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Validating Electronic Health Records System Effectiveness Questionnaire Using Partial Least Squares-Structural Equation Modeling

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ABSTRACT

Background: The government of Malaysia has invested more than half of its medical expenses in the Total Hospital Information System as the electronic health records system. There is thus a necessity to evaluate whether the system has been utilized effectively, particularly how it affects health care providers' work performance. Objective: The objective of this paper was to test and validate the proposed survey questionnaire estimating on electronic health records system effectiveness factors. **Methods:** During the pilot study, convenience sampling was employed for data collection among selected specialists, medical officers, and nurses in a single hospital for one month. The collected data were subjected to cleansing and bias checking before further partial least squares-structural equation modeling analysis. **Results:** For results, the measurement model indicated acceptable loadings, average variance extracted, and composite reliability for all items, thus validating convergent and discriminant validity. **Conclusion:** It was confirmed that system quality, information quality, service quality, knowledge quality, and individual impact were the primary latent constructs to evaluate the system effectiveness. A real study might consider knowledge quality as a new measure for system success, thus extending the conventional information system success models to evaluate the health care provider's performance.

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INTRODUCTION

The Health Information and Management Systems Society (2011) defined an electronic health record (EHR) as the longitudinal health information of an individual patient in an electronic format that is created, acquired, or generated by one or more health care practitioners in a single or in multiple health care institutions. It should allow for the storage and retrieval of patient demographics, laboratory and radiology test results, visit notes, problem lists, medication, prescriptions, and previous medical episodes. An EHR automates and combines a continuum of health care services including administrative, nursing, laboratory, clinical, radiology, pharmacy, and research. It thus integrates health information on an individual patient by using the clinical information systems (CIS) of multiple providers connected via EHR network services (Kruse, 2013).

To provide a better quality of health care services and reduce costs, the Ministry of Health Malaysia (MOHM) has launched an integrated HIS (Hospital Information System) or THIS (Total Hospital Information System). The THIS is mandatory to gain full access to patient medical records from different HIS applications (Abd Ghani *et al.*, 2008). This comprehensive integrated IS covers the entire system framework in order to perform clinical, administrative, financial, and radiology functions electronically and thus coordinate patient care (Ismail *et al.*, 2010). The aim of the THIS is to establish a paperless hospital with a single HIS for managing clinical and non-clinical operations (Sulaiman, 2011).

In the context of this research, the THIS is an EHR system. To date, 12 MOHM hospitals have implemented the THIS, mainly situated in the Klang Valley area and a few states across Malaysia (Ismail & Abdullah, 2013); (Abdullah, 2013). There are three phases of HIS implementation in MOHM hospitals, namely the Basic Health Information System (BHIS) for hospitals with fewer than 200 beds, Intermediate Health Information System (IHIS) for hospitals with more than 200 beds but fewer than 400 beds, and THIS for hospitals with more than 400 beds (Ismail *et al.*, 2013). First, the BHIS comprises the basic CIS, Patient Management System (PMS),

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and Financial Information System (FIS). Second, the IHIS covers the BHIS, Laboratory Information System (LIS), and Pharmacy Information System (PIS). Finally, the THIS supports the IHIS, Picture Archiving and Communication System (PACS), Radiology Information System (RIS), and other related applications (Li, 2010). Contrary to the BHIS and IHIS, which have limited integrated applications and are transaction-based, the THIS is an integrated enterprise-wide or large-scale IS that covers major clinical functionality. The MOHM has spent almost 98% of all public medical expenses on the THIS, as the top priority to foster advanced ICT infrastructure and e-health systems in public and private hospitals (Ahmad, 2008). Hassan (2012) revealed that the government has spent over 600 million Ringgit on THIS projects in selected MOHM hospitals at a cost of 80 million Ringgit per hospital for a complete package.

On the other hand, Li (2014) emphasized that although there are extensive evaluation studies of EHRs in the literature, there is still a challenge for researchers and practitioners to use the results due to their limitations. The first limitation is that many studies have been carried out in a single health care institution by using qualitative methods of data collection. Hence, there is a lack of quantitative findings on how practitioners' work is affected by EHR system use. The second limitation is the lack of measurement to evaluate the functionality of an EHR system or a unified framework to measure system characteristics and user acceptance. As the MOHM launched the THIS 15 years ago, there is thus a necessity for a comprehensive assessment in order to increase an individual health care provider's performance and thus contribute to the system effectiveness. Accordingly, this paper attempts to test the reliability and validity of a survey questionnaire measuring success or effectiveness factors of an EHR system.

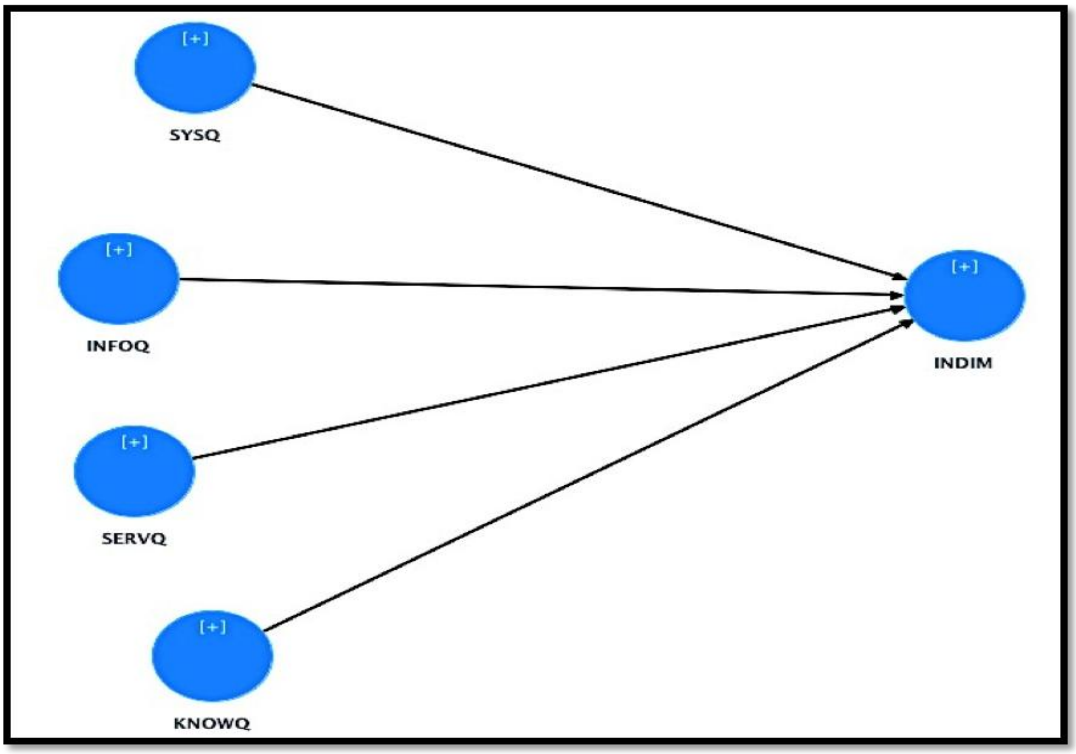

Fig. 1: Research Model

Literature review:

Over the past decade, western scholars have suggested renowned IS success and effectiveness models such as the DeLone and McLean IS Success Models (DMISMs) in 1992 and updated in 2003. However, the previously mentioned theories and models/frameworks have only focused on assessing certain success factors (e.g. system quality, information quality, service quality, actual use, user satisfaction, individual impact, organizational impact) to measure generic outcomes for individual IS users. Because an EHR is also a form of IS and because IT tasks performed by health care providers are linked to an organization's core business, the impact on other aspects of quality such as knowledge quality should be significant and meaningful if they are integrated as the new measure for the EHR system effectiveness factors. IT applications are also beneficial for generating knowledge activities (Whinston & Holsapple, 1996). EMR systems are regarded as a crucial source to support medical research and education in addition to the application of practitioner's knowledge in their tasks effectually. Comparing with information, it is a processed data that generates facts while knowledge is an integrated element of experiences, opinions, and values (Chang *et al*., 2012). Specifically, information was easy to be measured in a tangible form (explicit) while knowledge was hard to be measured as it contains in human mind (tacit).

On the other hand, traditional DMISM has indicated system use and user satisfaction as the important constructs for measuring IS success that adopted by IS researchers over the decade. Use and perceived usefulness constructs yet are only valid when it is voluntary from different aspects (DeLone & McLean, 1992); (Seddon, 1997). In other word, Li (2014) defended that system usage is an appropriate measure for success if the technology use is volitional. Hence, it is hard to be evaluated due to mandatory use of HIS (Abdullah, 2013). Meanwhile, for user satisfaction construct, past studies have proven that there is a high relationship of the construct between system quality, information quality, and individual impact (McGill *et al*, 2003); (Negash *et al*, 2003) thus indicated a low explanatory power (Sedera & Gable, 2004). Sedera and Tan (2005) validated that user satisfaction measure is actually comprised of system quality and individual impact. Based on these arguments, the proposed research model would be measured using the five success factors by omitting actual use and user satisfaction.

As shown in Figure 1, the proposed model was adopted from the EHR System Effectiveness Model (Mohd Salleh *et al*., 2014) that incorporates five latent variables, of which four were exogenous constructs, namely system quality (SYSQ), information quality (INFOQ), service quality (SERVQ), and knowledge quality (KNOWQ) that predict an endogenous construct, namely individual impact (INDM). This model actually is a theoretical framework with the aim to extend DMISM in the health care with KNOWQ as a new proposed dimension yet to be empirically tested (Mohd Salleh *et al*., 2014). The researcher was interested in exploring these IS success factors from an individual unit of analysis (not an organizational one). The followings were the brief literature review for proposed latent constructs:

System Quality (SYSQ):

System quality can be divided into four aspects, namely accessibility, navigation, interactivity, and usability (McKinney *et al*, 2002). Perceived ease of use of a health care system will be assumed if the system is stable in addition to system integration and flexibility (Pai & Huang, 2011). A study by Li (Li, 2014) also indicated that system quality is significantly affected EHR success compared to information quality and service quality. Quality of system is determined by high capability of system functionality and user-friendly interface that facilitated better communication among physicians and accessed clinical information easily.

Information Quality (INFOQ):

Information quality refers to the quality of output generated from the information systems evaluated in terms of its accuracy, precision, completeness, reliability, and relevance (Abdullah, 2013). From a health care IT perspective, information quality depends on the accuracy and reliability of accumulated and compiled patient data to produce a comprehensive patient medical history. Correctness and completeness of documentation shall be useful in both patient care and health care policy planning (Häyrinen *et al*, 2008).

Service Quality (SERVQ):

Service quality encompasses the perceived needs, experiences, and expectations of users when measuring the quality of service (Strawderman & Koubek, 2008). Other components recommended by Li *et al*. (2002) are technical expertise of IT personnel, maintenance and support, and training programs that are necessary to evaluate quality of service. In health care situations, clinicians will evaluate IT products supplied to them and the quality of service by providers to ensure they meet specifications and configurations based on their requirements (Hung *et al*, 2013). Pai and Huang (2011) surveyed nurses for a study on health care system adoption and found that user satisfaction improved when perceived usefulness and perceived ease of use are higher. Service quality should be continuously augmented while implementing systems to facilitate high system performance.

Knowledge Quality (KNOWQ):

Adoption of health information technology in the health care industry has provided enormous benefits from improving quality of services to efficiency of health care providers (Paré *et al*., 2014). One aspect of efficiency identified is knowledge quality. Knowledge creation in clinical practice means novel experiences, ideas, opinions, values, and best practices of providers in performing their tasks. This notion also includes standard operating procedures and routine tasks rather than the system database itself. Knowledge quality denotes the explicit knowledge of providers that is created, stored, and shared across diverse health care systems. The system will be the enabler or tool vital to supporting knowledge management activities among health care providers in facilitating tasks, problem solving, decision making besides medical research, and education (Chang *et al*., 2012). EMR system use has affected level of IT knowledge and skills among health care providers when using the systems to perform their works (Otieno *et al*., 2008). Shared health information via EHR system may increase knowledge among physicians to prevent any misdiagnosis or inappropriate treatment.

Individual Impact (INDIM):

Individual impact is defined as the outcomes produced by employees based on their applied knowledge, skills, competencies, and motivations (Chang *et al*., 2012). The system will act as a tool for performance if it is compatible with its user preferences (Karahanna *et al*., 2006). It has also been proven that IT is the key enabler of work performance when it is suited to the needs of a user's workplace (Tung *et al*., 2008). IT applications in the health care sector have significantly improved the value and efficiency of health care providers (Laflamme *et al*., 2010). In particular, health care providers viewed that EHR provided them with timely and accurate access to current patient information for improving the quality of care (El-Kareh *et al.*, 2009). Furthermore, task and technology characteristics have positive and significant relationships with task-technology fit, which eventually affects user performance based on EHR use (El-Gayar *et al*., 2010). Perceived usefulness significantly predicts the work performance of medical records personnel in managing EMR when the system has a good fit with the daily duties performed by staff (Mohd Salleh *et al*., 2013).

Methods:

Data Collection:

Pilot test is essential for a survey study. With testing of survey questionnaire, a researcher will produce a good quality of instrument before final data collection in the real study (Janicak, 2007). The samples of respondents were selected from the health care providers at an MOHM hospital situated in Kedah, Malaysia. Respondents were specialists, medical officers, and nurses who served in different clinical departments and who utilized the THIS in their daily clinical works. Prior to questionnaire distribution, the researcher has performed pre-testing of the instrument to establish content validity. Experts from the National Institutes of Health and the Medical Research and Ethics Committee have reviewed the questionnaire in advance before approving the study registration. Even though questionnaire items were derived from previous studies with well-established reliability and validity, pre-testing should be repeated to confirm the validity and reliability of the study's current situation (De Vaus, 2002). Only then, by using convenience sampling, 300 questionnaires were administered to respondents during the Continuing Medical Education program held by their respective clinical departments to gain better participation over the one-month period. Of the 300 questionnaires, 117 useable questionnaires were returned (response rate 39%) for this pilot study.

Descriptive Analysis:

In terms of the demographic profile, respondents consisted of 28 (23.9%) men and 89 (76.1%) women. Of these, six (5.1%) were below 25 years old, 75 (64.1%) were 25–35 years old, 30 (25.6%) were 36–45 years old, five (4.3%) were 46–55 years old, and one (0.9%) was 56 years old or above. Altogether, 44 (37.6%) were specialists, 24 (20.5%) were medical officers, and 49 (41.9%) were nurses. Of these positions, 47 (40.2%) had fewer than five years of working experience, 35 (29.9%) had 5 to 10 years, 28 (23.9%) had 11 to 20 years, five (4.3%) had 21 to 30 years, and two (1.7%) had 31 years or above.

Questionnaire Instrument:

Respondents were asked about their perceptions of using the EHR system for the system effectiveness factors (see Appendix A). All 34-question items were measured by using a seven-point Likert scale ranging from 1 (strongly disagree) to 7 as (strongly agree). Survey items were adopted from past instruments that had already been validated by earlier researchers in the different areas and then readjusted to suit the local sample and setting: SYSQ, INFOQ, SERVQ, and INDIM items by DeLone and McLean (2003), Seddon and Kiew (1996), Gable *et al*. (2008), and Bossen *et al*. (2013), and KNOWQ items by Wu and Wang (2006).

Data Analysis Technique:

All responses from the collected questionnaires were entered into SPSS version 22.0, subjected to data cleaning for missing values and outliers, and converted into a CSV format for further analysis in SmartPLS version 3.2. Researchers normally employ partial least squares-structural equation modeling (PLS-SEM) when using non-normal data and smaller samples in exploratory research settings. This is a powerful tool to overcome model identification problems and analyze complicated models (Ringle *et al*., 2012), making it applicable to analyze the acquired research data. The use of PLS-SEM can identify the most vital antecedents of the target construct or extend an existing theory (Sarstedt *et al*., 2014), in line with the paper objective.

Common Method Bias (CMB):

When an instrument describing endogenous and exogenous constructs is used at the same time acquired from the similar source, CMB must be avoided in order not to create noisy data (Lowry & Gaskin, 2014). CMB can be assessed by using Harman's one-factor test by inputting all the latent constructs into a principal component factor analysis. CMB exists if the tested construct explains the majority of the covariance between all constructs (Podsakoff & Organ, 1986). For this testing, the researcher applied unrotated factor analysis for all first-order constructs using SPSS. The results indicated that the tested single factor only explained 44.5% of the variance in the model. As this was less than 50%, there was weak evidence that CMB existed in the collected data.

Analysis and results:

Analysis of the Measurement Model:

The measurement model identified SYSQ, INFOQ, SERVQ, KNOWQ, and INDIM as the first-order constructs. To assess the reliability and validity of instrument, convergent and discriminant validity were assessed by using the PLS Algorithm feature. The extent to which a construct explains its items or indicators' variance can be measured by convergent validity (Sarstedt *et al*., 2014). To establish convergent validity, item loadings, average variance extracted (AVE), and composite reliability (CR) are compulsory (Hair *et al*., 2010). Table 1 shows the results of the measurement model for item loadings, AVE, and CR for the first- and second-order constructs. Loadings of individual items greater than 0.7 indicated that the construct explained more than 50% of an item's variance. As a rule of thumb, loadings must be greater than 0.5, AVE must be greater than 0.5, and CR must be greater than 0.7 (Fornell & Larcker, 1981). As presented in Table 1, the assessments for the item loadings, AVE, and CR were highly acceptable from their recommended values, implying that all latent constructs were internally consistent and reliable.

Table 1: Results Extracted from the Measurement Model

First-Order Constructs	Items	Loadings	AVE	CR
SYSQ	SYSQ1	0.702	0.621	0.929
	SYSQ2	0.787		
	SYSQ3	0.731		
	SYSQ4	0.860		
	SYSQ5	0.757		
	SYSQ6	0.790		
	SYSQ7	0.829		
	SYSQ8	0.835		
INFOQ	INFOQ1	0.807	0.719	0.947
	INFOQ2	0.879		
	INFOQ3	0.875		
	INFOQ4	0.868		
	INFOQ5	0.881		
	INFOQ6	0.792		
	INFOQ7	0.827		
SERVQ	SERVQ1	0.788	0.615	0.918
	SERVQ2	0.837		
	SERVQ3	0.814		
	SERVQ4	0.760		
	SERVQ5	0.691		
	SERVQ6	0.767		
	SERVQ7	0.824		
KNOWQ	KNOWQ1	0.830	0.778	0.955
	KNOWQ2	0.910		
	KNOWQ3	0.879		
	KNOWQ4	0.862		
	KNOWQ5	0.889		
	KNOWQ6	0.920		
INDIM	INDIM1	0.714	0.632	0.911
	INDIM2	0.846		
	INDIM3	0.804		
	INDIM4	0.828		
	INDIM5	0.853		
	INDIM6	0.713		

Note:AVE: Average Variance Explained, CR: Composite Reliability

Next, the assessment of discriminant validity commonly uses the Fornell and Larcker (1981) criterion and cross-loadings (Chin, 1998). Fornell and Larcker (1981) recommended that to satisfy discriminant validity, a latent variable must be able to explain more variance from its correlated indicators in a model. To achieve this, the AVE of every variable should be contrasted with its squared correlations with other variables (Henseler *et al*., 2014). In other words, the square root of AVE for a construct should be higher than the correlations between the particular constructs and other constructs. Any result for a construct greater than 0.5 suggests that it explains over 50% of its item's variance (i.e. it has sufficient discriminant validity). Hence, the measurement model was deemed to be valid for convergent validity in Table 1 and discriminant validity assessments in Table 2.

Table 2: Discriminant Validity for the Tested Constructs

	INDIM	INFOQ	KNOWQ	SERVQ	SYSQ
INDIM	0.795				
INFOQ	0.680	0.848			
KNOWQ	0.717	0.537	0.882		
SERVQ	0.587	0.584	0.366	0.784	
SYSQ	0.693	0.699	0.665	0.392	0.788

Note: Diagonal values (emboldened) represent the square root of AVE, while off-diagonals represent correlations

In other words, EHR success factors composed of these five dimensions and no item or construct should be dropped from the model as their scores met the acceptable criterions. Surprisingly, KNOWQ was obtained the high score for six question item loadings (more than 0.8) as well as its AVE and CR comparing than other latent constructs.

Conclusion:

This paper outlined the results from pilot study on measuring EHR effectiveness factors. From the measurement model, it was found that SYSQ, INFOQ, SERVQ, KNOWQ, and INDIM were the core measures for this effectiveness. As a new proposed measure, the DMISM might be extended to embrace KNOWQ to assess system effectiveness in the health care context or other pertinent IS research. The next steps or procedures recommended are to collect the final data from other hospitals that implemented THIS with the new samples and run the analysis for both measurement and structural models to test the study hypotheses.

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Appendix a:
Survey Questionnaire Items:

SYSQ1: EHR system is easy to use.
SYSQ2: EHR system is user friendly.
SYSQ3: The response time of EHR system is acceptable.
SYSQ4: EHR system responds quickly when changing between screens.
SYSQ5: EHR system is stable in the event of system failure.
SYSQ6: EHR system is fast to recover from errors.
SYSQ7: EHR system requires only minimum forms and text fields to complete a task.
SYSQ8: EHR system can be easily modified, corrected or improved.
INFOQ1: Information output from EHR system is presented in a useful format.
INFOQ2: Information output from EHR system is clear and understandable.
INFOQ3: Information output from EHR system is complete.
INFOQ4: Information output from EHR system is accurate and correct.
INFOQ5: Information output from EHR system is precise that grouped together on a single screen.
INFOQ6: Information output from EHR system is consistent when sharing patient records.
INFOQ7: Information output from EHR system is timely and up-to-date.
SERVQ1: IT support staff and vendor provide quick assistance when I am facing problems with EHR system.
SERVQ2: IT support staff and vendor are always willing to help.
SERVQ3: IT support staff and vendor have high knowledge to solve my problems with EHR system.
SERVQ4: IT support staff and vendor understand my needs and my work group.
SERVQ5: IT support staff and vendor provide follow-up service to EHR system users like me.
SERVQ6: IT support staff and vendor provide good training for me to use EHR system.
SERVQ7: IT support staff and vendor are always courteous and friendly with EHR system users like me.
KNOWQ1: EHR system is useful to research or create new medical knowledge.
KNOWQ2: EHR system is useful to apply my medical knowledge and skills to works.
KNOWQ3: EHR system provides complete medical source so that I can refer for more information.
KNOWQ4: EHR system assists me to share my medical knowledge and skills with other clinical staffs.
KNOWQ5: EHR system provides helpful expert directory for my medical specialty.
KNOWQ6: EHR system helps me to increase my medical knowledge and competency.
INDIM1: Using EHR system in my work enables me to accomplish my tasks faster.
INDIM2: Using EHR system increases quality of patients’ care.
INDIM3: Using EHR system increases safety of

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patients' care.
INDIM4: Using EHR system increases my work productivity and performance.
INDIM5: Using EHR system increases my decision-making capability.
INDIM6: Using EHR system increases my problem-solving capability.