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How business intelligence maturity enabling hospital agility

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ABSTRACT

Executives of information officers polled agree that rapid and accurate decision-making are essential to organizational agility and data plays an important role in decision making process. With Advanced information technologies, collecting data can be ubiquitously. However, the current volume of data accumulated in hospitals has exceeded the capacity of their medical information systems, not to mention using the data to make decisions. Hospitals started to employ business intelligence systems (BIS) to extract correct, timely, and useful information for hospital decision-makers. Most studies in the area focus on the establishment and related benefits of BIS. This research aims to evaluate the BIS maturity and its influences on decision quality to reveal the BIS impacts on hospital agility. To test the research model, opinions were collected by distributing questionnaires to clinical and administrative decision-makers who had experiences of using BIS in hospitals. The results showed that medical information quality was significantly influenced by BIS maturity. Furthermore, medical information quality exerted a significant effect on medical decision quality, BIS usage, and user satisfaction. The positive influence of user satisfaction on medical decision quality is also verified.

1. Introduction

With the adoption of advanced medical information technology, such as mobile devices or wearable connected devices to tract detailed vital signs of patients, hospitals are producing clinical and administrative "Big Data" (Brooks et al., 2015). The volume of information accumulated in hospitals has exceeded the processing capacity of their medical information systems; additionally, this information comes from different sources and in different formats, which increase the difficulty for hospital decision-makers to extract useful information (Cynthia McKinney et al., 2012). Executives of information officers polled agree that rapid and accurate decision-making are essential to organizational agility (Reid, 2015). Mach and Salem (2010) and Olszak and Batko (2012) pointed out that by employing a business intelligence systems (BIS) to process medical big data, hospital policy-makers can improve their administrative efficiency and make better decisions. Most of the related studies in the medical field have focused on the benefits and system construction of BIS, and some have paid attention to BIC level of maturity and impacts on decision quality.

After the implementation of the national healthcare insurance (NHI), only accredited hospitals would receive proper insurance reimbursements. There are 271 quality indicators regarding acute and chronic care, patient safety, and operating

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management performance suggested as the Taiwan Healthcare Indicator Series. To name a few, the clinical indicators include patients' survival rate, falls rate, and infection rate while administrating indicators include insurance reimbursement report, and service volume of in- and out-patients. Many hospitals assure their medical quality by meeting the indicators standards of accreditation. Physicians, nurses, technical staff and administrators are responsible for maintaining the indicators related to their profession which is time-consuming and requires efforts. The BIS can help them trace the indicators periodically and drill down the root causes of sentinel event.

Popovič et al. (2012) and Popovič et al. (2009) indicate that whether a BIS can provide good-quality information depends on the level of BIS maturity matters. Caniëls and Bakens (2012) concluded that good-quality information will further influence the quality of decisions made by policy-makers. The aforementioned studies are done in business area, few studies in the medical field have focused on BIC maturity and impacts. Therefore, this study constructs a research model to investigate the impacts of BIS on medical decision quality. Meanwhile, acceptance of technology is a key factor to system success, therefore this study adds users' satisfaction, and usage of BIS to further examine the influences of acceptance to technology on decision quality.

2. Theoretical background

Elbashir et al. (2008) proposed that a BIS is a specialized tool for data analysis, which can assist managerial personnel in decision-making needed in a wide range of business activities. Watson (2009) believes that business intelligence includes application, storage, process collection, techniques, interviews, and data analysis to help corporations make better decisions. In this study, BIS is regarded as a modern information technology, which extracts, integrates, and analyzes the timely and useful information internal and external to organizations, while also creating and accumulating user knowledge and insights in order to help them make accurate judgment.

Hribar Rajterič (2010) measured BIS maturity from the perspective of organizational culture which is based on management and focuses on transforming the methods of information use. BIS maturity within an organization can be defined as the capacity of an organization to provide quality information and enhance organization performance through this system. In other words, evaluating BIS maturity is evaluating the quality and level of application of a BIS within an organization (Popovič et al., 2012). Raber et al. (2013) also pointed out an direct way to measure BIS maturity is to evaluate the corresponding level or scale of the organization's that applies BIS. Lahrmann et al. (2011) summarized that different orientations of measuring BIS maturity leads to different impact orientation. In this study, Hribar Rajterič's (2010) measurement of BIS maturity is used.

Information quality has constantly been a topic discussed by scholars and experts in the information systems area. DeLone and McLean (1992) suggested that information quality represents the quality of the output from the information system in the form of reports or on-screen data and can be evaluated by the users. The most obvious benefit of implementing a BIS is improved information quality within the organization (Watson et al., 2002). Popovič et al. (2012) and Popovič et al. (2009) indicate that BIS maturity can affect the information quality of system output. Therefore, this study infers that a higher level of BIS maturity will lead to better medical information quality produced by the system.

After an information system is constructed, the benefits of the system fall into two categories: economic benefits and personal benefits (Galletta and Lederer, 1989). The economic benefit is mainly expressed as cost-savings brought by the higher operation efficacy, or better compliance, safety and security of the information system. The personal benefits focus on the users' satisfaction and system utilization. The economic benefit can be high or low only if the users accepted and used the system. Therefore, this study focused on the personal benefits. Previous studies discovered that user satisfaction is positively associated with medical information quality produced by medical information systems (Yusof et al., 2008; Park et al., 2010) and poor information output leads to user dissatisfaction with the system and further cause information system failure (Xu et al., 2003). Meanwhile, higher user satisfaction will lead to greater reliance on the information system. Therefore, this study infers that when better information quality is provided by BIS in a hospital, who use the BIS are likely to have higher levels of satisfaction and usage.

Borchers (2005) defines decision quality as a unique result of decision science of organizational values, goals, belief systems, ethics, and law. Decision quality can also be viewed as the capacity to optimize decisions, in other words, the capacity of a decision-maker to select the most appropriate solution to a problem among a variety of options (Decker, 1998). Caniëls and Bakens (2012) defined decision quality as whether the decision-maker believes that the decision quality has increased or decreased the amount of decision time needed. In addition, decision quality can be measured by the gap between the decision that has been made and the optimal decision (Gonzalez and Kasper, 1997; Jarvenpaa, 1989; Kaiser et al., 1992). In a group decision, higher decision quality is required, though this often consumes too much decision time and ignores decision efficiency. Given the impossibility of accomplishing two conflicting goals simultaneously, decision-makers often have to make a choice between "decision quality" and "decision efficiency". Therefore, executives of information officers polled agree that rapid and accurate decision-making are essential to organizational agility

3. Research methods

Based on the aforementioned literature research, the research model is shown in Diagram 1 and the associated hypotheses are developed as follows:

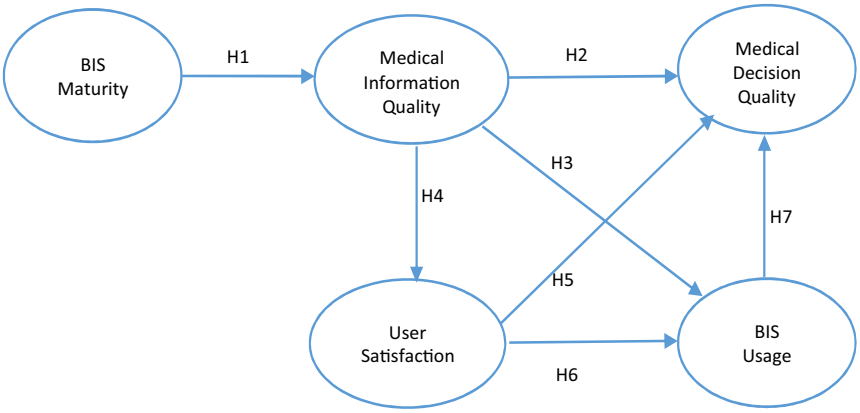

Diagram 1. Research model. H1: Business intelligence system maturity is positively related to medical information quality. H2: Medical information quality is positively related to medical decision quality. H3: Medical information quality is positively related to business intelligence system use. H4: Medical information quality is positively related to user satisfaction. H5: User satisfaction is positively related to medical decision quality. H6: User satisfaction is positively related to business intelligence system use. H7: Business intelligence system use is positively related to medical decision quality.

The definitions of variables: BIS maturity, medical information quality, user satisfaction, BIS use, and medical decision quality are listed in Appendix Table A1.

This study referred to previous scales with good reliability and validity, which were developed by Popovič et al. (2012), Moores (2012), Leea et al. (2002), Doll and Torkzadeh (1988), Caniëls and Bakens (2012), Wua and Wang (2006), and Hou (2012). Modifications were made according to the hospital scenario, and structured questionnaires were used for the survey.

The questionnaire is comprised of two parts. The first part contains the current status of BIS in hospitals and the basic information of respondents, such as age, gender, education, years of employment, and job title are included. The current status of the hospital BIS are obtained from respondents through their knowledge of BIS development and implementation. The second part contains the main research items. A Likert scale ranging from one to five, representing "strongly disagree" to "strongly agree" respectively, was used. A list of hospitals adopting BIS was obtained through a brief telephone interview. For those hospitals that was willing to participate the survey, a key person was selected to distribute and collect the questionnaires. The questionnaires were sent out during April to June 2015 and targeted at both the clinical and administrative decision-makers who use BIS in their daily work. An incentive was provided to promote the responding rate.

4. Data analysis

Two-hundred and fifty-five copies of questionnaires were delivered to 17 hospitals that were willing to participate the survey. After deleting incomplete and invalid questionnaires and excluding outliers using the outlier test of SPSS 20, the final number of valid questionnaires for the study was 158. The valid response rate was 61.96%. The majority of respondents are aged 31–40 years old (50.6%), female (58.9%), with bachelors and post-graduate research degrees (90.5%), have job titles as administrative personnel (51.3%), and work in job levels of department director and department supervisor/section chief (50%). For methods used in constructing the system, purchasing suite software ranked first with 52.2% and Microsoft/Analyzer was the most frequently purchased software. The self-development BIS accounted for 32.3% of the sample. The details of basic information are shown Table 1.

Our survey respondents include physicians, nurses, technical staff and administrators, therefore, the results of this study can be applied to most of the decision makers in hospital using BIS to assure the quality and meet stands of hospital accreditation.

The validity analysis of measurement scales was performed using SmartPLS version 2.0 M3. A full measurement model assessment was executed in order to test validities of all constructs in the model. The criterion for factor loading was greater than 0.6; If the construct item did not meet the criteria, it was removed from the model. This was done to achieve the best model fit. In our study, removing items with factor loading less than 0.6. Table 2 indicates that the factor loading of all the items was 0.6 or above. The composite reliability (CR) of each dimension was also above 0.7. The average variance extracted (AVE) also reached the critical value of 0.5. In summary, the measurement scales had good convergent validity. Meanwhile, the Cronbach's α values of measurement scale are greater than 0.6 represent reasonable reliability.

Discriminant validity is demonstrated by comparing the square root of the AVE to the correlations with other latent variables and CR. If the diagonal values are greater than any other correlation and CR is equal or higher than 0.7, then this establishes adequate discriminant validity. In Table 3, the value of the square root of AVE for each construct is higher than the other shared variance with another latent variable, meaning that all constructs are valid.

Table 1
Basic information of respondents and their hospital BIS.

Items	Class	Frequency	%	Accumulated %
Age	30 years and below	19	12.0	12.0
	31–40	80	50.6	62.7
	41–50	45	28.5	91.1
	51–60	14	8.9	100.0
Gender	Male	65	41.1	41.1
	Female	93	58.9	100.0
Education	High school	4	2.5	2.5
	Junior college	11	7.0	9.5
	College	81	51.3	60.8
	Graduate	62	39.2	100.0
Job title	Physician	6	3.8	3.8
	Nurse	36	22.8	26.6
	Technician	35	22.2	48.7
	Administration	81	51.3	100.0
Job level	Director	38	24.1	24.1
	Section leader	41	25.9	50.0
	General officer	79	50.0	100.0
Year of work experience	5 years and below	34	21.5	21.5
	5–10 years	43	27.2	48.7
	10–15 years	36	22.8	71.5
	15–20 years	23	14.6	86.1
	20 years and above	22	13.9	100.0
BIS development	Self-developed	52	32.3	32.3
	Outsource	20	12.4	44.7
	On-shelf software	84	52.2	96.9
	Others	5	3.1	100.0
BIS vendor	SAP/Business Objects	2	1.2	1.2
	SAS/Business Intelligence	20	11.6	12.8
	IBM/Cognos	19	11.0	23.8
	IBM/SPSS Statistics	19	11.0	34.9
	Oracle/Hyperion	39	22.7	57.6
	Microsoft Analyzer	50	29.1	86.6
	V-Point (Business Objects)	3	1.7	88.4
	Others	20	11.6	100.0

Table 2
Reliability and validity analysis.

Constructs	Loading	CR	AVE	Cronbach's α
Business intelligence maturity	0.60–0.84	0.80	0.50	0.67
Information quality	0.65–0.76	0.82	0.53	0.68
User satisfaction	0.77–0.81	0.87	0.63	0.70
Use business intelligence system	0.95–0.97	0.96	0.93	0.80
Decision quality	0.60–0.79	0.81	0.52	0.92

Table 3
Correlations between the latent variables and square roots of the average variance extracted.

	BIS maturity	Decision quality	Information quality	User satisfaction	BIS usage
BIS maturity	**0.7100**				
Decision quality	0.494713	**0.7178**			
Information quality	0.439632	0.514505	**0.7253**		
User satisfaction	0.302107	0.533921	0.482195	**0.7922**	
BIS usage	0.220576	0.437451	0.161656	0.341927	**0.9633**

Bold values represent the value of the square root of AVE for each construct.

5. Results

The PLS technique was used to conduct the data analysis for this research study. Compared to the SEM technique, PLS can handle formative constructs and does not require the normality and independence assumptions (Chin and Newsted, 1999). The software used is SmartPLS 2.0 (Ringle et al., 2005). The quality of the structural model was evaluated based on R-squared

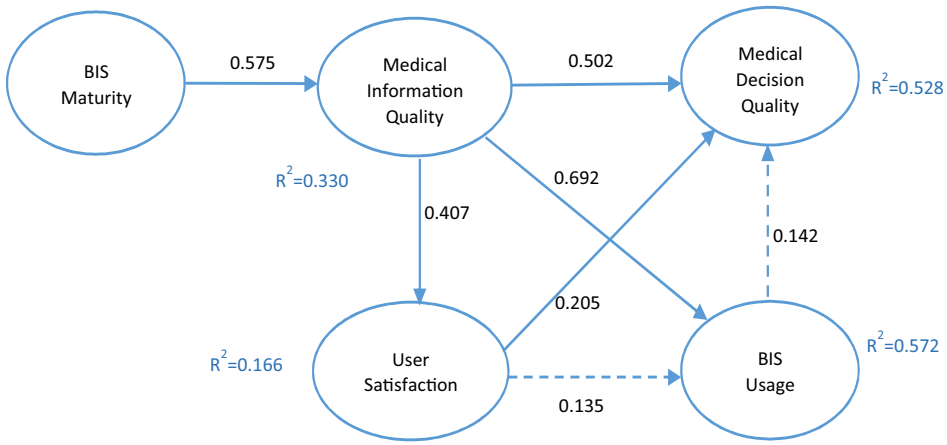

Diagram 2. Results of research model.

Table 4
Detail results of research model.

Hy	Relation	β	t statistics	P values	Results
H1	BIS maturity → MIQ	0.575	7.554	0.000	Support
H2	MIQ → Medical decision Q	0.502	4.269	0.000	Support
H3	MIQ → BIS usage	0.692	11.034	0.000	Support
H4	MIQ → User satisfaction	0.407	4.271	0.000	Support
H5	User satisfaction → Medical decision Q	0.205	2.564	0.01	Support
H6	User satisfaction → BIS usage	0.135	1.775	0.076	Not support
H7	BIS usage → Medical decision Q	0.142	1.075	0.283	Not support

MIQ: Medical Information Quality, Q: Quality, BIS: Business Intelligent System.

and redundancy. Structural paths were evaluated to test the relationship of research hypotheses. The R-squared values for the dependent variables indicate the percentage of variance in the dependent variable explained by the model. Diagram 2 shows the paths and their significance for model.

Medical information quality was significantly influenced by BIS maturity ($\beta = 0.575$, $p \leqslant 0.001$). The factor explained 33% of the variance in medical information quality. Accordingly, H1 is supported. Medical information quality exerted a significant effect on medical decision quality ($\beta = 0.502$, $p \leqslant 0.001$), BIS usage ($\beta = 0.692$, $p \leqslant 0.001$), and user satisfaction ($\beta = 0.407$, $p \leqslant 0.001$), thereby supporting H2 and H4. Based on the statistical results ($\beta = 0.205$, $p \leqslant 0.01$), the H5 is supported. In other words, the positive influence of user satisfaction on medical decision quality is verified. However, the user satisfaction exerted an insignificant effect on the BIS usage ($\beta = 0.135$, $p \leqslant 0.076$); therefore, H6 is not supported. The use of the BIS did not have a direct effect on the medical information quality ($\beta = 0.142$, $p = 0.283$); therefore, H7 is not supported either. The detailed results are showed in Table 4.

6. Discussions and conclusions

Five out of seven hypotheses were supported, except for H6 and H7. The finding of H6 indicates that regardless the high or low satisfaction of using BIS, the usages of BIS are the same. The finding of H7 indicates that regardless the high or low usage of BIS, the medical decision quality is the same. Further analysis and interpretation follow.

The significant effect of BIS maturity on information quality confirm the results of Popovič et al. (2012) and Popovič et al. (2009). The medical staff reveals that the degrees of data integration and analytics provided by BIS positively relate to the accuracy, timeless, completeness, relevancy of medical information quality. The results also confirm the conclusions of Elbashir et al. (2008), Werner and Abramson (2003) and Herschel and Jones (2005) that with accurate, timely, complete, relevant medical information produced by BIS, the users can improve decision quality effectively and efficiently. The results show when the medical information quality produced by the hospital's BIS is higher, the system's use increase significantly, which support the results by Popovič et al. (2012). Park et al. (2010) and Yusof et al. (2008) argued that high information quality would lead to high satisfaction of users with the system. The result of this study is consistent with these previous results.

DeLone and McLean (2003) argued that users' satisfaction is closely related to system usage. Yusof et al. (2008) also clarified that only when medical staff was significantly satisfied with medical information systems will their use frequency be above average. However, in this study the user satisfaction affected their BIS utilization insignificantly and the usage of BIS affected the medical decision quality insignificantly. After the process of data analysis, an informal interview was conducted. The interviewee is a vice-superintends in charge of assuring medical qualities of a hospital and also served as a committee member of the national hospital accreditation. It was discovered that the learning threshold for the BIS was higher than other statistical software. However, the decisions makers would use the BIS periodically to maintain the indicators they are responsible for. Therefore, whether their satisfaction levels are high or low have no impact on the usage of BIS. Meanwhile, the data used to make decisions are extracted from the Hospital Information Systems. The BIS calculates and analyzes the data to obtain needed information for decision makers. In other words, the decisions are rather structured, therefore using more or less of the BIS has no impact on the quality of medical decision for the time being.

Another possible reason was that different users use the BIS differently. For example, the majority of the respondents were administrator related staff and they use BIS to prepare accreditation documents weekly. The clinical staff may need to BIS daily for clinical decision support. Therefore, the insignificant relationships might need further investigation for different groups of users.

7. Research contributions

With hospital technologies capability migrate from wireless applications to internet of things, the collected information is growing exponentially and its strategic application is also becoming increasingly complicated. Good decision-making not only decreases the incidence of medical malpractice, but also contributes to the more comprehensive medical care of patients. After the implement of NHI, hospitals can no longer subjectively price their services and reason the treatment results. Furthermore, the Internet empowers patients to access more information to overcome the information asymmetry between patients and physicians. In other words, the competition in health industry reaches to a unprecedented peak. Meanwhile, the Taiwan superintendents are mostly doctors and need more decisions support to gain the competitive advantages for their organizations. Currently, using BIS is in the early stage to support structured decision making. Our study proves that the quality of decisions depends mainly on the quality of information largely. In later stages, the decision makers may move away from hospital accreditation to the unstructured decisions such as obtaining hospital-wide visibility on medical processes for further cost benefits analysis, coping with the continuous revolutions of the NHI payment system to enhance financial management, obtaining competitive strategies to offer preventive medical care, and managing global medical tourism. By then, the BIS can perform fully and help improve the hospital agility. Meanwhile, this study can help the government understand the BIS maturity of current hospitals in Taiwan and serve as a reference for policies makers to enhance medical decision plans.

7.1. Research limitations

Despite striving for rigor, this study has several limitations as follows. Firstly, the proposed research model and relevant hypotheses were derived from reviewing previous literature in business sector. The measurement items were based on translation of foreign literature and adjusted according to the research context. The model explained half of the variation of decision quality. In other words, other important medical related variables might be overlooked. Since the cost of establishing a BIS is high, more large-scale hospitals responded the questionnaire in this study. Additionally, there is a difference in the proportion of hospitals locations in terms of sampling. More hospitals in the northern part of Taiwan, metropolitan area, responded the questionnaire. Therefore, cautions are needed while applying the research results to other levels or locations of hospitals that have employed such systems.

BIS construct has been around in the business sector for years, but is only at a rudimentary stage in the medical sector. The majority of existing literature has mainly investigated BIS efficacy and design, paying less attention to its maturity and impacts. In response to the increasing applications for BIS in the medical field, more research is needed to further explore the factors of influencing BIS effects. This study proposed a research framework to analyze the impact of BIS maturity in hospitals on medical decision quality as enabler of hospital agility, which can serve as a reference for further studies in the research area.

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Appendix A

See Appendix Table A1.

Table A1
Research variables and their operational definitions.

Variable	Definition	Origin
Business intelligence system maturity	The integrity of BIS functions in hospitals	Hribar Rajterič (2010)
Medical information quality	The quality of medical information provided by a BIS in hospitals	DeLone and McLean (1992)
User satisfaction	The satisfaction level of clinical and administrative decision-makers who used a BIS	Doll and Torkzadeh (1988)
Business intelligence system use	The frequency and hours of BIS use by clinical and administrative decision-makers in hospitals	Igbaria et al. (1996)
Medical decision quality	The accuracy and time efficiency of decisions made by clinical and administrative decision-makers in hospitals	Caniëls and Bakens (2012)

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