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ORIGINAL ARTICLE

The relationship between healthcare information system and cost in hospital

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Abstract This study was purposed to study the relationship between healthcare information system (HIS) and cost in hospital. It also analyzed which organizational factors affect the adoption of information system in hospitals. The study included 577 hospitals in the statistical analysis. The HIS was measured by three indicators, which is based on the number of application systems in three core hospital functions (administration, management, and clinical). American Hospital Association and Dorenfest IHDS were merged to create sample data. Structural equation modeling was applied to estimate the parameters of the model. HIS is negatively associated with the total expense. However, it was not statistically significant. The internal variables of hospitals such as location, size, and system hospital variables were significantly related to the extent of HIS adoption.

Keywords Healthcare information system · Total expense · Structural equation model

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1 Introduction

The production and distribution of healthcare services is becoming more complex in healthcare organization. These complexities are causing the increase in cost [1]. Many countries are facing financial problem in providing healthcare services to their people. Hospital industry had experienced an economic crisis in 2008, and they are facing another financial crisis in 2011. These economic crises have precipitated the decline in hospital resources. They are required to balance the productivity for providing healthcare services and satisfying the need of people [2].

Healthcare information system (HIS) has been emphasized as a mechanism to achieve efficient operations. It is expected that they could play an important role in addressing the financial problem of the healthcare industry [3]. HIS application is expected to have hospitals to use less resource for patient care. This will save cost and increase overall profits [4]. A study analyzed the adoption of automated notes and records, computerized physician order entry (CPOE), and clinical decision support (CDS) system with cost in hospital. It found that HIS could lower hospital admission cost [5]. Other studies analyzed the effects of electronic medical record (EMR) and found that adoption of EMR could lower cost [6, 7]. These studies proposed that lowering cost will due to the enhanced healthcare delivery and transaction efficiency. COPE and electronic medical administration record (EMAR) were proposed to reduce cost per admission in select services [8]. Most of the previous studies analyzed the partial relationship between specific technologies and limited areas of hospital performance. In order to gain better understanding of HIS contribution to hospital performance, it will need all HIS functions to be combined at the national level.

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HIS was defined as a set of interrelated application systems working together [9]. Each application system consists of diverse subapplications used at different sites within a hospital [10]. In order to accomplish the successful adoption of HIS, hospitals need to install the application systems that could support and encompass their core functions. Zviran [11, 12] categorized hospital systems into four functional areas such as administrative, medical, patient management, and facilities management. As hospitals have many independent applications, HIS in hospital should be measured with the application systems in all related functions.

The objective of this study was to analyze the relationship between HIS and total expense in hospital. And also, it tried to identify organizational factors that affect the adoption of information system in US acute care hospitals. The measurement of hospital information system was based on the automated information system applied to the core functions of hospitals.

2 Methods

2.1 Data source

Data were based on two sources: (1) American Hospital Association (AHA) annual survey for 1997 and (2) Dorenfest IHDS+ database (version 2). AHA data were used for identifying the characteristics of hospitals and total expense. Dorenfest IHDS database provided data for the HIT application system in hospital.

AHA annually produced data about hospitals' organizational characteristics such as ownership, number of beds, teaching status, and financial data such as the total expense.

Dorenfest IHDS+ database contains data for information system for US hospital. Mail and telephone survey were used to collect data from the chief information officers. It provides fairly accurate and reliable information for the hospital information system used.

Sample hospitals were selected by merging AHA data in 1997 and Dorenfest IHDS (version 2). After the merging process, 577 hospitals with complete data were used for the analysis.

2.2 Study variable

2.2.1 HIS in hospital

This study measured HIS adoption, a latent construct, which could reflect the degree of information system installed by hospitals. A measurement model of HIS adoption was developed and validated in an early study [13].

The measurement model estimated the degree of HIS based on the number of application system in hospital-specific functional categories such as administration, management, and clinical functions. The generic assumption in measuring HIS adoption is that if hospitals had more number of application system in each functional area, they were considered to have invested more resources for HIS. Structural equation modeling is applied to the assessment of the measurement integrity of this construct.

Dorenfest database had information for the application system which was used in each hospital. Administration function was measured by sixty-one application systems such as patient registration, material management, and patient billing. Management function was measured by sixteen application systems such as managed care contract management, physician credentialing, and asset management. Clinical function was measured by sixty application systems such as medical record abstracting, laboratory, and chart deficiency.

2.2.2 Hospital total expense

This study used total hospital expense from AHA annual data to evaluate the performance of hospital. This variable measured a hospital's annual total expenditure.

2.2.3 Organizational variables

Variables representing the characteristics of hospital were included to analyze the effects of hospitals' internal and external environments on the adoption of HIS.

The included internal organizational factor were (1) teaching status whether hospital had training function, (2) ownership type whether hospital was for-profit or not-for-profit, (3) HMO (Health Maintenance Organization) contract whether hospital had contract with HMO, (4) system hospital whether hospital belonged to hospital system, and (5) number of beds, which represents the size of the hospital.

The included external factor of hospital was the location of hospitals whether they were located in a rural or an urban area. Organizational variables were represented by dummy variable (1, 0) except number of beds.

2.3 Structural equation modeling

This study used structural equation modeling with the maximum-likelihood method to estimate the parameters of the model. This model was applied to assess the relationship between HIS and hospital total expense.

This method simultaneously estimated the latent exogenous variables (HIS) from observed variables (administrative, management, and clinical system) and the structural

relations to the manifest endogenous variable, total expense. Organizational variables (HMO contract, teaching hospital, for-profit/not-for-profit, rural/urban, number of beds, and system hospital) were used as the exogenous variables in the model. The structural equation model is usually expressed by the following equation:

$$\eta = \beta\eta + \Gamma\xi + \zeta$$

where η is a vector of latent endogenous variables; β, a matrix of coefficients relating an endogenous variable to another endogenous variable; Γ, a matrix of coefficients relating the exogenous variables to the endogenous variables; ξ, a vector of latent exogenous variables, and ζ, an error term.

2.4 Analysis steps

This study analyzed the sample data on three phases. First, descriptive statistics for study variables were produced for the analysis of distribution. Also, correlation coefficients between study variables were analyzed. Second, a measurement model was developed for the latent construct of HIS and evaluated by model fit indexes. Third, structural equation modeling was applied to evaluate the relationship between HIS and hospital total expense. AMOS v18 was used for the analysis. The unit of analysis is hospital.

3 Results

Descriptive statistics of study variables are provided in Table 1. The average number of application systems for the administration function was 13.34, for the management function was 2.38, and for the clinical function was 10.88. Administration system had the highest average number of applications among three functions.

The average number of beds was 238.35. Most study hospitals had a contract with HMO (77.5 % of sample hospital). 5.2 % of the sample hospitals were teaching hospitals, 49 hospitals were for-profit, 41.9 % of the sample hospitals were located in rural area, and 59.6 % of hospitals were part of a hospital network system.

Table 2 provided the average number of automated application systems by the hospitals variables. Noticeable difference was found between for-profit and not-for-profit hospital. For-profit hospitals had average 9.0 application system for management function, but not-for-profit hospitals had average 2.3 application system. Other variables such as HMO contract, teaching status, rural/urban, and system hospital did not show large differences.

Before testing the hypothesized relationships, a measurement model of the latent construct (HIS) was evaluated. Pearson correlation coefficients and p values of the study variables were computed (Table 3). In the correlation analysis, three categories of application system had positive and statistically significant relations among each other (r for (A), (B) = 0.54, r for (A), (C) = 0.58, r for (B), (C) = 0.56). As these three variables show same directions, they were used to measure the common dimension of HIS.

Table 1 Descriptive statistics of the study variables ($N = 577$)

Variables	Statistics Average (SD)
Continuous variables	
Admin system	13.34 (2.23)
MGT system	2.38 (1.19)
Clinical system	10.88 (3.67)
Total expense	1,804,515,471 (41,631,842,214)
N of beds	238.35 (182.51)
	Frequency (%)
Dichotomous variables	
HMO contract	447 (77.5)
Teaching hospital	30 (5.2)
For-profit/Not-for-profit	49 (8.5)
Rural/urban	242 (41.9)
System hospital	344 (59.6)

Admin system, number of automated application systems in administration function; MGT system, number of automated application systems in management function; clinical system, number of automated application systems in clinical function; SD, standard deviation

Table 2 Application system by hospital variables [average (STD)]

Variables	Admin system	MGT system	Clinical system
HMO contract			
Yes	13.5 (2.2)	2.5 (1.1)	11.2 (3.4)
No	12.6 (2.3)	1.9 (1.3)	9.9 (4.3)
Teaching hospital			
Yes	14.7 (1.2)	3.0 (1.1)	12.5 (2.9)
No	13.3 (2.3)	2.3 (1.2)	10.8 (3.7)
For-profit/not-for-profit			
For-profit	14.2 (1.4)	9.0 (0.9)	11.0 (2.5)
Not-for-profit	13.3 (2.3)	2.3 (1.2)	10.9 (3.8)
Rural/urban			
Rural	12.6 (2.4)	2.0 (1.2)	9.6 (4.3)
Urban	13.9 (1.8)	2.7 (1.1)	11.8 (2.8)
System hospital			
Yes	13.7 (1.9)	2.6 (1.2)	11.4 (3.4)
No	12.8 (2.6)	2.1 (1.2)	10.1 (4.0)

Admin system: number of automated application systems in administration function, MGT system: number of automated application systems in management function, clinical system: number of automated application systems in clinical function

Table 3 Correlation coefficient of the study variables (p value)

	(A)	(B)	(C)	(D)
(A)	1.00			
(B)	0.54 (0.01)	1.00		
(C)	0.58 (0.01)	0.56 (0.01)	1.00	
(D)	−0.01 (0.89)	−0.01 (0.76)	−0.03 (0.44)	1.00

(A) Number of automated application systems in administration function, (B) number of automated application systems in management function, (C) number of automated application systems in clinical function, (D) total hospital expense

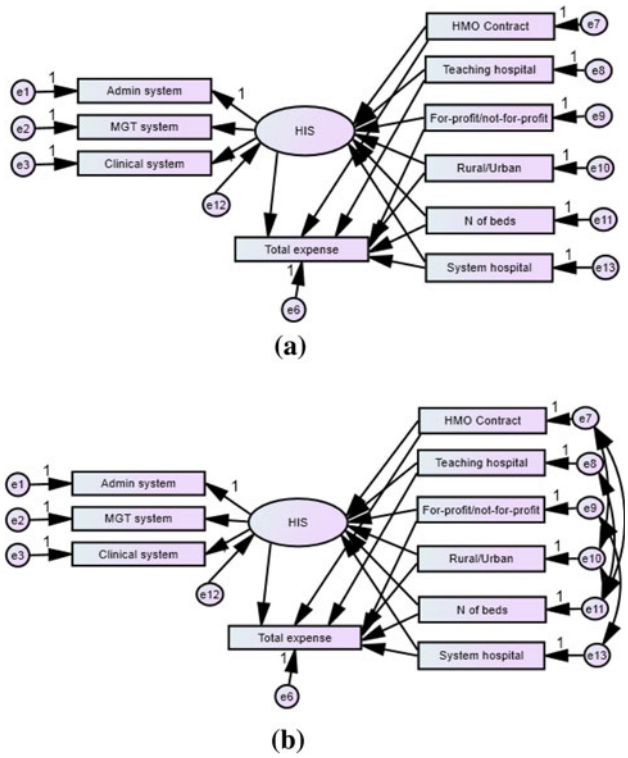

Fig. 1 Structural equation model. **a** Initial model, **b** revised model

Total expense variable had negative links with the three variables of HIT functions. It means that the higher number of application systems adopted in the hospitals, the lower the total hospital expense. But, the association was not statistically significant.

Three variables of application system categories were applied to develop the measurement model (HIS), and HIS construct was hypothesized to have a negative relationship with hospital total expense.

Initial model was modified to improve the model fit. High covariances were found among control variables from the initial model. Linkages between significantly correlated variables were added to the initial model. The initial and revised models are displayed in Fig. 1.

Table 4 Standardized parameter estimates of the structural equation model (p value)

	HIS ($\eta 1$)	Total expense ($\eta 2$)
HIS ($\eta 1$)	NA	−0.03 (0.62)
R^2	0.20	0.01
Control variables		
HMO contract	0.05 (0.28)	0.02 (0.64)
Teaching hospital	−0.02 (0.63)	0.00 (0.95)
For-profit/not-for-profit	0.79 (0.07)	−0.01 (0.81)
Rural/urban	−0.23 (<0.01)	−0.06 (0.20)
N of beds	0.23 (<0.01)	−0.03 (0.55)
System hospital	0.15 (<0.01)	−0.05 (0.22)
Goodness-of-fit measures		
χ^2		101.45
Degrees of freedom (df)		24
p value		0.00
Likelihood ratio (chi-square/df)		4.22
AGFI		0.92
CFI		0.93
RMSEA		0.07

Table 4 shows the standardized parameter estimates of the model. HIS was identified to have a negative relationship with total expense (−0.03), but it was not statistically significant. Negative and statistically significant association was found between rural/urban and HIS ($\gamma = -0.23$, $p < 0.01$). Two organizational variables, number of beds and system hospital, were found to have a statistically significant and positive relationship with HIS construct. All organizational variables did not have statistically significant association with the hospital total expense.

The model fit measures showed the goodness of fit of the model for the sample data. The likelihood ratio (4.22) was less than 5, and the adjusted goodness of fit index (AGFI) and comparative fit index (CFI) were greater than 0.9 (0.92 and 0.93, respectively). Root mean square residual error (RMSEA) index (0.07), which is a measure of the average of the residual variances and covariance, was also acceptable.

4 Discussion

This study analyzed the relationship between HIS and total expense. Previous studies [4–6, 14] proposed that adopting information system could decrease the cost of organization. The result of this study provided similar results. In terms of the total cost in hospital, the adoption of HIS application may lead to reduction in the total expense in hospital. Although the relationship was not statistically significant, it could provide implications for hospital CEOs.

Investment in HIS is viewed as a strategic decision of hospitals to minimize the cost in patient care. It is reported that controlling cost is the main motivation for adopting HIS. Healthcare industry has been focused on the financial aspects [15, 16]. Prior findings implied that HIS enables hospitals to spend less time for patient care, and it could save labor cost [4]. It is estimated that saving from the information system such as EMR is more than the cost for adopting the system [6]. It is argued that CPOE system can get more saving than the cost for installing in hospital [14].

The results indicated that hospital size and system hospitals were significant predictors of the adoption of information system. As the number of beds increased, the adopted number of system increased. The result supports the previous findings that provided a positive association between adoption of clinical, administrative IT, and hospital size [17–19]. Also, it is estimated that system hospitals are more likely to invest IT. This result will imply that larger and system hospitals could have advantage for adopting the advanced technologies from the outside and could have more slack resources for investing IT than others.

Teaching status of hospitals was found that it is not significantly related to the adoption of the technologies. A study found no significant relationship between the teaching status and the adoption of technologies [18], but other study reported that teaching hospitals were found to have a significant association with IT adoption [19].

The analysis indicated that the location of hospitals was a predictor of the adoption of HIS. Hospitals in an urban area were more likely to adopt application system than those in a rural area. It is argued that adoption of information technology is differed by hospital location [17, 19]. Hospital in urban areas could have better opportunities and access to resources and information. These environmental factors may have influenced hospitals to effectively adopt new information technologies.

The diffusion of innovation theory helps to understand the adoption of IT in healthcare industry. This theory explains how technologies diffuse among users [20, 21]. Hospital characteristics such as large size, system hospital, and urban hospital will indicate the abundance of resources in hospitals.

This study reported that technology adoption in hospital could save money. However, installing and operating information system will require substantial cost. This will make CEOs in hospitals having fewer resources to hesitate to adopt them. This study can provide evidence that support the relationship between the adoption of HIT and cost saving in a hospital. Wireless networks will have implications for the future hospital management [22–25].

Some limitations of this study should be mentioned. First, this study used 577 hospitals. Study sample was not selected randomly from the AHA data set. It limits the generality of study findings. Second, measurement model for HIS is focused on the structure aspects. Including other variables that could measure the operating process of information system can provide better explanation for HIS. Third, as the HIS technology advances rapidly, recent data will be required to provide more timely information.

5 Conclusion

This study found that HIS measuring by the information system applications had relationship with the reduced total cost. Although the relationship was not statistically significant, this result implied that hospitals investing more resources for IS could lower cost for providing healthcare services. HIS could be a strategy for improving the efficiency of patient care.

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