The influence of system quality characteristics on health care providers’ performance: Empirical evidence from Malaysia

Mohd Idzwan Mohd Salleh a,b,∗, Nasriah Zakaria a,c,d, Rosni Abdullah a,e

a School of Computer Sciences, Universiti Sains Malaysia, Malaysia
b Faculty of Information Management, Universiti Teknologi MARA, Malaysia
c Medical Informatics and e-Learning Unit, Medical Education Department, College of Medicine, King Saud University, Saudi Arabia
d The Research Chair of Health Informatics and Promotion, King Saud University, Saudi Arabia
e National Advanced IPv6 Centre of Excellence, Universiti Sains Malaysia, Malaysia

Received 23 June 2016; received in revised form 18 July 2016; accepted 1 September 2016

Summary
Background: The Ministry of Health Malaysia initiated the total hospital information system (THIS) as the first national electronic health record system for use in selected public hospitals across the country. Since its implementation 15 years ago, there has been the critical requirement for a systematic evaluation to assess its effectiveness in coping with the current system, task complexity, and rapid technological changes. The study aims to assess system quality factors to predict the performance of electronic health in a single public hospital in Malaysia.

Methods: Non-probability sampling was employed for data collection among selected providers in a single hospital for two months. Data cleaning and bias checking were performed before final analysis in partial least squares-structural equation modeling.

Results and conclusions: Convergent and discriminant validity assessments were satisfied the required criterions in the reflective measurement model. The structural model output revealed that the proposed adequate infrastructure, system interoperability, security control, and system compatibility were the significant predictors,
where system compatibility became the most critical characteristic to influence an individual health care provider’s performance. The previous DeLone and McLean information system success models should be extended to incorporate these technological factors in the medical system research domain to examine the effectiveness of modern electronic health record systems. In this study, care providers’ performance was expected when the system usage fits with patients’ needs that eventually increased their productivity.

© 2016 King Saud Bin Abdulaziz University for Health Sciences. Published by Elsevier Limited. All rights reserved.

Introduction

Total hospital information system (THIS) is an integrated hospital information system (IS) designed to manage both clinical and non-clinical functions for coordinated patient care [1]. THIS was the first initiative of the Ministry of Health Malaysia (MOHM) to implement a national electronic health record (EHR) system as part of telehealth project. Started at Selayang Hospital in 1999 and followed by Putrajaya Hospital in 2000, a total of 12 public hospitals in Malaysia have implemented THIS [2]. THIS will ensure the continuity of care and completeness of patient medical histories documented across different clinics and medical departments within a single hospital to create an EHR or lifetime health record of telehealth application. As an enterprise-wide hospital information system (HIS) covering significant clinical oriented functionalities, THIS is commonly deployed by a large hospital with at least 400 beds [3]. For the past 15 years, the Malaysian government has spent approximately a billion ringgit to fund THIS with roughly 80 million ringgit allocated for system deployment in one public hospital [4]. In considering the mandatory use of HIS in hospitals due to their massive investments by the government, it is critical to evaluate the effectiveness of the system on how the system can contribute significantly to the performance of health care providers. Understanding the impact of system quality on job performance and satisfaction are essential for hospital administrators to make a better decision concerning the quality of patient care [5].

For the theoretical aspect, the DeLone and McLean information system success model (DMISMs) in 1992 and 2003 have been adopted by IS researchers around the globe. Unfortunately, there is a gap in the theory that does not cover the core technological characteristics in the medical system domain. Apart from rapid technological changes from electronic medical records (EMR) to EHR, more features and impact of usage can be extended to new studies [6] to cope with technological advancements and task complexity of providers. When the DMISMs are too generic, along with the past IS acceptance frameworks, there is little information on measuring the particular IS characteristics to measure the HIS success [7]. Therefore, with the intention to extend DMISMs in the medical system research, and the central objective of the study was to assess how several system quality characteristics predict the care provider’s performance in this setting.

Proposed research model

In this study, we preferred to use an EHR system instead of THIS which strictly focused on clinical functionality [8]. As illustrated in Fig. 1, the proposed research model was adopted from the EHR System Effectiveness Model [6] with four latent constructs to evaluate the performance of care provider. This model undeniably was an extended version of the original DMISM developed to fit with current system quality measures in the medical system context yet to be estimated. The original DMISM consists of six information system success factors or effectiveness, namely system quality, information quality, use, user satisfaction, individual impact, and organizational impact [9]. However, this study was only interested in confirming the attributes of system quality for an individual unit of analysis by excluding use due to HIS mandatory use [10] and also user satisfaction as it contained system quality and individual impact measures [11,12]. Back to the research model, four exogenous constructs are known as adequate
Adequate infrastructure with two indicators, system interoperability with three indicators, perceived security control with four indicators, and system compatibility with four indicators drawn on the left side pointing the arrow individually to an endogenous construct, provider performance with four indicators. In this study, the individual impact would be replaced with health care provider performance and is the degree to which an individual care provider believes that using an EHR system would help him or her achieved benefits through increasing performance in the medical profession.

In clarifying the relationship between the proposed constructs, the following were used to justify the study’s hypotheses.

**Adequate infrastructure**

In EHR context, IT infrastructure is defined as the appropriate hardware, software, and supporting management systems to execute EHR applications. It also comprises of networks, servers, telecommunication hardware, and services [13]. Fairbanks [14] emphasized that EHR adoption is dependent on IT resources to manage the clinical processes that critically affected the quality care of patients. Medical practices of physicians will be significantly improved if a high performance of network devices and connectivity are in place for EHR system use [15]. Therefore, the research hypothesized that:

**H1.** Adequate infrastructure has a positive effect on provider performance.

**System interoperability**

Interoperability is the ability of different health information technology (HIT) and applications to exchange, use, and communicate medical data accurately and consistently in a medical context [16]. It enables the exchange and sharing of EHR across different departments and health care institutions [17]. System interoperability is vital, as it will lead to cost efficiency, effective patient treatment, and elimination of redundancy [18]. It can integrate care coordination of patient, reduce the time for medical documentation, and increase doctor-patient relationships. Based on these, the research hypothesized that:

**H2.** System interoperability has a positive effect on provider performance.

**Perceived security control**

In the context of health care, system security can be described as the ability of HIS to safeguard the users and records against unauthorized access [19]. An e-health application survey by Sequist and Cullen [20] indicated that data security is critical for operating EHR, as perceived by physicians. Nehemiah [21] also posits that the privacy and secu-
rity of patient data must be addressed to ensure successful EHR implementation. For this reason, it is asserted that:

**H3.** Perceived security control has a positive effect on provider performance.

**System compatibility**

One of technology characteristic namely IT compatibility is the major factor for organizational IT adoption. IT compatibility referred to the degree of perceived ease of use for IT software when integrates with related IT facilities, work culture, values, and organizational practices [22]. Based on the observations of 768 nurses by Hung et al. [23] in using primary health information systems, system compatibility affected their perceived usefulness and perceived trust. Similarly, Li [7] also performed online surveys with 219 residents who have EHR use experiences in both large and middle-sized hospitals at California. The results indicated a positive effect of EHR use on work impact of providers. From this literature, the research hypothesized that:

**H4.** System compatibility has a positive effect on provider performance.

**Methods**

The actual sample size required for this study was estimated in G*Power version 3.1 by selecting a priori analysis. After calculation, the proposed sample size was $n = 129$ (effect size $f^2 = 0.15$, $\alpha = 0.05$, number of predictors $= 4$). In one of the largest public hospitals situated on the north peninsular of Malaysia, the questionnaire surveys were distributed to the health care providers during a two-month period, which resulted in the collection of 367 responses from 400 surveys, a 92% response rate. Employing convenience sampling, the surveys were delivered through separate programs namely continuing medical education (CME) organized by the hospital among specialists and medical officers, while continuing nursing education (CNE) among nurses who were active users of the EHR system. Participation was voluntary, and an individual respondent’s identity remained anonymous at all times. The target respondents were asked to evaluate the proposed exogenous and endogenous constructs. The questionnaire involved eight items that adopted from previous IS studies [15,24–27] and modified to fit within the Malaysian medical practice context while introduced nine new items ready to be measured. All measurement items were anchored using a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree).

Methodologically, many IS researchers commonly employ partial least squares-structural equation modeling (PLS-SEM) due to small sample sizes, non-normal data, and use of latent formative constructs that unreliable perform in covariance-based structural equation modeling (CB-SEM) [28]. With regards to non-normal distribution, the PLS-SEM method would be employed for analyzing the collected data due to significant results for both male and female data at ($p < 0.05$) running using Shapiro’s–Wilks test in SPSS. Out of 367 responses, 358 were usable for analysis in SmartPLS version 3.2.0, with nine responses discarded due to unengaged responses. Before commencing the analysis, common method variance (CMV) was assessed using Harman’s one-factor test. Testing of CMV is necessary if the data collection is to be carried out through a cross-sectional survey [29]. Podsakoff and Organ [30] added that CMV is present if one principal factor explains the majority of the variance. After entering all latent construct items and executing unrotated factor analysis in SPSS, the result was 35.9%, confirming that CMV did not exist in the dataset. Briefly describing the descriptive statistics, the respondents included 124 (34.6%) males and 234 (65.4%) females. These unbalanced responses were due to 129 (55.1%) of the samples were nurses who mostly female. From this, 51 (14.2%) were below 25 years old, 219 (61.2%) were 25–35 years old, 66 (18.4%) were 36–45 years old, 18 (5%) were 46–55 years old, and four respondents were aged above 56 years old. Regarding clinical positions, 72 (20.1%) were assistant medical officers, 132 (36.9%) were medical officers, 19 (5.3%) were specialists, and 135 (37.7%) were nurses. Approximately 184 (51.4%) of them had less than three years of system use experience, 56 (15.6%) had less than five years, and 118 (33%) had more than five years.

**Results and discussion**

**Analysis of the measurement model**

The measurement model outlines the relationships between the latent constructs and their indicators [31]. The model can be reflective or formative, comparing causality direction, indicator interchangeability, and its correlations [32]. About this study, the exogenous and endogenous constructs identified as the reflective, and no construct defined as the formative. Convergent validity
Table 1 Convergent validity of the reflective measure.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Survey items</th>
<th>Loadings</th>
<th>CR</th>
<th>AVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate infrastructure</td>
<td>Faster network access is critical for me to use EHR system</td>
<td>0.926</td>
<td>0.903</td>
<td>0.823</td>
</tr>
<tr>
<td></td>
<td>Adequate computer hardware is critical for me to use EHR system</td>
<td>0.888</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System interoperability</td>
<td>The connection between different EHR systems is critical to enable coordinated patient care</td>
<td>0.807</td>
<td>0.807</td>
<td>0.583</td>
</tr>
<tr>
<td></td>
<td>I only need to enter and save data once, then use the system with multiple EHR modules</td>
<td>0.784</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The cost for patient’s treatment is reduced with the use of EHR system</td>
<td>0.696</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived security control</td>
<td>I believe my EHR system does not allow unauthorized access</td>
<td>0.919</td>
<td>0.926</td>
<td>0.759</td>
</tr>
<tr>
<td></td>
<td>I feel secure and safe using EHR system</td>
<td>0.888</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I believe my EHR system protects patient’s information</td>
<td>0.887</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I believe my EHR system has a robust security control</td>
<td>0.784</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System compatibility</td>
<td>EHR system fits my patients’ needs</td>
<td>0.863</td>
<td>0.910</td>
<td>0.716</td>
</tr>
<tr>
<td></td>
<td>EHR system fits my workflows</td>
<td>0.862</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EHR system fits the way I work and my work styles</td>
<td>0.849</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EHR system fits my clinical practices</td>
<td>0.810</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provider performance</td>
<td>EHR system increases my work productivity</td>
<td>0.871</td>
<td>0.900</td>
<td>0.691</td>
</tr>
<tr>
<td></td>
<td>EHR system increases my chances of obtaining better annual performance marks</td>
<td>0.851</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EHR system increases my time with patients</td>
<td>0.804</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EHR system enhances the safety of patient care</td>
<td>0.798</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

and discriminant validity were required to evaluate reflective measurement model. In assessing an ideal convergent validity for the reflective measure, an individual item must have a recommended outer loading above 0.5, a composite reliability (CR) recommended value above 0.6, and every construct’s average variance extracted (AVE) recommended value of 0.5 or above to explain 50% or more variance from its indicators [33]. As shown in Table 1, the convergent validity assessment for the proposed measures was achieved.

Discriminant validity, however, can be assessed for reflective measures by following the Fornell and Larcker criterion. The criterion stated that an individual latent construct must be able to share more variance with its indicators than with other constructs measured from its AVE value. The AVE for that particular construct should be greater than the highest squared correlation with other constructs [34]. As illustrated in Table 2, the squared AVE for each latent construct (boldface) was greater than the correlations of other constructs, and thus achieved the discriminant validity assessment to validate the measurement model.

Analysis of the structural model

Apart from the measurement model, the structural model was further analyzed to test the study’s hypotheses. The coefficient of determination ($R^2$) for ESE was 0.463, determining that 46% of its variance might be explained by the
Table 2 Discriminant validity for the reflective measure.

<table>
<thead>
<tr>
<th></th>
<th>Adequate infrastructure</th>
<th>Perceived security control</th>
<th>Provider performance</th>
<th>System compatibility</th>
<th>System interoperability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate infrastructure</td>
<td>0.907</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived security control</td>
<td>0.266</td>
<td>0.871</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provider performance</td>
<td>0.416</td>
<td>0.471</td>
<td>0.832</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System compatibility</td>
<td>0.391</td>
<td>0.396</td>
<td>0.594</td>
<td>0.846</td>
<td></td>
</tr>
<tr>
<td>System interoperability</td>
<td>0.265</td>
<td>0.472</td>
<td>0.450</td>
<td>0.409</td>
<td>0.764</td>
</tr>
</tbody>
</table>

Note: The bolded diagonal denote AVE values.

exogenous constructs. In another word, the remaining 54% could be described by other technological factors excluded in the study. This observed $R^2$ value could be classified as moderate according to Chin [35], who classified $R^2$ as 0.67 (substantial), 0.33 (moderate), and 0.19 (weak). For testing the path relationships between latent constructs in the model, the bootstrapping procedure using 500 subsamples was applied [34]. The results showed that all system quality characteristics have a positive and significant effect on the endogenous construct (see Fig. 2). Comparing the significant values among these exogenous constructs, system compatibility was the most important predictor ($t = 6.985$, $p < 0.01$) followed by perceived security control ($t = 3.325$, $p < 0.01$), system interoperability ($t = 3.087$, $p < 0.01$), and Adequate infrastructure ($t = 2.925$, $p < 0.01$). Hence, the results provided adequate support for all tested study hypotheses (H1, H2, H3, and H4).

Further analysis was preceded by the blindfolding procedure to estimate the predictive capability of the model by obtaining the cross-validated redundancy value. After running this procedure with an omission distance of seven, the estimated $Q^2$ value for the endogenous construct was 0.310 and indicated that the structural model provided adequate support for the predictive relevance with $Q^2$ greater than 0 [34]. Next, assessment for the structural model was performed to calculate the effect size ($f^2$) of the estimated significant results. Consequently, provider performance has an original included $R^2$ of 0.463, whereas Adequate infrastructure has excluded $R^2$ of 0.439, system...
interoperability has excluded $R^2$ of 0.447, perceived security control has excluded $R^2$ of 0.434, and system compatibility has excluded $R^2$ of 0.358. After computation, adequate infrastructure has $f^2$ of 0.045 (small), system interoperability has $f^2$ of 0.030 (small), perceived security control has $f^2$ of 0.054 (small), and system compatibility has $f^2$ of 0.196 (medium), separately based on Cohen’s [36] convention to explain the endogenous construct at the structural level. Also, a post hoc power analysis was conducted to estimate the size and strength of the statistical significance in G*Power. With a medium effect size ($f^2$) of 0.179, the total sample size of 358, and four predictors, the study managed to attain 0.999 of the statistical power which was large to detect the significant effects for the tested research hypotheses even employing non-probability sampling.

Applying Importance-Performance Matrix Analysis (IPMA) for latent construct scores can enhance the final PLS-SEM results. IPMA recognizes the critical importance and performance of every construct for concluding research by emphasizing major areas for improvement of managerial activities [37]. As depicted in Fig. 3, the IPMA of provider performance revealed that system compatibility was the most important system quality characteristics (importance score = 0.385, performance score = 66) to predict provider performance. Perceived security control has a relatively low importance score (0.201) with similar performance score (66) as system compatibility. Adequate infrastructure (0.171) and system interoperability (0.152) have a slight importance rating, but system interoperability has the highest performance rating of 69 among all. Therefore, the hospital administrator should concentrate on improving the performance of system compatibility for future EHR system upgrading.

A follow-up interview was conducted with two selected medical officers and one IT officer for the purpose of result verification. As the strongest predictor to influence the endogenous construct exhibited from the bootstrapping and IPMA results, the surveyed providers believed that the fitness of the system with the patients’ needs helped to increase their work productivity with the highest mean score of 5.031. For instances, the system allowed timely and convenient patient access to care, compliance with clinical practice guidelines, and continuous monitoring of patient conditions. With EHR, tracking of patient medical histories could not be easier—with a single click rather than referring to a medical department with paper-based records. These benefits would lead to more accurate and comprehensive patient records which can increase the efficiency of diagnosis and treatment. Applying access restriction with clinical task responsibility as the security control, the respondents believed that the system did not allow unauthorized access to protect the confidentiality of patient’s information. Thus, they expressed confidence in its safety and security. Specialists
and medical officers yet have access to patients’ records by only knowing their identification numbers. This access was critical, as these providers still have to examine incoming patients admitted to their clinics with different kinds of injuries or diseases in the case of emergency. System access was still monitored via access log, as they were only permitted to add, view, or even print certain patient information.

As an integrated EHR application, patient management system (PMS) module was found to be the most popular used application among the responded health care providers. There was interoperability between clinical departments in the surveyed hospital that would enable them to add, update, save, and share patient data with other EHR modules including laboratory, pharmacy, and radiology systems. Patient notes and complete medical histories could be retrieved from an EHR database for coordinated patient care when using different clinics to receive various types of treatments. Unfortunately, there was no interoperability between the surveyed hospital and other MOHM hospitals outside the state. With interoperability features of an EHR system, records duplication sometimes existed for a single patient during emergency admission not because of technical but more often human error. This mistake was then fixed by an authorized specialist through further records verification to merge them together.

For the technology infrastructure, providers agreed that their departments equipped with adequate personal computers (PCs) and faster network speed to access EHR system, which contradicted with the findings of previous studies [2,38–40]. Previously, the hospital has purchased more than 800 desktop and laptop computers to support HIS usage on Windows XP. More personal computers were also rented running on Windows 7 together with new dedicated servers purchased for EHR storage to accommodate new users and changing the operating system. In reducing traffic and system downtime, the system could be accessed only for intranet use.

**Conclusions**

This study makes a significant contribution to IS theories by extending DMISMs with technology characteristics measurements. In term of practicality, we found all measuring system quality factors have a positive impact on an individual health care providers’ performance with significant results. In particular, performance was anticipated when the use of the system fits with patients’ needs and therefore increased their productivity. More than 50% of responding providers have spent approximately five hours per day five to seven days per week to use the system. The medical officer was recorded as the highest EHR system user compared to others in this study. By referring to the study outcomes, the hospital management might enhance their annual IT allocation budget and strategically plan for future system’s development by considering the proposed technology characteristics mainly relating to clinical task-technology compatibility.

Conversely, it was noted that the implemented system still has limited integration and interoperability for supporting clinical operations among other MOHM hospitals, health centers, and clinics. The network infrastructure and the interoperability of the system could be upgraded to encourage their participations as well as boost adoption levels, minimize resources, and enable centralized care coordination using a single system to enhance effectiveness across the country. Additionally, future studies may enlarge the sample sizes among different hospitals implementing HIS with various providers such as radiologists, pharmacists, lab technologists, and imaging staffs through a random sampling to increase the effect sizes for improving the statistical power. Through a nationwide EHR system evaluation study the results could be generalized to the Malaysian health care population. Therefore, this study has provided some useful knowledge from the Malaysian health system’s perspective about the effectiveness of the EHR system — addressing technological factors rarely found in recent scholarly impact factor journal publications.

**Competing interests**

The authors declared that they had no competing interests.

**Ethical approval**

The study has received ethical approval from the Medical Research and Ethics Committee (MREC) Malaysia with reference number: NMRR-14-1203-23156 (IIIR).

**Acknowledgements**

The authors would like to thank the Director of Health Malaysia for permission to publish this paper.
Special thanks also to the selected medical personnel of Kedah Hospital for their participation in this study. The project was scientifically supported by King Saud University, Deanship of Scientific Research, The Research Chairs and The Research Chair of Health Informatics and Promotion.

References


[33] Hair JF, Sarstedt M, Hopkins L, Kuppelwieser VG. Partial least squares structural equation mod-
Influence of system quality characteristics on health care providers’ performance