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Design and evaluation of hospital-based business intelligence system (HBIS): A foundation for design science research methodology

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ABSTRACT

This paper describes the development of a hospital-based business intelligent system (HBIS) based on a novel developmental methodology, called the design science research methodology (DSRM), and implemented in a regional general hospital in Taiwan. A design science research methodology is adopted to cover six activities: problem identification and motivation, definition of solution objectives, design and development, demonstration, evaluation, and communication. Based on the DSRM developmental method, HBIS was successfully developed and deployed in the hospital case, and a survey of users shows positive results. In addition, the support and involvement of top management in HBIS development is found to be a critical success factor, and system implementation allowed the hospital to significantly improve performance of managerial indicators for the three abovementioned dimensions. This study contributes a novel developmental methodology from the Information Systems (IS) field as a reference model for future HBIS development, along with the integration of indicators from three major managerial dimensions - NHI, hospital accreditation, and healthcare quality.

1. Introduction

Business intelligence (BI) is the ability of an enterprise to collect, maintain, and organize knowledge, and has emerged as an important area of study for both practitioners and researchers, reflecting the magnitude and impact of data-related problems present in contemporary business organizations (Chen, Chiang, & Storey, 2012; Haque, Derksen, Calado, & Foster, 2015; Shollo & Galliers, 2015). From the perspective of information systems, BI systems combine data gathering and data storage with analytical tools to present complex internal and competitive information for planners and decision makers (Ghosh & Scott, 2011; Negash, 2004). Moreover, BI is a powerful tool for causality analysis and corporate analyses since it provides a data-driven approach to link firms' strategic goals to tactical policies and operational actions (Wang, 2016). For example, electronic commerce platforms, blogs, and social media contain useful information (e.g., insightful product reviews and information-rich consumer communities) that could potentially be of great value for business intelligence, providing significant opportunities for both academic research and the development of business applications (Chau & Xu, 2012). In addition, several recent studies have focused on behavior and attitude issues of using business intelligence in information systems contexts (Deng & Chi, 2012; Li, Hsieh, & Rai, 2013).

In the medical and healthcare fields, BI systems are designed to deliver decision-support information and have been repeatedly shown to provide value to organizations. Evidence-based decision making relies on reliable access to timely and accurate information (Foshay & Kuziemsky, 2014). BI with healthcare analytics is an emerging technological approach that provides analytical capability to help the healthcare industry improve service quality, reduce costs, and manage risks (Zheng, Zhang, & Li, 2014). Demand for BI applications in healthcare continues to grow with the

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increasing volume of data and the desire to apply such data usefully. A key characteristic of BI is that it integrates data from a wide variety of internal and external sources, thus providing an effective information platform for healthcare decision makers (Mettler & Vimarlund, 2009). It is widely acknowledged that BI can provide benefits to healthcare organizations including improved patient care and outcomes (Tremblay, Hevner, & Berndt, 2012), improved process efficiency (Flower, 2006) and cost avoidance (Pine, Schindler, Stanek, Hanlon, & Manas, 2012). Furthermore, implementing a BI system represents a hospital's readiness to embrace the future of data analysis for performance improvement. Hospitals can exploit BI systems to improve quality of care, margins, employee and patient satisfaction, clinical and operational efficiencies (Spruit, Vroon, & Batenburg, 2014).

BI tools allow administrators to correlate data elements for the multidimensional macro- and microanalysis of information to facilitate effective strategic decision making (Chung, Chen, & Nunamaker, 2005; Langseth & Vivatrat, 2003; Willen, 2002). A variety of decision support mechanisms are needed to increase the productivity of medical personnel, analyze care outcomes, and continually refine care delivery processes to allow the organization to remain profitable while holding the line on costs and maintaining quality of care (Coddington & Moore, 2012; Dutta & Heda, 2000). Ferranti, Langman, Tanaka, McCall, and Ahmad (2010) presented three case studies that illustrate the use of health analytics to leverage preexisting data resources to support improvements in patient safety and quality of care, improve billing accuracy and collection efficacy, and enhance the effectiveness of responding to emerging health issues (Effken et al., 2011; Ferranti et al., 2010).

We believe the implementation of BI is crucial for improving the effectiveness of hospital management, but argue that national and regional healthcare conditions and contexts vary widely. Business intelligence can help organizations improve efficiency in managing information for decision making, but BI is more than just a technology, entailing an understanding of the interaction of several key organizational, technology, and people process areas within an organization. In Taiwan, top hospital management is chiefly concerned with indicator integration from different managerial dimensions including the National Health Insurance (NHI) scheme, hospital accreditation, and health care quality (S. H. Cheng & Chiang, 1997; S. H. Cheng, Jan, & Liu, 2008; T.-M. Cheng, 2003; Davis & Huang, 2008; Taiwan, 2012). Such indicators are always subject to change with governmental regulations and policies, and these changes can result in disruptions, especially in terms of efficiency of information collection, consistency of indicator definitions, and complexity in indicator monitoring. Responsibility for indicator management is frequently delegated to multiple departments, resulting in inconsistent information gathering and reporting. Specifically to regional hospitals in Taiwan, indicator data collection and tracking is performed by different departments depending on medical specialization. For example, the obstetrics and gynecology department monitors its own specialty indicators (e.g., the C-section rate). In addition, health insurance indicators (e.g., abnormal payment indicators as defined by the NHI) are managed by the hospital's department of medical affairs. The hospital's stratified organizational structure results in a lack of cohesion and consistency in indicator management, making the collection, gathering and analysis of information unnecessarily time-consuming and inefficient (de Keizer & Ammenwerth, 2008; Nirel et al., 2010). Despite the potential of BI systems to address these shortcomings, many healthcare organizations have yet to implement them (Hanson, 2011) and there has been very limited research on the factors that contribute to the successful implementation of BI in healthcare-specific contexts (Foshay & Kuziemsky, 2014). These issues can potentially be resolved by implementing BI systems to create an integrated mechanism to collect, store, and analyze important indicators from different managerial dimensions, providing management with a valuable tool for indicator management and decision-making.

This study describes the development of a hospital-based business intelligent system (HBIS) based on a novel developmental methodology, namely the design science research methodology (DSRM). This method consists of six major processes: identify problem and motivation, define solution objectives, design and development, demonstration, evaluation, and communication (A. R. Hevner, 2007; Alan R Hevner, March, Park, & Ram, 2004; S. T. March & Storey, 2008). In the context of BI, technology can be seen as an enabler for storing, analyzing, visualizing, and giving access to a great amount of data. For this purpose, a wide range of expert systems, online analytical processing (OLAP) and data mining tools are used coevally in a BI system. On the other hand, technology is required to provide an integrated view of both internal and external data (for example by means of a data warehouse) and is thus the base for BI (Haque et al., 2015; Haque, Urquhart, Berg, & Dhanoa, 2014).

The HBIS architecture consists of internal and external data sources, a three-tier data warehouse server structure, an OLAP server, and front-end tools. The HBIS modules include five parts: (1) the user login provides various authorization and access levels for different roles within the hospital, (2) total managerial decision-making indicators, including important NHI indicators, and others related to hospital accreditation and healthcare quality such as non-payment status or indicators for diagnosis related group (DRG) monitoring (El-Jardali, Jamal, Dimassi, Ammar, & Tchaghchaghian, 2008; Hirose, Imanaka, Ishizaki, & Evans, 2003; Moffett, Morgan, & Ashton, 2005; Sack et al., 2011; Wung et al., 2011), (3) decision-making diagrams provide various data visualizations to assist top management decision-making, (4) specific indicators analysis with roll-up and down functions provide analytic figures for various time frames, and (5) department- and physician-specific analytics provide quantitative comparisons for all indicators across departments and physicians.

The present study reports the overall experience of developing and implementing the HBIS in a regional general hospital of southern Taiwan. We adopt DSRM as a novel developmental approach for HBIS and provide useful guidance for the design of hospital information systems (HIS). We also provide important results for the development and implementation of HBIS from the standpoint of indicator integration of three managerial dimensions: NHI, hospital accreditation, and healthcare quality. Finally, we draw implications for decision-making among top hospital management. The remainder of this study is structured as follows: Section 2 describes the novel DSRM methodology with its six major activities. Section3 presents the results of the development and implementation in the test hospital. The results are discussed in Section 4, along with conclusions and implications for practice.

2. Materials and methods

Design science research methodology (DSRM) was developed in engineering (Hoffman, Roesler, & Moon, 2004; Walls, Widmeyer, & El Sawy, 2004), with Eekels and Roozenburg (1991) raising the need for a common DSRM (Eekels & Roozenburg, 1991). Archer's methodology focuses on one kind of DS research, with building system instantiations as the intended research outcome (Archer, 1984), or “the purposeful seeking of a solution” to a problem formulated from design theory proposed by McPhee (1996). Archer believed that design could be codified, even its creative aspects, and his industrial engineering research outcomes reflect his views on research methodology. His work included purpose-oriented