MEDINFO 2010
C. Safran et al. (Eds.)
IOS Press, 2010

doi:10.3233/978-1-60750-588-4-1231

A Multi-method Approach to Evaluate Health Information Systems

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Abstract

Systematic evaluation of the introduction and impact of health information systems (HIS) is a challenging task. As the implementation is a dynamic process, with diverse issues emerge at various stages of system introduction, it is challenge to weigh the contribution of various factors and differentiate the critical ones. A conceptual framework will be helpful in guiding the evaluation effort; otherwise data collection may not be comprehensive and accurate. This may again lead to inadequate interpretation of the phenomena under study. Based on comprehensive literature research and own practice of evaluating health information systems, the author proposes a multi-method approach that incorporates both quantitative and qualitative measurement and centered around DeLone and McLean Information System Success Model. This approach aims to quantify the performance of HIS and its impact, and provide comprehensive and accurate explanations about the casual relationships of the different factors. This approach will provide decision makers with accurate and actionable information for improving the performance of the introduced HIS.

Keywords:

Evaluation, Health information system, Implementation, DeLone and McLean IS success model, Multiple methods

Introduction

Many healthcare organizations around the world are introducing health information systems (HIS) to improve health care quality and efficiency. To ensure that their HIS will be accepted and used by the intended users and bring in the expected outcomes, the decision makers would wish to fully understand the extent to which the HIS fulfilling its objectives, the strategies, processes and final outcomes of introducing the system, particularly its impact on health care quality and efficiency. Therefore, an important area of health informatics research is to evaluate the processes and outcomes of introducing HIS in health care organizations. Evaluating HIS is a complex issue that has long plagued HIS researchers [1-5]. As different stakeholders have different interest in the evaluation study; the nature and types of questions to be asked can be quite different; health care organizations vary in size, organizational culture, power structure and management; there is no one-size-fits-all solution. Also different issues may emerge at different stages of system introduction; therefore, the evaluation methods and approaches vary significantly. The previous researchers have discussed the challenges in evaluating HIS and raised the problem of lacking a uniform conceptual framework to guide the evaluation research [1,2]. In an effort to conceptualize and conduct a comprehensive investigation to produce thorough and accurate answers about the best strategies, practices and outcomes of HIS introduction, this paper discusses a multi-method approach to evaluating HIS. This is followed by a case study to illustrate how various evaluation methods are integrated in a comprehensive evaluation project that has been undertaking in long-term care facilities in Australia.

End user HIS perspectives

In 1992, the DeLone and McLean Information System Success Model (abbreviated as the D&M IS success model) was developed [6]. This model consists of six interrelated dimensions of success: system quality, information quality, system use, user satisfaction, individual impact and organizational impact. In response to the increasing importance of information services, DeLone and McLone added another dimension - service quality to the quality constructs [7]. To increase the genealizability of the model, they collapsed the two constructs about individual impact and organizational impact into one construct: net benefits. Therefore, the reformulated D&M IS success model is composed of six constructs: (1) system quality, (2) information quality, (3) service quality, (4) user satisfaction, (5) use and (6) net benefits. They believe that use and user satisfaction are determined by information quality, system quality and service quality, besides their mutual influences. Use and user satisfaction determine the final outcome of system introduction – net benefits (see Figure 1).

The D&M IS success model has been widely adopted by many researchers in measuring success of introducing various information systems into organizations. It was used by van der Meijden *et al.* [8] as a conceptual framework to summarize the critical factors that contribute to the success of inpatient clinical information system introductions from 31 empirical studies during the period of 1991 to 2001. This study shows that the majority of variables or attributes the previous researchers used to measure the success of HIS introduction can be successfully assigned to the six dimensions in the D&M IS suc-

cess model. Lehmann et al. adapted the model to qualitatively interpret the critical success factors of a mobile bed management system in a regional hospital in New Zealand [9]. Jen et al. used it to measure a mobile patient safety information system success in Taiwan quantitatively [10].

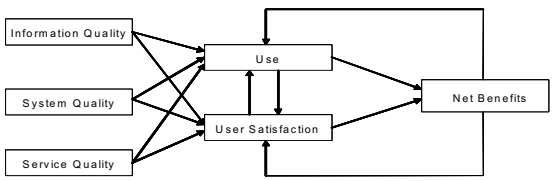

Figure 1- The reformulated DeLone and McLean Information System Success Model

Qualitative requirements

It is recognized that the introduction of HIS involves not only technological systems but also a significant change in culture, politics and power that tie professional groups together in organizations [11]. Organizational change and the implementation of information and communication technology are closely intertwined. It is an innovation and learning process. Therefore, Seddon [11] and DeLone and McLean [7] all recognize that the application of the D&M IS success model to empirical research requires a contextual variance specification of the model. Friedman and Wyatt [12] also emphasize the importance of context for the empirical investigation of the practice of introducing HIS into health care settings. However, the context issue is not addressed in the D&M IS success model. This leads to an inability of the D&M model to interpret the failure cases in the systematic review of the published literature about inpatient clinical information system implementation by van der Meijden *et al.* [8]. To remedy this deficiency, Yusof et al. [5] proposed a new model of human, organization and technology-fit evaluation framework (HOT-fit), which is a combination of D&M IS success model and the IT-Organization Fit Model adapted from Morton [13].

The D&M IS success model describes the relationships between different inputs, process variables and outputs. According to Lee and Lings [14], a model by itself can only describe what happens, but not explain how phenomena relate to each other and why this may be so. Although the proposed HOT-fit model was used successfully to explain what happened, how and why in the implementation of a Fundus Imaging System in a health care setting through qualitative case study approach [5], this mixed model appears to have lost significant potential of each of the original ones as psychometric measurement models. In order to understand this perspective, it is essential for us to understand the basics of psychometric measurement theory.

Psychometric measurement theory

"Measurement is the process of mapping the magnitude of an attribute to a numerical value – to transferring the amount of a quality to a quantity" [14]. As the science of psychological measurement [15], psychometrics is based on the assumption that latent constructs actually exist, although unobservable, they influence some things that we can actually observe [14]. Structural equation modeling is the conventional statistical method used to conduct psychometric analysis to test the causal relationships between the constructs. There are two models in a structural equation model: a structural model and a measurement model [16]. A structural model consists of the unobservable, latent constructs and the theoretical relationships among them, such as the six latent constructs in the D&M IS success model (see Figure 1). For each construct in a structural model, there is a related measurement model, which links the latent construct with a set of observed items. The measurement model consists of the relationships between the observed variables (questionnaire items) and the latent constructs which they measure [16]. For example, questionnaire items can be built to measure each construct, such as 'system quality' in the D&M IS success model. The relationships between the questionnaire items and the latent construct 'system quality' are the interests of the measurement model. Together, the structural and measurement models form a network of constructs and measures.

Psychometrics is widely used to measure knowledge, abilities, attitudes and personality traits. The D&M IS success model is derived from empirical data analysis and has been proved to be a validated psychometric measurement model. Petter and McLean [17] included 52 empirical studies that examined relationships within the IS success model at the individual level of analysis in their meta-analytic assessment of the D&M IS success model. The recent empirical psychometric examination of the D&M IS success model includes Wu and Wang [18], Wang and Liao [19].

The limitation of the HOT-fit model

Come back to the limitations of the HOT-fit model. This model was proposed as a conceptual framework for researchers to incorporate comprehensive dimensions and measures of HIS [5]. The case study of the Fundus Imaging System provides a good example on how to use the HOT-fit model to interpret the complex, interweaved relationships amongst people, organization, processes and technology. However, by this extension of the original D&M IS success model, the causal relationships among the constructs in the D&M model is mixed with the concept of 'fit', which is not a term in psychometrics.

Quantifying the weight of each construct is important, because without rigorous quantification, the magnitude of the impact of each contributing factor to the success of HIS can not be decided. As most healthcare organizations are resource stressed, without adequate information about the weight of each construct, the decision makers would find it challenge to make informed decisions on how to effectively allocate

resources to the much needed area to support HIS implementation.

Lee and Lings [14] suggest that the function of model is to describe, whereas the function of theory is to explain. Ortigueira believes that it is a utopia to think that it is possible to build models with all attributes, properties and characteristics of a specific system [cited by 20]. Roldå and Leal [20] also suggest that it is impossible to obtain a total correspondence between the attributes of the real-world system and the model. Thus the ambitious HOT-fit model is yet to prove its capacity to accurately and thoroughly explain the complex phenomena associated with the introduction of HIS and be validated quantitatively.

Having discussed various evaluation frameworks, their contributions and limitations in guiding HIS evaluation effort, we propose a multi-method approach combining the strength of quantitative evaluation guided by D&M IS success model and supported by other quantitative and qualitative methods.

A multi-method evaluation of HIS

To accurately identify and classify the issues that are critical for the introduction of HIS and explain the observed phenomena thoroughly and accurately, both quantitative and qualitative research methods need to be adopted in HIS evaluation research.

In order to implement the evaluation framework of the D&M IS success model, appropriate measurement items need to be adopted in a self-administered questionnaire to measure each construct. This questionnaire survey can then be implemented to gather end users' responses to each measurement statement.

This strategy of evaluating IS through structured questionnaire survey has a long established tradition in IS research. It is supported by Goodhue, who believes that users are capable of performing the evaluation of the task-technology fit of a particular technology that they have been using [21]. The modified technology acceptance model developed by Venkatesh and Davis [22] has been applied in more than 1000 empirical investigations through questionnaire survey to predict end user acceptance of information technology. In addition, questionnaire surveys also have a number of distinct advantages, including the ease of distributing questionnaires to a large number of users and the automated analysis of the results with statistical packages [23].

Therefore, the approach and rational for the undertaking of each type of research is summarized below:

Approach 1. Both cross sectional and longitudinal questionnaire survey of HIS end users to ascertain their changing perceptions about the HIS to be evaluated. The questionnaire is structured to measure the six theoretical constructs of the D&M IS success model (see Figure 1).

Rational. Self-administered questionnaire is the proven best method for measuring personal belief, perception and attitude. It has been employed broadly in information system and health research. Cross sectional questionnaire survey can quantify the performance of each construct in different sites; longitudinal survey can quantify the change of end users' perceptions about each measurement items.

Approach 2. Conduct Interview or focus group discussion with a convenient sample of HIS end users at different levels of participating organizations. This activity should be conducted at the same period of time when questionnaire data was collected.

Rational. In-depth interview and focus group discussion is effective for understanding how and why things have happened and would happen, and end users' perceptions on what can be done better. This will provide relevant explanations to the results of the questionnaire survey.

Approach 3. Work sampling with direct observational study to objectively measure any changes in work activities undertaking by each member of the care team and validate whether there is any objective evidence that the introduction of the HIS has improved the efficiency of work tasks that the system supports or vise versa.

Rational. End users' perceptions and opinions can be biased; therefore, objective measurement is required to validate the changes in work practices associated with the introduction of the HIS under evaluation. Work sampling is also effective in providing objective, relatively accurate measurement of the proportions of time end users spend on different work activities.

Approach 4. Auditing records that have been recorded both before and after the introduction of the HIS if the system is a health record system. Both quantitative and qualitative auditing needs to be conducted.

Rational. Direct auditing of health records can provide objective evidence about the changes in quality of records associated with the introduction of the HIS, if the HIS is a health record system. The results of cross-sectional auditing will be sound evidence for benchmarking across sites. Regular, longitudinal auditing will provide valid evidence about the longitudinal changes in quality of records.

The information collected from the above four sources, once triangulated, will provide a comprehensive and accurate picture of what has happened, why and how and what is the direction for the further evolution of the HIS. It is useful for the decision makers to implement effective interventions to ensure adequate return on investment from the HIS at different stages of system introduction and infusion.

A case study

The health information systems evaluated in this case are commercial electronic nursing documentation systems introduced by two aged care management groups in two states in Australia. Our research settings are residential aged care facilities belonging to these two aged care management groups. The project started in June 2008 and the planned completion date is May 2011.

For elderly people living in residential aged care facilities in Australia, nursing documentation includes functional assessment, care planning and daily progress reporting. Such documentation is essential for providing care that reflects the needs of the elderly [24, 25]. The functions of the two electronic nursing documentation systems were similar; both include resident details, assessment forms, progress notes, care plans, charts and printing out reports. The system was used by all levels of care staff members and management to record and review nursing records.

This particular evaluation study aimed to develop and validate the D&M IS success model and instruments to measure the model and identify factors that affect IT implementation in residential aged care using the above mentioned multi-method evaluation framework.

Approach

A multiple case study with both cross sectional and longitudinal research design has been undertaken. The above mentioned research methods were adopted. The implementation of each research component is described below:

Questionnaire survey. The questionnaire survey instrument was further developed from that used by Yu et al. [26]. Face validity of the instrument was validated through a consultation process with 16 personnel, including three focus group discussions with nursing managers (11 people in total), interviewing managers in aged care organisations (3 people), two vendors of HIS and health IT managers (6 people). The questionnaire survey was conduct 1-3 months before the introduction of an electronic documentation system, repeated 3 months, 6 months and 12 months after the electronic documentation system was introduced.

Interview. Interview guide was designed to elicit care staff members' perceptions about 'why' and 'how' things have happened and what can be done better. After acquiring consent, each interview was audio-recorded and transcribed. The interview transcripts are analysed in NVivo software.

Work sampling study. After a systematic literature review and detailed observation of care staff members' work practices in residential aged care facilities, a staff work activity classification system was developed. It included six major categories of care staff activities in a residential aged care facility: direct care, indirect care, nursing documentation, communication, personal and transit (such as walking between residents' rooms). There are many sub-categories of activities under each of the above six categories of the activities. The work sampling instrument was validated through two focus group consultations with care staff members in two aged care facilities.

Pilot study was conducted before the start of the formal measurement. The data quantified how different categories of care staff members spend time and how many proportions of their time is spent on each activity.

Auditing nursing records. A registered nurse was recruited to undertake this research component. The person developed nursing documentation audit tool based on extensive literature review and residential aged care accreditation standards in Australia. As most of the previous studies in this field were conducted in Europe in hospital setting, whereas Australian residential aged care setting has specific documentation requirements and protocols, significant development has been conducted to reflect Australian aged care documentation standards and practice.

Results

Currently 351 questionnaire responses were collected from eleven residential aged care facilities. Preliminary data analysis suggests that the instrument is adequate in detecting the performance difference of each measurement item between facilities; as well as different measurement points in one facility. This allows the research team to confidently inform the management group about the performance of the HIS as perceived by the participating care staff members in each aged care facility, between different facilities, and the longitudinal changes of their perceptions over time. Through triangulating questionnaire survey data with interview and work sampling data, a comprehensive picture about what happened, why and how were drawn.

For example, longitudinal questionnaire survey results in one facility suggest that the care staff members' perceptions about HIS quality and information quality were less positive than those measured in the previous survey. The interview data suggested that new staff members were not trained properly, also the support services could be more accessible. Based on the feedback, the facility management implemented more effective training and support strategies, such as peer-support, HIS training for any new member joining the team. After the enhancement of education and training programs, the survey conducted one year later found that the care staff members' perceptions about the performance of the system was improved in all aspects. The cross-sectional survey results also suggested that the electronic documentation out-weighed the paper-based documentation system in another facility. This re-enforced the management that investment in electronic documentation was correct.

Future work

The author is in the process of building structural equation model to validate the HIS success model in residential aged care settings in Australia. The members of the research team are in the process of analysing data collected from interview and work sampling study.

The nursing documentation audit instrument has been developed. It has been validated through two focus group discussions with RNs in two aged care management groups and consultation with nursing experts. The next step is to recruit two RNs to conduct nursing documentation audit, together with our RN researcher to test inter-radar reliability, then start nursing documentation audit in each participating site.

Conclusion

After explaining the importance of HIS evaluation, this paper introduced the D&M IS success model for evaluating HIS.

The limitations of the D&M IS success model are discussed. This led to the introduction of a recently developed HIS evaluation framework HOT-IT fit model. The weakness of this model is addressed through the introduction of the basic concept of psychometric measurement theory and the importance of quantitative measurement for both cross sectional and longitudinal benchmarking of HIS performance and impacts. Then a new model of HIS evaluation was introduced. This model is based on a multi-method approach that incorporates both quantitative and qualitative methods and centered on the D&M IS success model. A case study was presented to show an approach to implement the multiple methods to a large scope, both cross sectional and longitudinal HIS evolution project.

Acknowledgement

This research is funded by Australian Research Council Industry Linkage Grant Scheme (Project ID: LP0882430) and the five partner organizations: Illawarra Retirement Trust, RSL Care, UnitingCare Ageing South Eastern Region, Warrigal Care and Aged and Community Services Australia.

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