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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

designs for hospital beds and for mechanisms that prevented fire doors from being propped open.

Following this direction, several researchers have succeeded in bringing design research into the information systems (IS) research community, successfully making the case for the validity and value of design science (DS) as an IS research paradigm (Alan R Hevner et al., 2004; Salvatore T March & Smith, 1995; Walls, Widmeyer, & El Sawy, 1992) and actually integrating design as a major component of research (Nunamaker, Chen, & Purdin, 1990). More importantly, Peffers, Tuunanen, Rothenberger, and Chatterjee (2007) stressed that the lack of a methodology to serve as a commonly accepted framework for DS research or as a template for its presentation may have slowed the adoption of DS research (Peffers et al., 2007). The DSRM presented here incorporates principles, practices, and procedures required to carry out such research and meets three objectives: it is consistent with the prior literature, it provides a nominal process model for doing DS research, and it provides a mental model for presenting and evaluating DS research in IS. The DS process includes six activities: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication. Table 1 summarizes these six DSRM activities.

3. Results

This study follows the above DSRM activities to develop and implement a BI system for routine and specific management operations for a regional hospital in southern Taiwan.

3.1. Problem identification and motivation

Hospital Y was established in 1946 and gradually expanded to its current size of 520 beds and over 1200 employees, making it one of the largest teaching hospitals accredited by the Taiwan Joint Commission on Hospital Accreditation (TJCHA). However, a lack of automated support makes it difficult to effectively gather data to track indicators for Taiwan's National Health Insurance (NHI) scheme, hospital accreditation, and healthcare quality. Such data must be collected in a cohesive and consistent manner that allows managers to share indicators. The current inability to automatically collect and analyze such data leaves managers are at a severe disadvantage.

Motivated to secure the advantages of BI, Hospital Y's management sought to implement a data warehouse system to support the development of a BI system. Hospitals can use BI systems to improve quality of care, margins, employee and patient satisfaction, and operational and clinical efficiencies. BI tools allow users to correlate data elements for multidimensional macro- and micro-analysis for effective strategic decision-making. Therefore, the BI system was designed to collect information regarding the progress of administrators' decision-making processes, providing significant benefits for healthcare management.

3.2. Define the solution objectives

The objective of the project was to develop an artifact referred to as the hospital-based business intelligent system (HBIS) based on a novel developmental methodology, called the design science research methodology (DSRM). The major challenges to implementation included the diversity of the data sources, the diversity of objectives for which reports were generated, and the need to conform to health insurance administration policy and other quality requirements from three managerial dimensions - NHI, hospital accreditation, and healthcare quality. The HBIS system provides a rich environment to promote the improvement of management capabilities for critical healthcare issues, with the long-term goal of monitoring and improving the effectiveness of decision-making processes using BI tools.

3.3. Design and development

Fig. 1 illustrates the HBIS system architecture, which consists mainly of internal and external data sources and a three-tier structure: data warehouse server, OLAP server, and front-end tools. The system was developed using Oracle 8i database; Windows 2008 Server; SQL Server 2005; Analyzer 2005; Extract, Transform and Load data (ETL); OLAP multidimensional design tools; and Microsoft Excel.

For decision-making, hospital management required access to data retrieved from a variety of internal databases including HIS (Oracle), patient safety reports (MS SQL), and physicians' profiles, along with external databases including NHI, JCTHA, TQIP (Taiwan Quality Indicator Project), and THIS (Taiwan Healthcare Indicator Systems) (Excel).

Given these diverse data sources, Hospital Y established a three-tier structure as proposed by Strum (2000). In the first tier, the data warehouse layer provides access to data hosted within the boundaries of the system, along with data exposed by other networked systems and accessed through different data sources. This layer exposes generic interfaces that can be used by the components in the OLAP server layer. Hospital Y used SQL server Integration Services tools to import ETL into the data warehouse from databases for health insurance information, hospital accreditations, and medical quality indicators (Bala, Venkatesh, Venkatraman, Bates, & Brown, 2009). For example, the hospital conducted ETL procedures to gather differently formatted information from several sources into the SQL server data warehouse, using indicator rules and dimension tables as shown in Fig. 1.

In the second tier, the OLAP server layer implements the system's core functionality, and encapsulates the relevant analysis logic. Some of the OLAP server layer's components may provide service interfaces for other users. Given that the data warehouse does not store historical transaction data, aggregate information was calculated prior to storage in the data cube to provide query efficiency (Tremblay et al., 2012). Furthermore, OLAP tools enable

Table 1
DSRM activities.

Activities	Description
Problem identification and motivation	Define the specific research problem and justify the value of a solution.
Define solution objectives	Infer the solution objectives from the problem definition and the determination of what is feasible.
Design and development	Create the artifact. Such artifacts are potentially constructs, models, methods, or instantiations.
Demonstration	Demonstrate the use of the artifact to solve one or more instances of the problem.
Evaluation	Observe and measure how well the artifact supports a solution to the problem.
Communication	Where appropriate, communicate the problem's importance, the artifact's utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences such as practicing professionals.

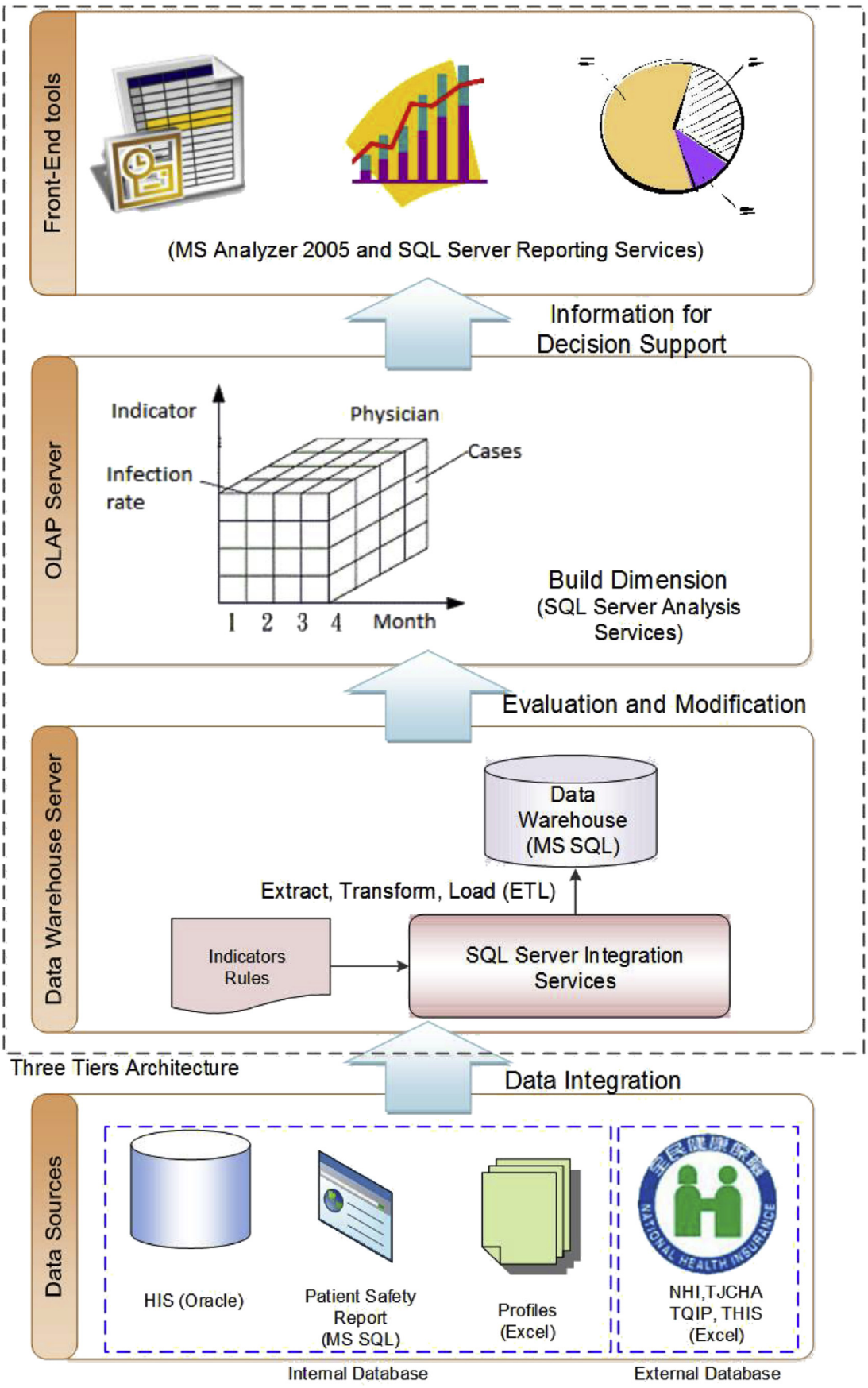

Fig. 1. HBIS system architecture.

users to analyze multidimensional data interactivity from multiple perspectives. OLAP consists of three basic analytical operations: roll-up, drill-down, and slicing. For example, through the implemented system all physicians can access monthly information for infection rate trends through the roll-up function, as shown in Fig. 1.

Finally, in the third tier, Hospital Y developed front-end tools to maximize usability. Analysis tools and SQL Server Reporting Services were applied to monitor indicators and graph the multi-patterns of reports for decision making. The user interface of the healthcare administration indicator support system was designed to clearly present graphs and tables, assisting users within the hospital in presenting and reporting the results of queries in a flexible viewing format. For example, analytic methods include rotation, dicing, and roll up and down of the data cube. In addition, discrepancies in data combinations are highlighted to instantly alert users of abnormal indicators and suggest steps needed to correct them.

3.4. Demonstration

This section presents some selected snapshots to illustrate HBIS functionality, including the data warehouse and its entities, query creation, indicator monitoring, slicing analysis, roll-up and drill down queries, and indicator trend distributions. Fig. 2 shows the data warehouse constructed the relationships between dimension tables and fact tables. This structure allows for the collection of specified information to satisfy management queries, and the integrated database provides the specified information to the OLAP service layer for analysis.

Fig. 3 presents the flexibility functions by which users create need-specific queries. Users choose the dimensions and attributes, and drag these into the pivot report. For example, the user can drag the accounting item for a particular physician into the filter area, and then drag the peer weight average into the attributes area.

Fig. 4 provides the indicator pivot report to assist users in their decision making. For example, the results highlight the difference between the actual and target performance of each physician, information which can be used in performance reviews. Fig. 5 shows how the slicing function provides a cross sectional visualization of distributions over various time frames to allow for performance comparisons among various individual physicians. Moreover, the pivot report provides the data cube function to roll-up or drill-down in specific dimensions to create different views. This allows for easy comprehension of the variability of dimension and attribute changes or trends required by different managers (e.g., by year or by physician) and allows for the convenient comparison of attributes to provide rich information, as shown in Fig. 6.

Fig. 7 presents tables and graphs of indicator trend distributions to assist decision making, supporting the automatic or manual setting of standards for indicators to provide flexibility for a range of managerial requirements.

3.5. Evaluation

System implementation was followed by usability testing. The International Organization for Standardization (ISO) defines usability testing as an assessment of the degree to which a user can

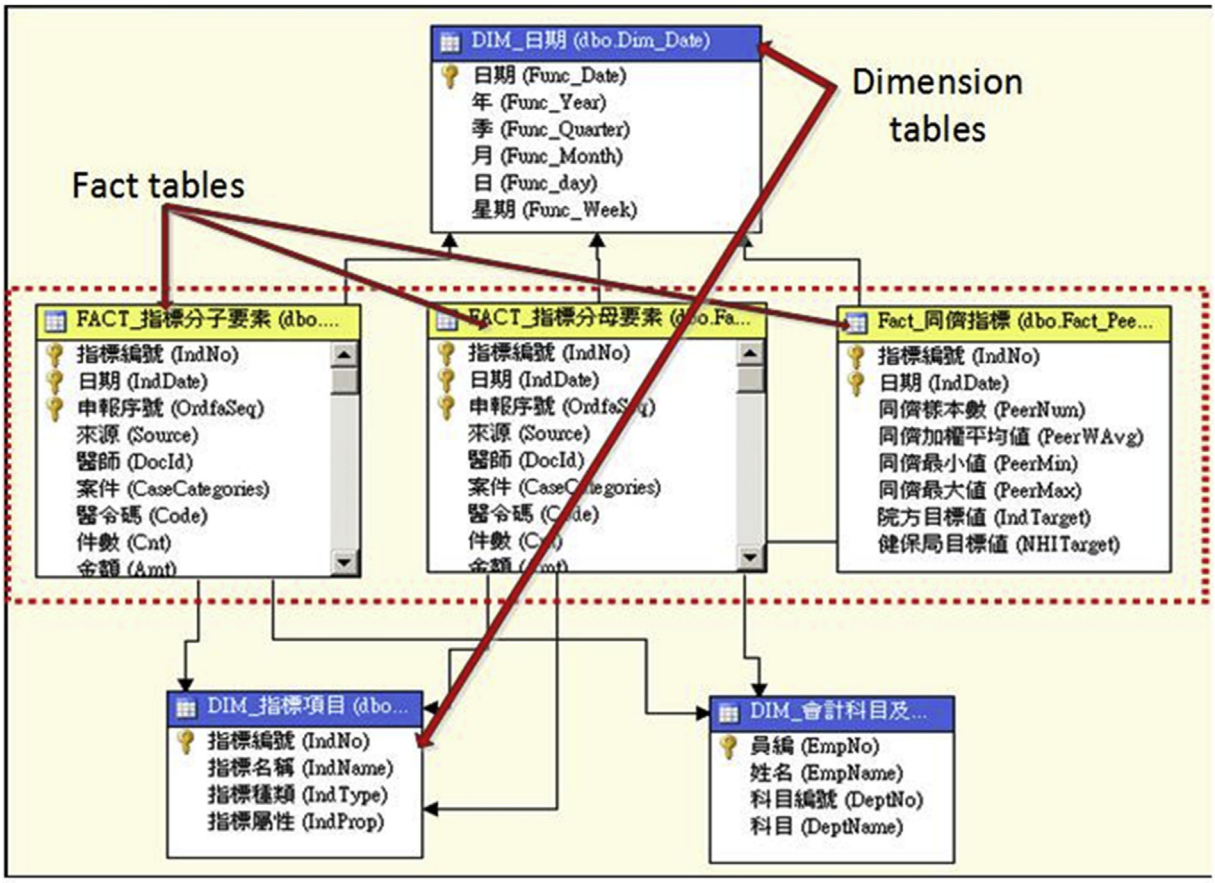

Fig. 2. Data warehouse and its entities.

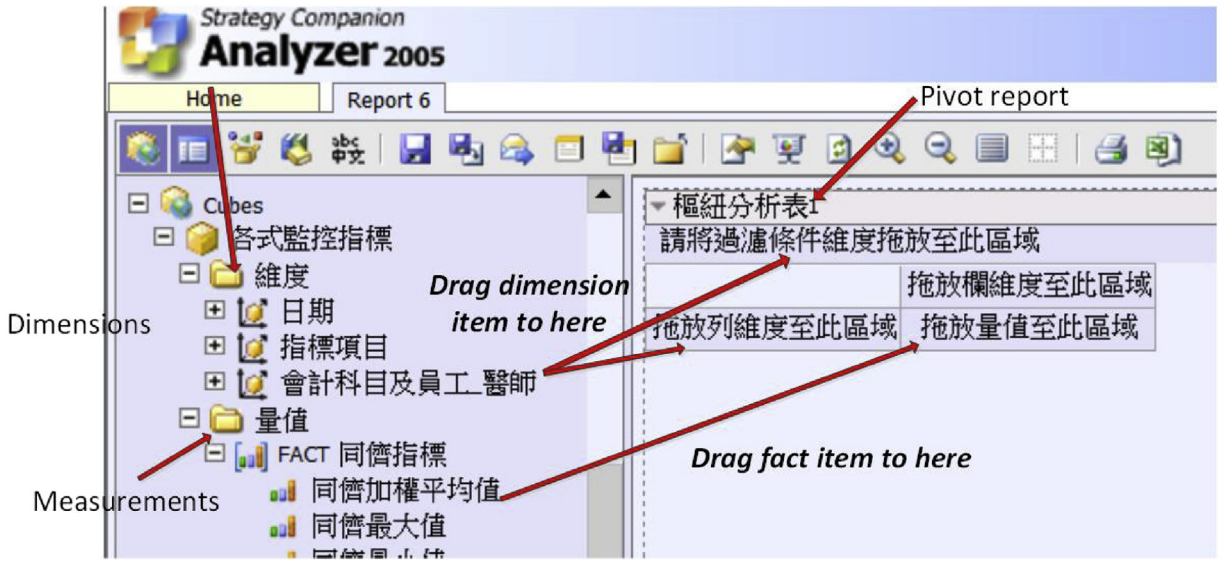

Fig. 3. Query creation.

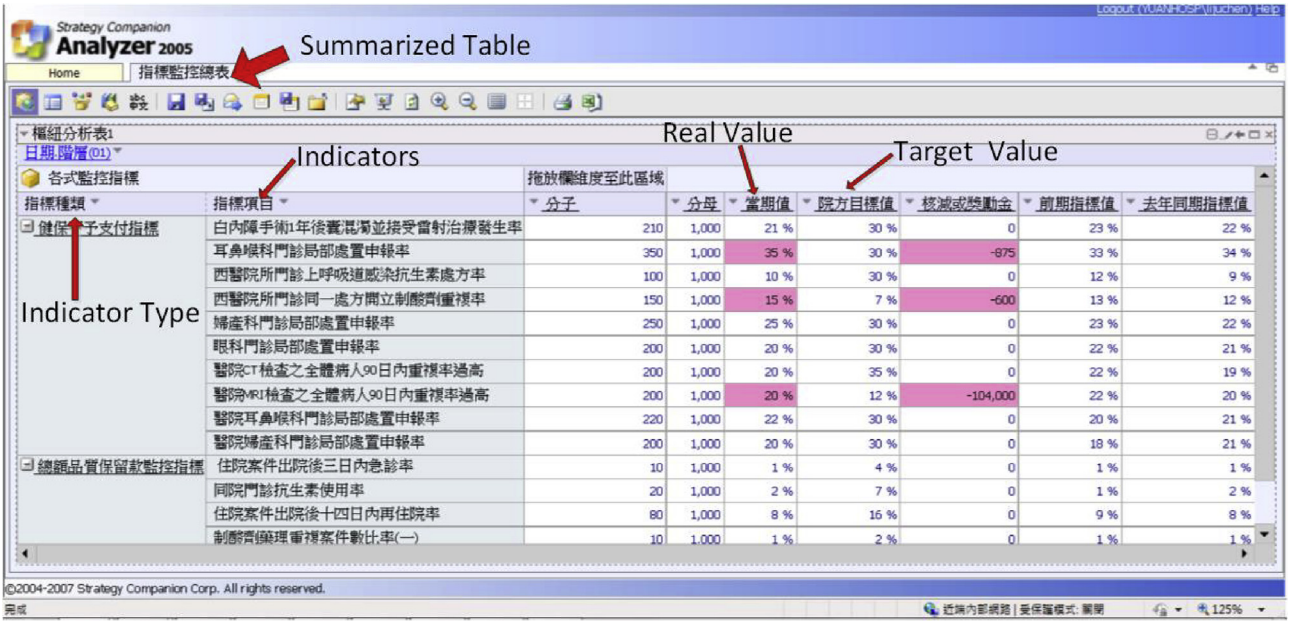

Fig. 4. Indicator monitoring.

use the product in a specified context to achieve the objective of use, and covers efficacy, effectiveness, and satisfaction. The objective of usability testing is to explore the strengths and weaknesses of the application, and to improve usability. This study adopted the Post-Study System Usability Questionnaire (PSSUQ) proposed by Lewis (1995) to assess the usability and satisfaction for information system use (Lewis, 1995). The contents of PSSUQ were constructed to measure to usefulness, ease of learning, information quality, and interface quality, with the evaluation constructs listed in Table 2. The PSSUQ survey was used to obtain feedback from users who had completed the specific tasks. The questions were answered using a scale from 1 to 7 (1 – Strongly Disagree to 7 – Strongly Agree).

Usability testing reflects the five constructs of system usefulness, ease of learning, information quality, interface quality, and overall satisfaction. HBIS was found to assist users in collecting and monitoring indicators, thus increasing work efficiency. The results show a clear need to collect and integrate data across different departments. For example, using report patterns with HBIS, HIS was able to provide the Division of Health Affairs with a complete set of data sufficient for effective analysis whereas, previously, a complete data set would have to be sourced from multiple departments. The results also indicate that ease of use and interface usability are critical factors in improving work efficiency and streamlining the debugging process.

3.6. Communication

Research on BI system development has been published in journals including the Journal of the American Medical Informatics Association (i.e., Ferranti et al., 2010) and the authors of the present

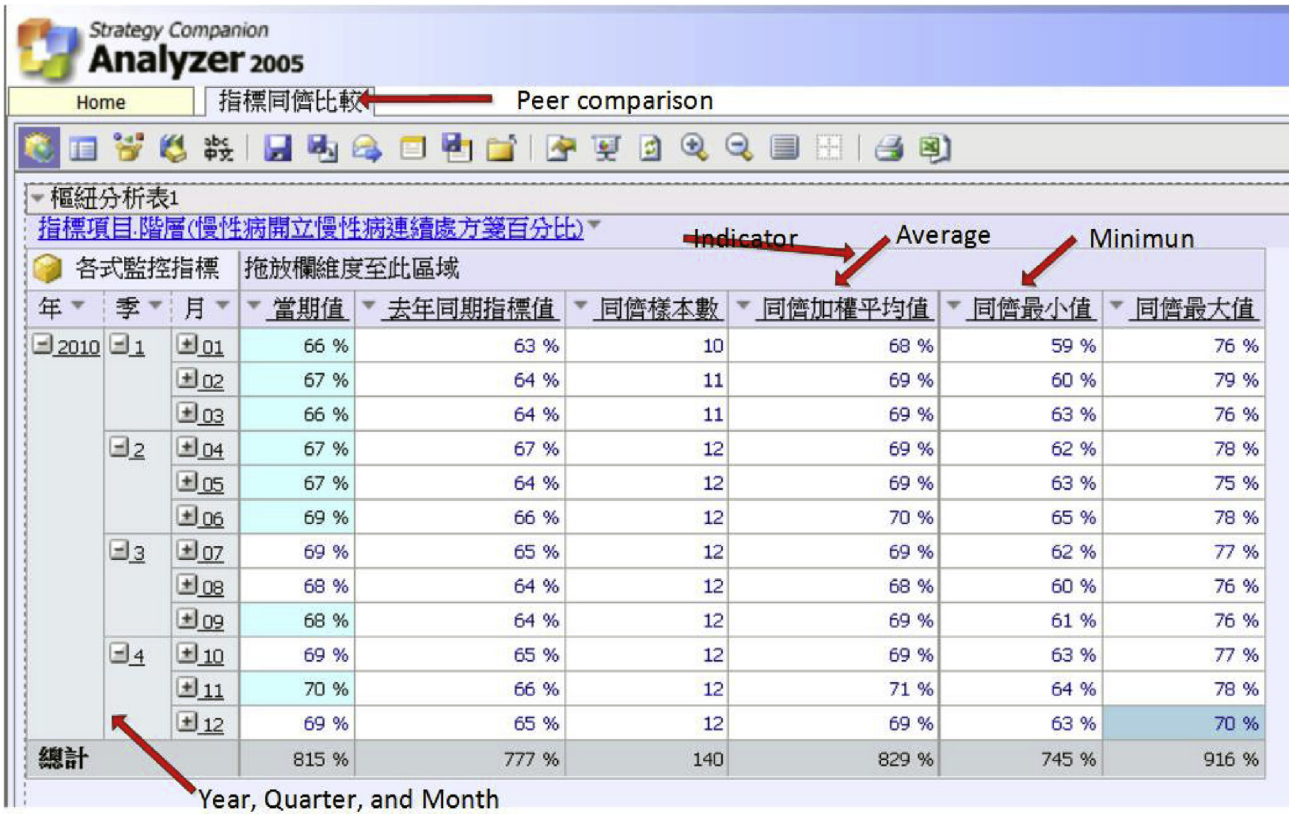

Fig. 5. Slicing analysis.

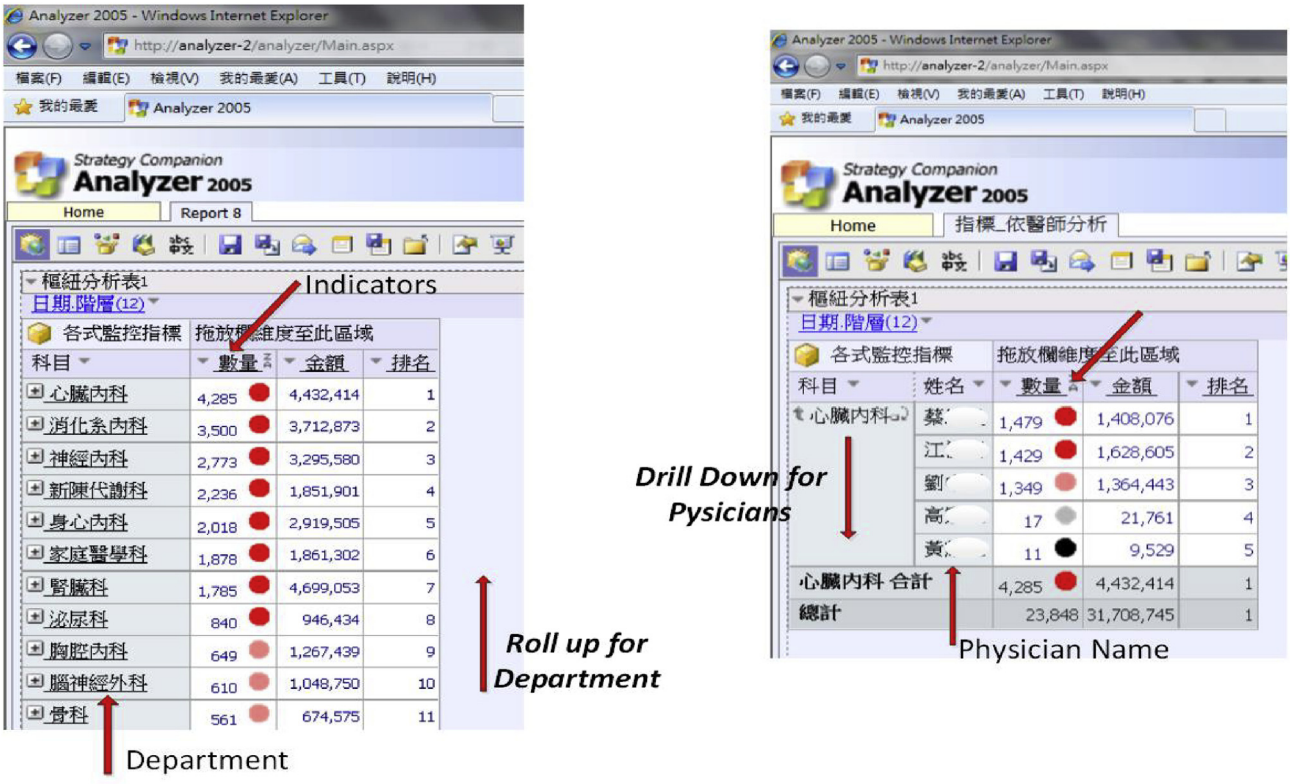

Fig. 6. Roll-up and drill-down queries.

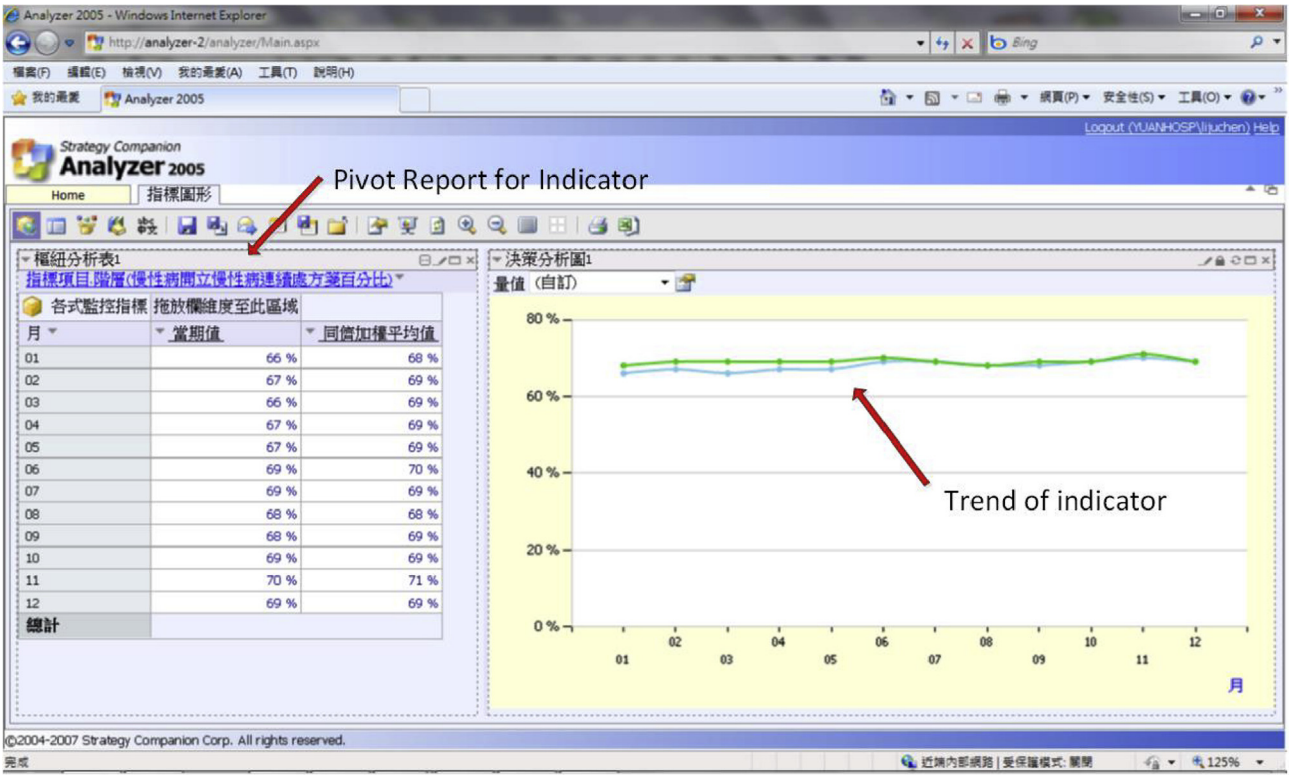

Fig. 7. Indicator trend distribution.

Table 2
PSSUQ measurement items and results.

Item	Measurement	Results	Construct
1	The system is easy to use.	5.2 ± 1.23	System usefulness
2	The system helps me complete my work efficiently	5.7 ± 1.45	5.63 ± 1.78
3	The system helps me complete my work quickly.	5.8 ± 1.34	
4	The system helps me complete my work effectively.	5.8 ± 1.42	
5	It is easy to learn how to operate the system.	5.4 ± 1.13	Ease of learning
6	I believe I have learned how to operate the system.	5.8 ± 1.71	5.60 ± 1.51
7	The system provides appropriate error messages and clear instructions of how to address errors.	4.2 ± 1.84	Information quality
8	It is easy to find the information I need.	5.0 ± 1.25	5.01 ± 1.35
9	The system provides easily understood information.	5.1 ± 1.12	
10	The system provides information that helps me finish projects effectively.	5.7 ± 1.17	
11	The system interface is easy to use.	5.5 ± 1.33	Interface quality
12	I like to use the system interface.	5.4 ± 1.45	5.45 ± 1.37
13	The system had all expected functions and abilities.	5.5 ± 1.52	Overall satisfaction
14	Overall, the system is easy to use.	5.5 ± 1.58	5.5 ± 1.62
15	Overall, I am satisfied with the system.	5.4 ± 1.74	

work presented academic conference proceedings on the subject at Medical Informatics in Europe (MIE) 2012. The current manuscript is based on that presentation, with revisions based on reviewers' comments for submission to journals such as International Journal of Medical Informatics. From a practical standpoint, the HBIS case of Hospital Y presents insight into best practices and provides a source of valuable experience for other hospitals.

4. Discussion

From the academic perspective, the BI implementation assessment goes beyond a review of the technology infrastructure to include an understanding of governance, policy, culture, and business processes. It is not uncommon for organizations to assume that successful BI application only entails the efficient generation of accurate and visually appealing reports. However, BI implementation entails many other elements that must be taken into consideration, including business processes, organizational culture, people, resources, technology, and the organizational environment (Brooks, El-Gayar, & Sarnikar, 2015). From the perspective of information system research, several studies have focused on understanding the role of business intelligence systems within organizations (Shollo & Galliers, 2015) to conduct causality analysis and corporate diagnoses (Wang, 2016), the use of BI systems in electronic commerce, blogs, and social media to create significant opportunities for both academic research and business applications (Chau & Xu, 2012), or behavior and attitude issues raised in BI implementation (Deng & Chi, 2012; Li et al., 2013). Several studies on Business Intelligence Research focused on the potential of IS to better serve the needs of business decision makers in light of

maturing and emerging BI technologies, ubiquitous Big Data, and the increasing demand for data-savvy managers and business professionals with deep analytical skills (Chen et al., 2012). While these studies propose additional benefits from BI system development and deployment from a range of viewpoints, their findings fail to provide a holistic view or appropriate methodologies for the construction and assessment of BI systems, leaving a significant research gap in the healthcare domain.

BI systems are designed to support information evidence-based decision making (Foshay & Kuziemsky, 2014); promote the integration of emerging technologies to improve service quality, reduce costs, and manage risks (Zheng et al., 2014); improve patient care and outcomes (Tremblay et al., 2012); and improve process efficiency (Flower, 2006; Pine et al., 2012). Other studies have discussed the implementation of commercial software (e.g. SAP) in healthcare (Ivan & Velicanu, 2015), provided design steps for domain-specific BI maturity model development (Brooks et al., 2015), or explored knowledge discovery techniques based on large datasets to better manage both quality of care and spending (Spruit et al., 2014). 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 et al., 2014). Several studies have addressed the application of BI systems in healthcare contexts, but fail to present an overall discussion of the entire process from design through deployment to assessment. For example, how can emerging BI technologies continue to meet the needs of healthcare administrators, while also providing healthcare professionals with new analytical skills? A new vision for BI may be needed to address this and other questions (Chau & Xu, 2012; Chen et al., 2012). For these reasons, we extend these research results and conducted a case study to represent the entire process through the application of design science and novel assessment methods (e.g., usability testing). Hence, this explorative research also provides an example for the design and construction of BI systems which meet administrators' needs through methodology-based perspectives. The findings of this research should lead to a the development of a design science base approach which can help researchers successfully deploy DSRM methodology and advance related studies in healthcare domain.

From the practical viewpoints of healthcare administration, we have demonstrated how BI techniques and tools can be used in non-traditional areas of the health care environment to allow administrators to make informed decisions to improve resource allocation and quality of patient care. The multidimensional cube allows for data analysis from several dimensions and reports are generated within seconds. The data can be kept up to date year round while preserving data integrity during interim reporting. To gain further insight into the usability testing results, we conducted post-use interviews with 5 respondents, including the hospital's vice-superintendent, CIO, director, and other staff, each of whom have over 10 years of decision making experience. Moreover, we modified the concepts of the MIT 90 Model to understand the influences of BI adoption. The MIT90s framework was developed by Morton as part of the “MIT90s” initiative at MIT in the early 1990s (Hayter, Chisholm, & Cross, 2004; Morton, 1991). In addition, the MIT 90 Model seeks to account for all vital areas to ensure enterprise success: technology, individual/role, structure, management process, and strategy.

Our study addresses major findings based on the post-interview results as below.

4.1. Organization and people

Business intelligence can help organizations improve efficiency in managing information for decision making. BI is more than simply a technology, and entails understanding the interaction of key institutions, technologies, and people within an organization. Respondents in this study indicated stressed that responsibly allocating scarce healthcare resources requires them to identify sources of efficiency or tools that can contribute to improved outcomes. In the health sector, managers and users need real-time information to better manage data, and to generate the information and knowledge to improve healthcare service quality and diminish risks. This study's findings clearly indicate that organizational decision processes are significantly compromised by a lack of quality information. The implementation of effective BI systems could potentially deliver significant and tangible improvements. Hence, we suggest that organizations must establish unified information sources to provide top management team (TMT) members or employees with accurate, timely data. This unified data source can not only help prevent inconsistent cost/benefit calculations between departments, but can also help the TMT conduct effective impact analysis. Therefore, organizations need to continuously collect successful and unsuccessful case studies and share the experience derived from these cases with employees along with knowledge of experienced healthcare professionals.

4.2. Process and task

In the context of BI, processes can be seen as primary triggers for information and data collection, processing and distribution and are therefore very important. The healthcare industry relies on multiple data sources to support the diagnosis, treatment and prevention of disease, illness, and injury, as well as the operation of healthcare service providers and organizations. Healthcare data includes patient information, clinical data, financial data, medical knowledge, and operational data (Groves, Kayyali, Knott, & Van Kuiken, 2013). Healthcare data is typically characterized by fragmented data sources, data complexity (Zheng et al., 2014), levels of regulation, and the potential impact on a patient's health and life.

4.3. Information system

In the context of BI, technology can be seen as enabling the storage, analysis, visualization, and access to a great amount of data. To these ends, BI systems employ a wide range of expert systems, OLAP and data mining tools. The BI system can not only monitor the quality of care delivery, but also can provide statistical data on healthcare management and strategies, reflecting concerns raised in the post-implementation interview. Therefore, we recommend that organizations increase resources devoted to data integration, providing staff with easily accessible tools and accurate information to ensure the quality of this key unified data source. Hence, we suggest that healthcare organizations should reengineer their care processes, adjusting existing operational models to increase process effectiveness. BI systems can also archive important decision making data for TMT. The Information Systems Success Model is derived from information systems (IS) theory to provide a comprehensive understanding of IS success through the identification, description, and explanation of the relationships among the most critical success factors along which information systems are commonly evaluated (Delone & McLean, 2003). Finally, organizations should consider integrating other internal information systems (e.g., hospital information systems or reimbursement systems) to increase management effectiveness.

In sum, the adoption of thoughtful and effective analytic

approaches allows hospital administrators to capitalize upon existing data stores to improve operating efficiency, clinical quality, and financial effectiveness. Ferranti et al. (2010) suggested that BI can comprise an integrated array of IT tools allowing users to transform data into informed actions. Also, BI tools can help users better understand complex processes and relationships by means of easily assimilated, customized visual reports, thus improving the timeliness and correctness of management decisions, enhancing organizational performance, and providing improved understanding of the holistic impact of management actions on the organization as a whole.

5. Conclusions and implications

This study reports the development and assessment of an HBIS system based on DSRM methodology in a regional hospital in Taiwan. Top management support and involvement is found to be a critical success factor to the development of HBIS, which is consistent with previous studies (Ragu-Nathan, Apigian, Ragu-Nathan, & Tu, 2004) in IS. By highlighting several applications such as e-commerce, market intelligence, e-government, healthcare, and security, and by mapping important facets of the current BI knowledge landscape, we hope to contribute to current discussions on the importance of academic research in this field (Chen et al., 2012). The system integrates and provides easy access to medical management indicators, allowing administrators and practitioners to improve the correctness and timeliness of remedial actions, thus reducing problems and increasing overall efficiency.

The hospital case presented here addresses two key issues. Firstly, the hospital is actively investing in health analytics, data integration, and data sharing for HBIS. Secondly, this case adopted a novel developmental approach, DSRM for data visualization and analysis for HBIS, allowing top management to continuously monitor variations in medical managerial indicators. More importantly, the HBIS not only supports the improvement of patient safety and financial effectiveness (Ferranti et al., 2010), but also integrates indicators from three key managerial dimensions - NHI, hospital accreditation, and healthcare quality. Future work may apply these insights to the contexts of other national health systems.

Finally, the appropriate deployment and application of BI health analytics tools can improve decision-making by hospital and health system administrators, thus maximizing the value of clinical and administrative data. In particular, this study contributes a novel developmental methodology from the field of IS as a reference model for medical informatics field. The six activities in the proposed methodology (DSRM) provide a good guideline for future HIS development.

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