• 医学信息技术 •

Methods to Evaluate Health Information Systems*

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〔**Abstract**〕 To ensure the introduction of a health information system (HIS) is on track and will bring in the expected outcomes, it is essential to evaluate the critical success factors at every stage of the system introduction life cycle. Based on comprehensive literature research and personal experience of evaluating HIS, the author proposes a multi – method approach that incorporates both quantitative and qualitative research, conceptualized through the DeLone and McLean Information Systems Success Model. The advantage of this approach is not only identifying the factors impacting on implementation success, but also distinguishing the critical factors from the less important ones. Thus it will facilitate management in prioritizing effort to address the key challenges at different stages of system introduction. This evidence – based management decision support will reduce the failure rate and maximize the benefits of HIS investment.

〔**Keywords**〕 Evaluation; Multiple methods; Quantitative methods; Anthropological research methods; Health information system; Implementation; DeLone and McLean IS success model

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〔**摘要**〕 为了保证卫生信息系统引进的顺利进行, 达到预期的目的, 有必要在系统引进的每个阶段对影响系统成功引进的关键因素进行评估。基于系统性的文献分析研究和自身多年对卫生信息系统评估工作的经验, 提出一个以笛伦和麦克伦信息系统成功模型为基础的整合多元方法的评估方案。这个方案的优势在于它不仅能分辨决定卫生信息系统成功引进的因素, 而且能将不同因素的影响程度量化, 从而产生对影响因素有轻重缓急之分的评估结果。该结果有利于决策者及时处理解决系统引进不同时期出现的关键问题。这种有量化证据支持的决策行为将有效地降低卫生信息系统引进失败的可能性, 进而增大卫生信息系统的投入产出回报。

〔**关键词**〕 评估; 多元方法; 定量研究法; 人类学研究法; 卫生信息系统; 引进, 笛伦和麦克伦信息系统成功模型

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1 Introduction

Although health information systems (HIS) hold the promise of improving patient safety, healthcare quality and efficiency, how do we know whether a particular HIS introduced into a health care organization meets the above expectations? Without evaluating the processes and outcomes of HIS introduction, it is impossible to validate whether the system's promised outcomes have been achieved. Therefore, an important area of health informatics research is to evaluate the processes and outcomes of introducing HIS in health care organizations.

As the introduction of HIS into healthcare organizations is a dynamic process, with diverse issues emerging at various stages of system introduction, it is a challenge to weigh the contribution of multiple factors and differentiate the critical ones. As different stakeholders have different expectations and needs from the system, what information to gather from whom and how to gather that information need to be carefully considered. Health care organizations vary in size, culture, structure and politics; therefore the complexity of system introduction is not comparable in different types and sizes of organizations. As each HIS is built on a specific type of technology for specific functions, the exact impact of each system on health care services needs to be carefully examined. From the process perspective, different challenges may emerge at different stages of system introduction; therefore, different questions should be asked and addressed by different research methods at different stages of system introduction. The above challenges have increased the difficulty for system evaluators to reach balanced, evidence - based, comprehensive and accurate conclusions.

A lack of unified methods and approaches for evaluating HIS has been a long - standing challenge for health informatics researchers. To draw the attention of health informatics researchers in China to the importance of systematic, rigorous evaluation for the successful introduction of HIS into health care organizations, this paper discusses various methods and approaches to evaluating HIS and suggests a holistic, multi - method approach to HIS evaluation.

2 DeLone and McLean Information Systems Success Model provides an excellent conceptual framework for evaluating the success of HIS

2.1 The DeLone and McLean Information Systems Success Model (D&M IS Success Model)

Drawing on the research findings of a systematic literature review of the publications on factors determining the success of information systems in organizations, DeLone and McLean proposed their famous Information Systems Success Model[1]. According to this model, information systems success can be conceptualized in six dimensions: system quality, information quality, system use, user satisfaction, individual impact and organizational impact. Since its inception, the DeLone and McLean Information Systems Success Model (abbreviated as the D&M IS Success Model) has drawn broad attention from information systems (IS) researchers in the world, evidenced by 3082 citations of the original paper[1] according to Google Scholar.

In response to the shifting role of information systems departments towards information services, DeLone and McLean added another dimension - service quality - to the determinants of success[2]. To increase the generalisability of the model, they collapsed the two dependent variables: individual impact and organizational impact, into one variable: net benefits. Therefore, the reformulated D&M IS Success Model has six dimensions: (1) system quality, (2) information quality, (3) service quality, (4) user satisfaction, (5) use and (6) net benefits. According to DeLean and McLean, use and user satisfaction are determined by in-

formation quality, system quality and service quality, besides their influences on each other; whereas use and user satisfaction determine the net benefits of system introduction. Conceivable net benefits will add to end users' satisfaction and stimulate them to use the system (see Figure 1).

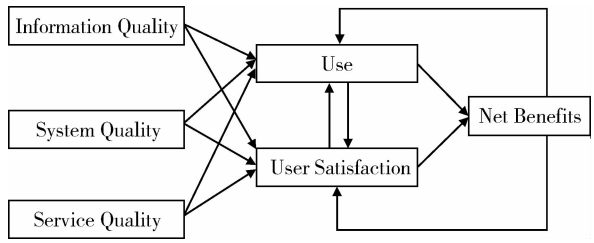

Fig. 1 The reformulated DeLone and McLean Information System Success Model[2]

2.2 The application of the D&M IS Success Model in evaluating HIS

A few health informatics researchers have applied the D&M IS Success Model to identify and interpret the critical factors determining HIS success. Golob et al[3]. used the model to guide their evaluation of a prototype electronic clinical information system in the surgical and trauma intensive care unit in a hospital. van der Meijden et al[4]. classified the critical factors for the success of inpatient clinical information systems drawn from 31 empirical studies into the six dimensions of the reformulated D&M model. Their study suggests that the majority of critical HIS success factors identified by the previous researchers can be assigned to one or more of the six dimensions of the reformulated D&M IS Success Model. Lehmann et al[5]. adapted the model as a conceptual framework to qualitatively interpret the critical factors determining the success of a mobile bed management system in a regional hospital in New Zealand. Jen et al[6]. used an augmented version of the D&M IS Success Model to quantitatively measure a mobile patient safety information system success in Taiwan. A questionnaire survey instrument has been developed and used to collect nursing staff members' perceptions about the success of an electronic nursing documentation system by the author according to the dimensions of the D&M IS Success Model. However, increasing application of the D&M IS Success Model to HIS evaluation is yet to be promoted given the importance of evaluation and the challenge in conducting it in large scale HIS introduction projects.

2.3 A need for multi – method approach to HIS evaluation

Although the D&M IS Success Model is able to pinpoint which factors determine the success of HIS, Lee and Lings[7] noticed the weakness of a model – based approach in interpreting why and how actions and consequences relate to each other. It is commonly understood by leading IS researchers that the introduction of IS involves not only technical systems but also a significant change in culture, politics and power that tie professional groups together in organizations[8]. It is an innovation and learning process. Therefore, it is suggested that the application of the D&M IS Success Model to empirical research requires contextual knowledge, i. e., knowledge about the social technical environment in which the IS has been introduced[2,8]. As the context variable is not included in the D&M IS Success Model, this has led to the inability of the model to provide a satisfactory interpretation about the failure cases for the inpatient clinical information system implementation, as reported by van der Meijden et al[4]. Obviously other evaluation methods and approaches are needed to complement the D&M IS Success Model in evaluating HIS success.

The leading scholars in health informatics research believe that HIS is a social technical system that can only be fully understood by (1) technical and systems features, (2) cost – benefit analysis, (3) user acceptance and (4) patient outcomes[9]. Therefore, it is proposed that multiple research methods are required in evalua-

ting HIS success[9, 10]. These include health outcome and cost benefit analysis, critical incident logs, document analysis, interviews, observations and surveys. Longitudinal study designs can capture changes over time; whereas formative evaluation, i. e., evaluating on the run with system introduction, will allow the improvement of the system[9].

3 A multi – method approach to evaluate HIS success

3.1 Quantitative methods to evaluate HIS success[11]

Quantitative evaluation can provide hard evidence to answer the questions about "what is going on", "how much changes have been made after the usage of the HIS"; thus is useful for understanding the processes and outcomes of HIS introduction.

Questionnaire survey is a commonly used quantitative evaluation method, although open – ended questions are more qualitatively oriented. A questionnaire can be structured to measure each dimension of the D&M IS Success Model. Organizational document auditing gives direct evidence of the extent of change in various indicators, such as health care diagnoses or treatment or the level of occurrence of medical errors before and after the adoption and use of a newly introduced HIS. Direct observational studies provide objective measurement on changes in health care work practices and time health care workers spend on various activities. Therefore, they are useful in measuring whether or not the expected efficiency gain has been achieved by the introduction of a particular HIS. Each evaluation method will be described briefly in the following paragraphs.

3.1.1 Questionnaire survey Evaluating IS success through a structured questionnaire survey is a common method in IS research. The questionnaire survey is based on the assumption that users are best placed to evaluate the fit of a particular technology that they have been using for their tasks[12]. Its advantages include ease of distribution to a large sample of participants and automated analysis of the results with statistical packages to provide quantitative results[13]. A self – administered questionnaire is the proven best method for measuring personal belief, perception and attitude. Both cross sectional and longitudinal questionnaire surveys of HIS can be conducted on end users to ascertain their changing perceptions about the HIS. A cross sectional survey can quantify end users' perceptions about the performance of the system at different sites; a longitudinal survey can quantify the changes of end users' perceptions about each measurement item over time at one site.

3.1.2 Auditing organizational documents, such as medical records Auditing organizational documents, such as medical records, both before and after the introduction of the HIS if the system is an electronic health record system, is essential for the objective measurement of change in record quality after the introduction of the HIS. Both quantitative and qualitative auditing needs to be conducted. Quantitative auditing can give solid evidence about the changes in records about medical procedures, such as diagnosis or treatment after the introduction of the electronic health record; it therefore, reflects the impact of HIS introduction on medical procedures. Qualitative auditing will reveal whether using the system will improve compliance with the regulatory or organizational requirements.

Cross – sectional auditing amongst organizations, sites or operational units will provide sound evidence about the differences in record quality across organizations, sites or operational units; whereas regular, longitudinal auditing will uncover the longitudinal changes in the quality of medical records at the same site.

3.1.3 Observational studies End users' perceptions and opinions can be biased; therefore, an objective observational study is required to validate the changes in health care workers' work practices and time spent on tasks after the introduction of the HIS. Before

conducting direct observation, a classification of work activities needs to be developed and used as guidelines for recording the work activities observed. There are two types of observational studies: time – motion studies and work sampling with direct observation study.

Time – motion study: A time – motion study is a useful approach for gathering data about work related activities. Time – motion sampling combines both the observation and timing techniques. It requires the observer to follow up the health care worker under study throughout the observational period in order to record the activities and time the staff member spends on the various activities and the time spent on each activity.

The time – motion study is a challenging method because it is human resource intensive; also, the behaviour of the health care worker under observation may change due to the `Hawthorne effect'. As only one person can be followed up in a particular observational period, the number of health care workers who can be observed is limited, thus the representativeness of the study findings is compromised.

Work sampling: Work sampling has widely been accepted and utilized as a credible method in measuring time spent on an activity by health care staff such as nurses, pharmacists and physicians. Work sampling examines particular activities being carried out by the study participants. This is carried out by implementing observations on the whole team of study participants at random intervals or equally spaced, observation intervals. Strategies in the implementation of work sampling methods are varied and they include observations, use of video cameras and self – reporting. The original strategy (observation) requires the use of trained observers who have already familiar with the work practices in the setting.

Work sampling with direct observation can objectively measure any changes in work activities undertaken by a whole team of health care workers in a specific work unit using the HIS. It can validate whether the introduction of the HIS has led to the improvement in efficiency in completing work tasks that the system supports or vice versa. Instead of an individual health care worker, the whole team is observed; therefore the `Hawthorne effect' is minimized. The method is also effective in providing objective, relatively accurate measurements of the proportions of time end users spend on different work activities.

3.2 An ethnographic approach to evaluate HIS success

Ethnography is a common research strategy in social sciences to gather empirical data to reveal the nature of group, culture or societies. Ethnographic researchers may immerse themselves in the group that they study in order to obtain a `holistic', full picture about the group, culture or society.

The introduction of a HIS into a healthcare organization is an innovative process with success or failure determined by the interplay of people, organization and technology; therefore, an ethnographic approach is useful in holistically understanding the interplay and impact of people, organization and technology on HIS success. The methods for ethnographic data collection include interviews or focus group discussion, questionnaires, participant observation and document analysis. The following sections briefly introduce the common methods for ethnographic data collection for HIS evaluation.

3.2.1 Interviews or focus group discussions Interviews or focus group discussions with a convenient sample of HIS end users at different levels of the organization can be conducted concurrently with the questionnaire survey. In – depth interviews and focus group discussions will provide answers about why and how actions and consequences relate to each other. They will explain what is going on suggested by the questionnaire survey, documentation auditing or direct observational studies.

To acquire the best research outcomes from interviews or focus group discussions, the following issues

need to be considered. (1) To ensure the discussion with the study participants is on track and will provide answers to the research questions or lead to the identification of key issues impact on HIS introduction, a detailed interview or focus group discussion guide needs to be developed before the field investigation. (2) An adequate number and variety of stakeholders need to be interviewed to ensure that the interview results truly represent the perceptions of the study population. A general principle is that the sample size is saturated when no new issues are raised by the interviewees. (3) To avoid researcher bias, it is recommended that the interviews are audio - recorded, then transcribed into Microsoft Word documents for detailed content analysis. (4) Content analysis need to be conducted systematically. Constant comparison and categorization is required. There are several software packages for systematic qualitative data analysis, such as QSR NVIVO.

3.2.2 Other qualitative data collection methods Questionnarie survey, documentation auditing and observational study can be both quantitative and qualitative data collection methods, depending on the questions the method is designed to solve and the structure of the instrument. Open - ended questionnaires are used to seek answers from the respondents about particular issues or questions. It advantage is easy to administer across a large population. As the answers to the open - ended questions can be diverse, qualitative content analysis needs to be conducted on the answers, the same as for interviews and focus group discussions.

If the purpose of the observation is to understand how health care workers work, what is the process they follow to complete a particular task, instead of measuring the amount of time spent on each activity, then the observation is qualitative. Qualitative observation can provide answers about how healthcare workers use the system or work, what is the workflow that they follow to complete a particular task.

If the aim of the documentation analysis is to gather information about how and why decision has been made, whether a particular information exists or not, then the nature of document analysis is qualitative, not quantitative.

The information gathered from the above quantitative and ethnographic research, once triangulated, will depict a holistic and accurate picture of what has happened, why and how and what is the direction for the further evolution of the HIS. The rich information with adequate granularity will form a solid evidence base for the decision makers to justify their strategies and interventions for improving the performance of the HIS to support organizational mission and vision. This will again manifest the essential role of HIS evaluation in ensuring return on investment from the HIS at each stage of system implementation and post - adoption evolution.

4 Conclusion

After justifying the importance of HIS evaluation, this paper suggests the application of the D&M IS Success Model as a conceptual framework for evaluating HIS. The limitations of the D&M IS Success Model is lacking the capacity to explain why and how actions and consequences relate to each other, thus cannot lead to comprehensive and accurate understanding about the change processes for the introduction of HIS. Therefore, a multi - method approach that incorporates both quantitative and ethnographic methods, underpinned by the D&M IS Success Model is suggested.

It is important for the success of HIS evaluation that an evaluator triangulates the multiple methods and the results to reach balanced, accurate and complete findings about the processes and outcomes of HIS introduction. Thus the common research methods for field data collection and the research questions each method addresses are briefly explained. Using the multi - method approach introduced in this paper will facilitate management in identifying and prioritizing effort to address

the key challenges at different stages of system introduction; therefore will reduce the failure rate and maximize the benefits of HIS investment.

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5 结论

GIS 技术极大地促进了空间分析的需求和应用。GIS 应用的最高目标是空间决策支持，而空间决策支持的核心必然是空间分析。在 2003 年非典疫情中，利用 GIS 系统为研究北京市非典型性肺炎的分布，确定高危人群和高发地区发挥了积极的作用。因此，基于 GIS 的空间分析来分析疾病发生、发展中所涉及的诸多影响因素以及相关的危险因素，首先能够准确地传递和及时地表达疫情的时空变化趋势，其次能够客观地反映各方的信息，综合分析，给决策层提供一个清晰的、定量的、动态的疫情数据印象。通过在先进的地理信息系统（MapInfo）平台上开发的疫情分析应用软件，建立地图数据与传染病信息库的关联，将疫情数据与其空间位置相联系，实现了区域疫情分析、病例分布分析、病例转归分布等空间直观展示的功能，为有效控制疫情发挥重要作用。目前 GIS 系统已成为很多公共卫生和流行病学项目的一个重要组成部分。建立疾病流行的 GIS 数据平台，在此基础上充分利用 GIS 系统为预防控制疾病，保护人群健康提供决策依据。

随着 GIS 在疾病控制领域的不断应用，今后需要从传染病发病信息的收集、传递、分析、分析结果的表达、对政府决策的影响以及进而对传染病的控制带来的直接和间接影响等方面，对 GIS 系统进行效果和效益评价，评价 GIS 系统在控制传染病的过程中的有效性。