2013

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Recommended Citation

Brooks, P., El-Gayar, O., & Sarnikar, S. (2013, January). Towards a business intelligence maturity model for healthcare. In 2013 46th Hawaii International Conference on System Sciences (pp. 3807-3816). IEEE.

2013 46th Hawaii International Conference on System Sciences

Towards a Business Intelligence Maturity Model for Healthcare

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Abstract

Healthcare is a very complex, knowledge-driven industry. Electronic health record implementations have created massive amounts of clinical and financial data. The accumulation of data is outpacing the ability of organizations to leverage the data for improving financial and clinical efficiencies and quality of care. It is believed that careful and attentive use of business intelligence (BI) in healthcare can transform data into knowledge that can improve patient outcomes and operational efficiency. BI maturity models are a way of identifying strengths and weaknesses of the information maturity of a business.

This paper presents a comprehensive review of existing BI maturity models to determine their adequacy for use in healthcare. The review identifies gaps in existing BI maturity models and presents requirements for a healthcare-specific maturity model. The results of this study will be used to develop a BI maturity model that addresses the complex characteristics and needs of healthcare organizations.

1. Introduction

Recent advances in healthcare information technology (HIT) have resulted in massive volumes of both clinical and financial data. Although healthcare is increasingly dependent upon HIT, the accumulation of data has outpaced our capacity to use it to improve operational efficiency, clinical quality, and financial effectiveness [1] [2]. The culture of healthcare is increasingly being driven by a fundamental need to maximize the quality of care while minimizing costs [3].

Healthcare executives and clinicians are faced with the challenge of sifting through massive amounts of information at many different levels to answer complex questions. The data comes from many different sources and formats and at different points in time. This increases difficulty for end users to evaluate information [4].

One way organizations can improve efficiency in managing information and achieving higher business goals is through the use of business intelligence. There are many different definitions for BI, but for our research purposes, we will use the following definition: "Business intelligence (BI) is a broad category of technologies, applications, and processes for gathering, accessing, and analyzing data to help its users make better decisions." [5]. The primary objective of BI systems is to improve the timeliness and quality of input required in the decision making process. This implies that actionable information needs to be delivered at the right time in the right location and in the right form [6].

With careful and attentive use of business intelligence (BI) in healthcare, it is believed hospitals can transform huge amounts of data into information that can improve patient outcomes, increase safety, enhance operational efficiency, and support public health efforts [1]. Thoughtful approaches that would allow managers and providers to understand their readiness for business intelligence and critical steps to a mature BI process can assist in developing an overall strategy for BI.

A method organizations can use to assess their readiness for business intelligence is through the use of a maturity model. The importance of a sound maturity model lies in the ability to guide and provide systematic maturity and a readiness assessment for BI stakeholders to implement BI [7]. Because of additional complexities in healthcare, the processes included in existing BI maturity models do not appear to take into consideration the complex information needs for BI maturity in healthcare.

The objective of this paper is to identify the gaps in existing BI maturity models relative to healthcare needs and to develop an agenda for creating a BI maturity model in healthcare. We will explore the complexities in healthcare that make BI a challenge and review existing BI maturity models to identify gaps and issues with existing models. From the gaps,

1530-1605/12 $26.00 © 2012 IEEE
DOI 10.1109/HICSS.2013.560

we will develop a list of requirements for a healthcare BI maturity model and an agenda for future maturity model development.

The remainder of the paper is organized as follows. In section two, we review complexities in healthcare that make information needs challenging. In section three, we present background information on maturity models. Section four includes an analysis of the gaps in BI maturity models relative to healthcare complexities. In section five, we provide a list of requirements for a healthcare BI maturity model. Section six presents an agenda for future research and development and section seven concludes with a summary of contributions.

2. Understanding BI Complexity in Healthcare

Today's healthcare decisions makers are facing growing demands for both clinical and administrative information [2]. The existing literature in BI has focused primarily on retail, manufacturing, finance and government entities [2, 8]. Generally the models are not directed toward any particular domain. When evaluating BI in the context of healthcare, it is important to understand the complexities of healthcare and how BI needs may be impacted. Some of the key healthcare complexities are listed in Table 1.

Table 1. Healthcare complexities and BI implications

Healthcare Complexities	Description	BI Implications
Complex decision making processes	Healthcare decision making is often complicated by the need to integrate ill-structured, uncertain, and potentially conflicting information from different sources [9]. Medicine is both an art and a science; not every patient will react the same way to a treatment. Decisions may depend on the function of the task and the expertise of the decision maker [9].	• Both discrete and non-discrete data are components of the electronic health record, including documentation in discrete, free text, and imaging formats. • To achieve full benefits of BI, organizations need to integrate data that has historically been siloed in financial, operational, and clinical systems[10]. • Whenever possible, evidence-based practice provides the means to provide consistent, quality care [11]. Current practice involves little time for evaluating research to make clinical decisions. Consequently, every attempt must be made to embed clinical decision support tools into the workflow of clinicians.
Reimbursement methodologies	Mixed payment mechanisms make healthcare reimbursement very complex.	• The mixture of payment mechanisms makes processing and analyzing of data complicated [12].
Delivery models to eliminate fragmentation of services	Different payment and delivery models are being developed in an effort to decrease overall healthcare costs. Accountable Care Organizations (ACOs) are one delivery model to control the total cost of care, quality, and effectiveness of services across the continuum of care including hospitals, clinics, nursing homes, home health agencies, and other entities. The concept behind an ACO is to shift the paradigm from payment per service rendered to a focus on wellness [11].	• Changes in delivery and payment methods require the integration of information from multiple organizations to make decisions. • By combining information across the continuum of care, predictive analytics can be used for more concrete decisions about patient care. • Data standards have only been minimally required causing interoperability and integration issues.
Focus on patient-centered care and	There is an ongoing movement to involve patients in healthcare decisions. This includes sharing health information and providing tools,	• As PHRs mature, patients will be requesting their PHR information be shared with providers and integrated

consumer-driven healthcare	such as telehealth and personal health records (PHRs) to assist in communicating and managing care [11].	into electronic health records.

Three key areas that make healthcare BI efforts particularly challenging are the need for integration of clinical and financial data, the diverse types of data formats that may provide information for higher level analytics, and the demands and expectations of external data for clinical and financial decisions. External data is a challenge because of the lack of standard terminology and classification systems [12]. This causes issues with interoperability and integration of health data.

Clinical and operational/financial information is needed to measure, assess, control, and improve the quality and productivity of operations at the organizational level. On a global level, federal and state funding and regulatory agencies as well as research institutions need information on the health status of specific populations and the quality and performance of providers and organizations to execute regulatory oversight, protect and advance public health, evaluate new forms of care, accelerate research, and disseminate new medical knowledge and evidence [13] Clinical and financial data are often segregated into separate proprietary systems with incompatible formats [14, 15]. This makes it hard to integrate metrics into the processes for both clinical and administrative decision making [2]. Most healthcare systems have multiple, typically departmentally focused, reporting capabilities. Rarely are these systems linked in a way to create on-demand cross departmental/enterprise views for upper management. Departments often spend an incredible amount of time trying to pull data from multiple sources to make a clean and concise report for managerial staff [16].

Information from electronic health records often contains patient information recorded in many different structured formats, such as clinical, financial, and laboratory databases. In addition, there are many unstructured formats in an electronic health record including free text reports, dictation, image data, wave forms, and genomics. [1, 8, 17]. This makes it difficult to extract and analyze clinical information to use for healthcare management and clinical decision making. The needs of users and the complexities of clinical work need to be analyzed and evaluated for potential solutions [18]. While it is not unique to the healthcare industry to have a mixture of structured and unstructured data, the fact that there are different formats of information to analyze for clinical decision making can be a challenge.

In healthcare, not only are there many internal customers to satisfy, but also external agencies and governmental authorities tying reimbursement to quality and cost effectiveness of patient care. Exchanging data can be difficult because of inconsistent structure and format. In order to share and use data efficiently from multiple institutions, data must be built upon common words (data elements and terminology), structures, and organization. This requirement is a component of interoperability [19]. While there has been significant movement toward data standards for interoperability, there is a considerable amount of work yet to be done in order to freely exchange and interpret data from outside sources. The need to make electronic health records interoperable continues to grow with a vision for a National Health Information Network (NHIN) [11]

Healthcare systems are rapidly changing and being driven by a system of accountable care, of which integration is one of the key components. The goal of integration within accountable care organizations (ACOs) is to ensure that the health and wellness of the population is managed, the most cost-effective care is provided, clinical processes are streamlined and follow the best evidence, necessary reporting is in place, and payments and reimbursement are appropriate [20]. Because ACOs encompass many health care facilities, they create pressure to obtain, analyze, and use data from external sources across the continuum of care to make healthcare decisions [21].

It is claimed that healthcare is the most complex, knowledge-driven industry in the world and represents one of our most significant economic challenges [20]. Business intelligence is becomingly increasing important because of the need to improve effectiveness, efficiency, and quality of health services, as well as improve the availability of information in real time [2] In the next section, we will cover an overview of existing maturity models to understand their purpose and primary process/dimension areas used in BI maturity models.

3. Maturity Models

Maturity models (MMs) are a means to support effective management and continuous improvement for initiatives that are complex and have multiple components [22, 23]. Important characteristics of maturity models include the maturity concept,

dimensions, levels, maturity principle, and assessment approach [24]. Maturity concepts can be distinguished by people or workforce capabilities [25], process maturity [26], or technology maturity [27]. Dimensions are specific capability areas, process areas, or design objects structuring the field of interest [28]. Each dimension is further specified by a number of measures (practices, objects, or activities) at each level [28, 29]. Levels are the states of maturity of a certain dimension. Each level has a distinguishing descriptor providing the intent of the level. Maturity models can be continuous or staged. Continuous allows scoring to be done for each dimension while staged means all goals and key practices must be met before moving to the next level. The assessment approach can be qualitative or quantitative using measurements, such as a Likert scale [29].

More than one hundred maturity models have been published in the information systems field to date [30]. Maturity models by themselves typically do not address organizational maturity with respect to how data is managed [31]. Business intelligence maturity models provide systematic maturity guidelines and readiness assessment for the use of technology and data to transform into usable information to develop insight and make informed decisions.

Fifteen of the most common and well-published BI maturity models were reviewed to determine the purpose of the maturity model as well as the staging and dimensions for the maturity model. The majority of the models use five levels of maturity, with many of them using very similar levels. Two key shortcomings of many existing models identified in the literature are a lack of processes covering the relationships between technology, people, and organizational processes [32, 33] and lack of an underlying theoretical foundation [32, 34]. In addition, many of the models do not have documentation of the reliability of the model and several require third party assistance from vendors or consultants.

Dimensions are the specific capability or process areas that are evaluated in a maturity model. Table 2 summarizes and consolidates the number of times similar dimensions were used in the BI maturity models evaluated. It is noted that the majority of the BI maturity models focus on the technical aspects of a maturity model followed by the BI strategy and people focus of BI initiatives.

Table 2. Dimensions in business intelligence maturity models

Dimensions/Process Areas	# of BI Models
Technical - Readiness, system, architecture	12
BI strategy and program management	8
People - Skill level of users, IT and business users, workload complexity	8
Organizational impacts - Performance improvement, value	7
Information management - Data quality, master data management, meta data management, data sophistication and delivery	5
Partnership between business units and IT	4
Decision and analysis culture - Risk and reward	3

Maturity models have been used for many different functions within different industries, such as project management, performance management, data warehousing, and information system maturity. While the BI maturity models that were evaluated are more focused on data and information, they do not focus specifically on any one domain. An advantage of a generic BI maturity model is that is can be used for any domain. A disadvantage is that unique or highly important information needs of a specific domain, such as healthcare, cannot be addressed in detail.

There is no evidence in the literature that a BI maturity model has been specifically created for healthcare. However, with the multifaceted needs of information management in the healthcare industry, we argue that existing models are incomplete in capturing the complexities of healthcare including integrated operational/financial and clinical information and the demands of exchanging and making data interoperable among external systems to drive healthcare decisions.

4. Analysis of gaps in BI maturity models relative to healthcare complexities

From the original group of the 15 maturity models referred to in Section 3, an analysis of potential gaps in BI maturity models relative to healthcare complexities was done and summarized in Table 3. The purpose of the analysis was to determine if the current processes being used in the models could be used for healthcare and cover the complexities in healthcare BI. Only the models that met the following criteria were evaluated: (1) a list of the dimensions/processes and sub-processes in the model could be obtained and (2) the model can be used without the assistance of a third party vendor or consultant.

Included in the maturity model analysis is (1) the general purpose of the model, (2) a list of dimensions/processes and sub-processes included in the model, (3) an analysis to determine if a process related to integration of complex data and external data and interoperability is addressed, and (4) an analysis to determine if the known shortcomings of addressing a combination of technology, people, and organizational processes was addressed as well as a review of which models were explicitly theory-based. These last two areas were singled out because the literature addressed them as shortcomings in many models.

Table 3. BI Maturity Model Gaps

BI Maturity Model	Purpose	Processes Discussing Integration of Complex Data	Processes Discussing External Data and Inter-operability	Processes Addressing Links Between Technology, People, and Organiza-Tions	Model Explicitly Theory-Based
Business Information Maturity Model	Focuses on increasing the importance of BI [35]. Key process areas include BI strategic position, partnership between business units and IT, BI portfolio management, information and analysis usage culture, process of improving business culture, process of establishing decision culture, and technical readiness for BI/data warehousing.	No	No	No	No
CMM for BI	Focuses on people, processes and technology using the capability maturity model [34]. The dimensions include strategy, social system, technology system, quality, and use/impact.	No	No	Yes	Yes
Data Warehousing Stages of Growth	Focuses on data warehousing and nine variables that define each stage [36]. Process areas include data, architecture, stability of the production environment, warehouse staff, users, impact on users' skills and jobs, applications, costs and benefits, and organizational impacts.	No	No	No	Yes
Dataflux	Focuses on the Enterprise Data Management MM to help companies identify and quantify their data maturity as well as assess the risks of undervalued data management practices [31]. Dimensions include people, process, technology, and risk and reward.	No	No	Yes	No
EB12M	Focuses on both staged and continuous representation for enterprise business changes as well as data maturity. Thirteen dimensions including change	No	No	Yes, however, this model is still being	No

	management, organization culture, strategic management, people, performance management, balanced scorecard, information quality, data warehousing, master data management, metadata management, analytical, infrastructure management, and knowledge management. The seven factors considered for key maturity indicators include data warehousing, master data management, metadata management, analytical, infrastructures, performance management, and balanced scorecard [37]			tested	
TDWI's BI Maturity Model	Focuses primarily on the technical aspects of maturity. The eight key process areas include scope, sponsorship, funding, value, architecture, data, development, and delivery [38].	No	No	No	No

It can be noted that healthcare specific processes including integration and external data needs were not a part of any of the BI maturity models. However, in an article discussing the EBI2M model, the need to review integration needs in any particular domain as a step towards reaching higher BI maturity levels was discussed [37]. The integration that is suggested is integration of both business intelligence and technical aspects of an organization into one maturity model. The EM12M model is fairly new and is still being tested.

It was felt appropriate to review the models for the known shortcomings addressed in the literature because the requirements for any proposed new model would probably include the shortcomings. Therefore, models were evaluated for processes addressing technology, people, and organizational processes as an explicit theory base.

Processes for people, processes, and technology are all included in the CMMI for BI, as the processes for these three areas working together is the primary focus of this model. This model does have a theoretical foundation and questionnaire. It is a fairly new model and may need to be tested further [34].

Three of the four dimensions in the Dataflux maturity model include people, process, and technology. The maturity concept is based on capabilities of an organization and the thought that organizations increasingly understand their data management problems and the importance of data to the success of the organization [31]. It should be noted that the reliability of this model is not documented [39].

In the EB12M, one of the dimensions focuses on people. However, two other dimensions organizational culture and change management) are specific to processes related to people as well. The EM12M is fairly new and has not been well tested at this time [37].

The CMM for BI and Data Warehousing Stages of Growth use a theoretical foundation through the IS success model. The variables of the IS success model include quality, use, and impact. [34]. The Data Warehousing Stages of Growth uses the stages of growth theory that things change over time in sequential, predictable ways. The focus of this model is on three data warehousing stages of growth. [36].

A review of the maturity models included in Table 3 suggests potential issues with usage of the models for healthcare. A review of the model processes and known shortcomings in existing maturity models solidifies the fact that it may be hard to operationalize the complex processes within healthcare through an existing maturity model. We propose that both the integration of clinical and financial data and external data needs in healthcare be considered as processes in a BI maturity model specifically customized for healthcare.

While other industries require integrated data and data from external sources, we believe the depth of information needed for healthcare is unique, especially in light of changes with healthcare reform. Payment structures and delivery models are changing to incorporate responsibility for populations of consumers. The drive for patient safety, transparency in healthcare, error reduction, increased efficiency, and additional requirements from regulatory agencies will continue to shape the delivery of healthcare. In addition, consumers will assume greater responsibility for their healthcare and will demand the exchange of information [11].

By including integration and external data as separate processes, assessment questions can be used

to ascertain an organization's readiness for the higher levels of BI that will be required for true integration and interoperability and the ability to make health care decisions based on the integrated and external data. While the earlier issue of diverse data formats in healthcare is a challenge, one could argue that this consideration should be covered as functionality in the maturity leveling within the technical process.

5. Requirements for the development of a healthcare BI maturity model

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 business intelligence success. The intended user of the BI maturity model would be management staff within a healthcare organization. Therefore, the requirements need to be very practical with the intent an organization can understand their maturity level once an organizational assessment is complete.

Requirement #1:

- *Provide a conceptual structure for managing the use of business intelligence in healthcare.*

A maturity model for BI in healthcare should provide a framework that allows for a consistent approach to the development of business intelligence in healthcare. An appropriate process maturity framework for healthcare complexities can assist in evaluating maturity levels. As an example, if there is a process focusing on the exchange and interoperability of external data, maturity levels can be assigned ranging from inconsistent data definitions and lack of data standards to full integration into internal data systems.

Requirement #2:

- *Focus on the needs of operational/financial and clinical information.*

In healthcare, both operational/financial and clinical reporting is needed. Healthcare processes typically cross departmental boundaries [2] [10]. In order to fully utilize business intelligence, it is imperative that data from operational, financial, and clinical systems be integrated. Recent industry research has shown that healthcare organizations that are focusing on the integration of data are eliminating waste, improving profit margins and patient satisfaction, and providing better care [10][40]. Higher level functionality would include predictive data mining and predictive analytics at the point of care [41, 42].

Requirement #3:

- *Focus on capturing key business intelligence processes and practices, taking into consideration specific processes within healthcare.*

Maturity models should capture the key set of development processes and practices which are grounded in practice and academic literature [43]. A healthcare business intelligence maturity model should capture the key process areas and critical success factors in the development of business and clinical intelligence. Because the integration of operational/financial and clinical information and the exchange and interoperability of external data are key components in achieving full benefits of BI in healthcare, we propose they be included in the key process areas in the maturity model.

Requirement #4:

- *Incorporate key processes that include people, technology, and organizational processes.*

One of the shortcomings in BI maturity models is that the majority of them do not take into consideration processes for technology, people, and organizational processes. When all three of these broad categories of processes are included, we can consider evaluating maturity levels for areas such as vision and BI strategy, management support, change management, staff skill levels, knowledge management, data quality, and technology infrastructure. These areas coupled with healthcare processes including integration and interoperability should create a well-rounded BI maturity model for healthcare.

Requirement #5:

- *Incorporate aspects of quality including system quality, information quality, and service quality.*

Data quality is becoming increasingly important to many organizations. This is especially true in healthcare with extreme cost pressures and the desire to improve patient care [44]. One of the key

components in the IS success model is that IS use primarily focuses on IS quality and IS use/impact. [45] Quality is comprised of system quality, information quality, and service quality. If the quality of data cannot be trusted, it will impact how it is actually used.

Requirement #6:

- *Provide an understanding of relationships between the different levels and key processes involved in a maturity model by incorporating theoretical underpinnings.*

As stated earlier, many maturity models lack a theoretical foundation, which can make it more difficult to understand the underlying maturity concept and relationships between the different parts of a maturity model [34]. This was demonstrated in our analysis of the most common maturity models. One theory that fits well with BI capability is the socio-technical theory. The argument in this theory is that social IS subsystems, comprised of people, methodological capabilities, and organizational practices, as well as the technical IS subsystems are interdependent and need to work with each other in order to maximize the benefits of a system [46]. This aligns with incorporating people, technology, and organizational processes into a healthcare BI maturity model, especially in light of the number of different clinicians and entities involved in patient care.

6. Future research and development

This paper presents the current gaps and issues with existing BI maturity models and provides a list of requirements for a BI maturity model in healthcare. It sets the agenda for future research in this area. Future research includes validating the list of requirements, creating a maturity model by further defining healthcare processes, maturity levels, and functionality or capability at each sub-process/dimension at each maturity level, and then actually validating the model.

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. The requirements lay the foundation for the next steps in the development of a BI maturity model.

The processes included in maturity model development will be expanded to include the unique processes important for a healthcare BI maturity model. Appropriate maturity model level definitions will be determined by evaluating existing maturity models. Functionalities for each of the sub-processes/dimensions will be defined for each maturity level after performing an extensive literature review and empirical evaluation.

Once a maturity model has been created, the processes, sub-processes/dimensions, and defined functionality at each maturity level will be verified by a group of experts as a part of iterative model development. The validation will include both a quantitative and qualitative component. A quantitative assessment questionnaire will be developed to assess the perceived maturity level of each process. In addition, a qualitative tool will be developed for use with additional key BI stakeholders within the same healthcare system to gather a more qualitative perception of the BI maturity level within the organization. This process will actually be pilot tested within an organization with the intent an overall maturity level will be ascertained from the assessments.

7. Contribution and concluding remarks

The creation of a maturity model for business intelligence in healthcare has great opportunity for contribution to information and knowledge management in healthcare. The overarching need for a maturity model for business intelligence is to provide guidance to BI deployment initiatives and serve as a readiness assessment to move up each level in maturity.

This paper makes four important contributions to research. First, evaluating the complexities and differences of information management in healthcare, we further understand challenges to the business intelligence environment in healthcare. This understanding assists with the guidance of maturity model creation. Second, by analyzing existing BI maturity model processes, we can determine if there are gaps in processes that should be considered for the information needs in healthcare. The BI maturity models that have been used in healthcare to date have not focused on specific processes that are unique or of high importance to healthcare. Third, by performing a thorough literature review on healthcare complexities and information needs as well as shortcomings of existing BI maturity models, we were able to develop a list of requirements for a BI maturity model for healthcare. And finally, we provide an agenda for future research in the area of a BI maturity model for healthcare. This is an area rich

in opportunities for research to strengthen business intelligence in healthcare.

Healthcare is a very complex, knowledge-driven industry, and as such, a maturity model that can be developed specifically for use in healthcare could provide great benefit. 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.

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