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A novel mixed sustainability-resilience framework for evaluating hospital information systems

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ABSTRACT

Information systems (ISs) are one of the most widely used systems in different organizations especially hospitals. Improving the performance of a hospital information system (HIS) is one of the most important tasks for patient satisfaction and health. To do this, a mixed sustainability-resilience framework for evaluating HISs is proposed in this study in order to enhance their performance from a mixed sustainability-resilience view. First, a comprehensive framework including suitable sustainable and resilience indicators for performance enhancement of HISs is provided. Then, the importance weight of each indicator is achieved by using the best-worst method (BWM). Required data is obtained through a standard questionnaire. A data envelopment analysis (DEA) is applied to evaluate HIS performance in different departments of a real case study. Additionally, improvement actions are obtained by considering the effect of each selected indicator on the HIS performance through a sensitivity analysis. Also, appropriate strategies for improving the resilience and sustainability aspects of the HIS are presented using strengths-weaknesses-opportunities-threats (SWOT) matrix. Using the results, designers can build more intelligent HISs from both sustainability and resilience perspectives.

1. Introduction

Information technology has an insightful impact on various complex information systems (ISs) such as hospital information systems (HISs). It reduces costs and improves the quality of care. In this regard, it is quite necessary to assess HIS from a mixed sustainable and resilience viewpoint. The reason is that such a resilient and sustainable system not only works well in disastrous/disruptive situations but also accounts for environmental, social and economic issues.

Resilience engineering (RE) as a recent concept is increasingly considered by several researchers to cope with disruptive events/incidents in different systems/supply chains [1–4]. Today, there are several risks threatening organizations. Therefore, in light of developing a business continuity management (BCM) system, they are forced to design resilient systems and infrastructures to be able to continue their business even in disruptive situations [5–8].

The main goals of a HIS are to increase the quality, effectiveness and efficiency of health services. To achieve these goals, healthcare systems should be continuously monitored and evaluated. In this regard, a healthcare organization should normally invest in information technology (IT) to improve the quality of healthcare and reduce costs [9]. Based on previous studies, the quality of patient care and safety will be enhanced by implementation of HISs. This aim is achieved by reducing drug mistakes, improving the performance and effectiveness of service providers, reducing treatment costs, and saving resources in the health and medical organization. Hence, evaluation of HISs seems essential to increase the performance of healthcare systems and identification of their weaknesses and strengths. Considering sustainability and resilience simultaneously, not only makes the system more resilient in crises, but also considers the environmental, social, and economic issues and provides a comprehensive assessment. In this way, a novel and comprehensive framework including RE and sustainability is provided based on previous studies and experts' opinions in this study. A standard questionnaire is designed and used for collecting the required data, and Best-Worst Method (BWM) is applied to rank each indicator of the proposed framework. It should be noted that each IS includes three components namely software, hardware, and human. This study not only addresses software aspects of HIS, but also includes hardware and human resources. To show applicability of the proposed framework, a real hospital is evaluated by data envelopment analysis (DEA). Finally, improvement actions regarding sustainability and resilience aspects are derived by applying a number of sensitivity analyses. Moreover, enhancement strategies are derived by applying strengths-weaknesses-opportunities-threats (SWOT) analysis. In this manner, HIS decision

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makers (DMs) can develop and enhance their own HIS by considering the obtained results from this study and continue their business in disruptive/disastrous situations.

The rest of this paper is organized as follows. The relevant studies are reviewed in Section 2. The proposed framework is explained in Section 3. Section 4 presents the proposed methodology. Computational results are provided in Section 5. Finally, conclusions and future studies are provided in Section 6.

2. Literature reviews

In this section, relevant studies regarding the evaluation of HISs are reviewed. There are different evaluation methods for assessment of HISs. In this regard, Kushniruk and Patel [10] studied about the evaluation methods of HISs for which they considered cognitive and usability engineering methods. Peute et al. [11] applied a framework to evaluate HISs from objectives, medical domain, designs, and user profiles viewpoints. In addition, Ash et al. [12] pointed out that error reduction is one of the major results of cooperation of IS regarding patient care. Nguyen et al. [13] prepared a review about electronic health record and provided benefit of implantation of this electronic record. Yusof et al. [14] proposed a qualitative framework including human, technology, and organizational factors to evaluate HIS. Karahoca et al. [15] designed and developed software prototypes for emergency department. They evaluated effectiveness and user satisfaction of the proposed software by using a case study. Lee et al. [16] identified the difficulties and the obstacles regarding the success of a IS in three categories namely human factors, organizational and technology based on literature review.

Several studies used statistical methods and questionnaire to evaluate HIS. In this regard, Khalifa and Alswailem [17] identified those factors affecting the performance and satisfaction of HISs. They used statistical methods and questionnaire to recognize important factors. Finally, availability of staff to equipment was recognized as one of the most crucial factor. Chen and Hsiao [18] applied questionnaire and structural equation model (SEM) technique to identify the most important factors to enhance the quality of ISs. Rahman et al. [19] considered the impact of hospital development, IT knowledge, and equipment on e-services by questionnaires and multiple regression method.

HISs can be evaluated through decision making methods. Ahmadi et al. [20] identified important hospital adoption factors regarding HIS technology in Malaysia. To do this, they applied fuzzy analytic hierarchy process (AHP) to determine the most important factors. Also, Ahmadi et al. [21] proposed a new framework based on human organization technology model for HIS adoption in Malaysia. Nilashi et al. [22] applied fuzzy analytic network process (ANP) to recognize HIS adoption factors in a real case study. Yucel et al. [23] used a fuzzy decision-making model to assess HIS by considering technological, individual, and organizational factors. Also, to suggest appropriated strategies and benchmarking regarding IT/IS, SWOT analysis [24] and balanced scorecard (BSC) [25] were applied respectively.

One of the important issues regarding HIS is sustainability. Watson et al. [26] studied green ISs and developed an energy informatics framework based on eco-goals for environmentally sustainable ISs. Moreover, Nyström and Mustaquim [27] took into account sustainable IS from human computer interaction viewpoint to design the interfaces regarding users for more sustainability.

Unpredictable events may occur in any emergency departments. A robust IS helps to coordinate among hospitals, professionals, and government [28]. Azadeh et al. [29] proposed a resilience based framework for evaluation of ISs. They used fuzzy DEA to rank different IS departments from the resilience viewpoint. Zhang and Lin [30] considered resilience and RE from different viewpoints and proposed five components to design a resilient enterprise IS namely, redundancy infrastructure system, redundancy management, monitoring, vulnerability, and learning. Wang et al. [31] proposed a model to measure the resilience degree of an IS. To establish their model, they considered the recovery ability of a IS after its damage. Riolli and Savicki [32] considered an organizational resilience framework for ISs. They took into account community, competence, connections, commitment, communication, coordination, and consideration as resilience factors regarding ISs. Also, Yan [33] considered a security approach for evaluation of ISs. The author pointed out that boundary expansion creates more complexity for the security while the proposed approach overcomes this issue. Feng et al. [34] considered security as a crucial issue regarding ISs. To do so, a secure risk model was developed based on Bayesian network.

As mentioned before, HISs play a significant role in the community health; hence the continuous assessment of these systems seems to be essential. Sustainability and resilience are two important issues regarding the evaluation of ISs, which were studied separately in previous studies. In this paper, to evaluate the potential failures and planning to cope with unexpected events in a HIS, a novel comprehensive sustainability-resilience framework is introduced for HISs. This study simultaneously takes into account the sustainability and resilience aspects, which results in a more comprehensive evaluation and, ultimately, more effective HIS design. Also, in this study, not only the aspects of software are considered, but also the human and hardware aspects are taken into account. Finally, strategic actions for enhancement of HIS from a mixed sustainability-resilience framework are suggested by SWOT analysis. Moreover, using a combination of qualitative and quantitative modeling methods to evaluate a real HIS is another contribution of this paper.

3. Proposed mixed sustainability-resilience framework

In recent years, sustainability is a key concept in business management. This concept accounts for economic, environmental, and social issues simultaneously. Hereupon, organizations can make more effective decisions by considering these dimensions [35]. This concept is one of the key issues in supply chain management considered by researchers in the recent years [35–37].

As maintained before, one of the important issues in order to achieve a more effective IS is considering the sustainability dimensions in the design/redesign phase. It is clear that the role of IS in achieving sustainability is undeniable [38]. Moreover, several academic research works have been conducted in the area of sustainable IS [26,38,39]. Therefore, this concept is one of the important issues that is increasingly being considered by researchers in different topics. Due to the importance of this concept, it is incorporated in the proposed framework to evaluate comprehensively a HIS from the economic, environmental, and social viewpoints.

Another concept that has been considered in the proposed framework is resilience. Resilience as a new concept can be used for better responding to random accidents in different industries [1–3]. In the face of disruptions, organizations can come back to the normal state by incorporating resilience strategies [35,40]. In this paper, RE factors introduced by Wreathall [41] are considered for the evaluation of HIS from resilience viewpoint. These factors were considered in several studies for assessment of different systems and industries for example; information systems ([42]), Petrochemical plants [2]; pharmaceutical plants [43]. Based on previous studies, this concept has an important role in controlling the incidents and keep the performance of the organization at the acceptance level in the face of disruptions [5,8]. Because the availability and function of the HIS is very important in order to improve the quality of care and patient satisfaction, resilience concept is taken into account to make HIS more effective in the time of crises. That is why the proposed framework accounts for this concept.

It should be noted that considering the sustainability and resilience measures concurrently even in the development of supply chain networks is in its infancy [6,7,35,37,44]. Therefore, given the importance of sustainability and resilience concepts in different systems especially