pharmacy). Some level of medical image access from picture archive and communication systems (PACS) is available for access by physicians outside the Radiology department via the organization's intranet.
Stage 4	Computerized Practitioner Order Entry (CPOE) for use by any clinician is added to the nursing and CDR environment along with the second level of clinical decision support capabilities related to evidence based medicine protocols. If one patient service area has implemented CPOE with physicians entering orders and completed the previous stages, then this stage has been achieved.
Stage 5	The closed loop medication administration environment is fully implemented. The eMAR and bar coding or other auto identification technology, such as radio frequency identification (RFID), are implemented and integrated with CPOE and pharmacy to maximize point of care patient safety processes for medication administration.
Stage 6	Full physician documentation/charting (structured templates) is implemented for at least one patient care service area. Level three of clinical decision support provides guidance for all clinician activities related to protocols and outcomes in the form of variance and compliance alerts. A full complement of PACS systems provides medical images to physicians via an intranet and displaces all film-based images.
Stage 7	The hospital no longer uses paper charts to deliver and manage patient care and has a mixture of discrete data, document images, and medical images within its EMR environment. Clinical data warehouses are being used to analyze patterns of clinical data to improve quality of care and patient safety. Clinical information can be readily shared via standardized electronic transactions (i.e. CCD) with all entities who are authorized to treat the patient, or a health information exchange (i.e., other non-associated hospitals, ambulatory clinics, sub-acute environments, employers, payers and patients in a data sharing environment). The hospital demonstrates summary data continuity for all hospital services (e.g. inpatient, outpatient, ED, and with any owned or managed ambulatory clinics.

Table 4. HIMSS Maturity Model for Electronic Medical Record

Stage I ***Basic HIS***	**Stage II** ***Advanced HIS***	**Stage III** ***Advanced HIS Core Clinicals***	**Stage IV** ***Digital Hospital***	**Stage V** ***Digital Virtual Enterprise***
· Patient registration/ inpatient admission discharge and transfer · Patient billing and accounts receivable · HRIS/payroll · General ledger / financial reporting · Purchasing/accounts payable	· Electronic claims submission · Electronic payment processing · Inventory, supply requisitioning, and distribution · Basic order communications · E-mail · Internet access · Intranet	· Laboratory information · RIS/radiology results reporting · PACS · Pharmacy · Operating room scheduling and management	· Patient appointment scheduling · Computerized physician order entry · Nursing documentation · Emergency department management · Cardiology department management · Physician portal · Patient portal · Wireless infrastructure · Inpatient electronic medical record (EMR) · Ambulatory EMR · Enterprise master patient index	· Secure email (provider-provider / provider-patient) · Participation in regionalized patient CDR · Home health case management · Remote patient monitoring / telemedicine

Table 5. IDC Maturity Model for IST in Hospitals

Stage I ***Clinical administrative data***	**Stage II** ***Integrated clinical diagnosis and treatment support***	**Stage III** ***Clinical activity support***	**Stage IV** ***Clinical Knowledge and decision support***	**Stage V** ***Speciality specific support***	**Stage VI** ***Advanced multi-media and telematics***
Patient administration and independent departmental systems	Stage 1 + • Integrated master patient index, departmental systems	Stage 2 + • Electronic clinical orders, results reporting, prescribing, multi-professional care pathways	Stage 3 + • Electronic access to knowledge basis, embedded guidelines, rules, electronic alerts, expert system support	Stage 4 + • Special clinical modules, document imaging	Stage 5 + • Telemedicine, other multi-media applications (e.g., Picture archiving and communication systems)

Table 6. NHS Maturity Model for Electronic Patient Record

5.4. Maturity Model for Electronic Patient Record

According to the NHS (United Kingdom National Health Service), there are six different stages of functionalities implemented on top of each other, until achieving a complete and comprehensive Electronic Patient Record (EPR) [Priestman 2007]. These six stages are summarized in Table 6.

Moving towards the final stage, more and more information will be available at the touch of a button using traditional computers, mobile handsets, computers and portable devices. The EPR system will be the primary source of all patient information. It will allow access to the entire medical record and will be available online and at the point of contact with the patient.

6. Conclusion and Future Work

As part of this paper, we surveyed maturity models focusing on IST management in healthcare. To this end, we resort to our knowledge, major digital libraries in the IST area, and the Google search engine, which resulted in identifying the maturity models mentioned and presented.

Consequently, we conclude that the research on maturity models focusing on IST management in healthcare is still embryonic. In the survey, we found that few models are insufficiently detailed, do not provide tools for determining maturity, and don't have the characteristics of the maturity stages structured by influence factors.

This finding marks the opportunity to develop new maturity models focusing on IST management in healthcare to fill in the gaps identified above. Within the universe of maturity models that we know, we believe that the Revised Model of Maturity Stages of Galliers and Sutherland (1991) could inspire, especially in defining influence factors and developing an instrument to assess maturity.

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