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Research Article

Ranking evaluation factors in hospital information systems

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Abstract. Objective: Hospital information systems can improve the quality of health care. Evaluations of these systems use different methods and criteria. The present study ranked the most important factors influencing evaluation in various systems. Prioritizing the essential factors can increase the efficiency of the evaluation process and reduce the cost and time of evaluation by focusing on target factors. Methods: A survey of relevant literature extracted three main factors and 29 subfactors with which to design a study framework. The suggested framework includes three factors (organization, technical, and human), seven subfactors, 17 sub-subfactors, and five sub-sub-subfactors. A questionnaire format was developed using analytical hierarchy process and 28 paired comparisons using the Saaty scale. The questionnaires were completed by ten experts in health information management and medical informatics. Results: The findings ranked human factors, with a weight of 0.55, as the most important, followed by organization (0.25), and technology (0.19). Of the subfactors, security was accrued the most points (0.617) and work flow, with a weight of 0.827, was the most important among sub-subfactors. Conclusions: This study showed that multiple criteria decision-making methods such as analytical hierarchy process have the potential for use in health research and provide positive opportunities for health domain decision-makers.

Key Words: Analytic hierarchy process, Multiple criteria decision-making, Hospital information system, Evaluation factor, Criteria.

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Introduction

Health information management can revolutionize delivery of health services if accepted by health personnel (Tan & Payton, 2010). The adoption of a health management system can decrease the cost of and improve health services and business management (Brigl et al 2005). A hospital information system (HIS) is a comprehensive software program which integrates patient information and makes possible communication between different parts of the hospital and other health care centers. It is designed to manage the administrative, financial and clinical aspects of hospitals and healthcare facilities and accelerates patient health care (Ismail et al 2010).

Health information systems are designed to promote performance of health professionals and health organizational output. Considering the intervention of these kind of systems, it is ethically necessary to evaluate them and ensure their efficiency (Ammenwerth et al 2004). A HIS evaluation can be used as a tool for the measurement and comparison of HIS properties (Hyatt, 2015). Failure to evaluate the system can increase misunderstanding the potential benefits of the HIS, but evaluation must be done according standard criteria and the requirements specified to achieve maximum benefit (Abdelhak et al 2007).

The complexity of a HIS makes it more difficult to design an evaluation process (Booth et al 2001). Many studies have evaluated information systems from different perspectives. Delone and Mclean assessed the success of HISs and recommended the indicators of system quality, information quality, service quality, intentions for use, user satisfaction, and its effect on individuals and organizations (Delone & McLean, 1992; Delone & McLean, 2001). Yusof et al. used a model called HOT-fit to categorize HIS evaluation criteria into three groups: human, organization, and technology (Yusof et al 2008).

Hamborg et al. introduced isometrics as a valid technique for evaluation of HISs based on ISO 9241 Part 10 standards. These include the criteria of suitability for task, self-descriptiveness, controllability, conformity with user expectations, error tolerance, suitability for individualization, and suitability for learning (Hamborg et al 2004). Hunber and Blunder listed seven categories for evaluation of HISs: technical quality, software quality, architecture and interface quality, IT vendor quality, IT support and IT department quality, workflow support quality, IT outcome quality and IT cost (Hübner-Bloder & Ammenwerth, 2009). Littenjons and Wyatt assessed criteria such as optimal training, change management and support, improving the communication between systems, increasing revenue, and reducing service costs to evaluate HISs (Littlejohns et al 2003). Evaluation of HISs must also consider multidimensional aspects of user needs, goals, and cost containment (Farzandipour et al 2011).

HIS can be evaluated using numerous quantitative and qualitative factors and various frameworks; however, the importance and weight of each evaluation factor is not the same. Simply gathering a list of these factors and presenting them to stakeholders having different organizational environments, needs, and tastes would lead to disagreement (Hussain, 2014). Limited studies have focused on a specific subject, such as the factors influencing user satisfaction, critical success factors, and implementation of HIS (Hussain, 2014; Kimiafar et al 2014; Ahmadi et al 2014). The present study developed a new framework for HIS evaluation using multi-criterion decision-making (MCDM) and analytical hierarchy process (AHP). This method prioritizes relevant factors and sub-factors, and presents the most important factors for the evaluation of the systems.

Materials and methods

Selection of study method

MCDM was selected for use because several indicators exist for evaluating HISs. MCDM is a method for decision-makers who must assess multiple criteria and different alternatives to make the best decision (Tzeng & Huang, 2011). One MCDM method is AHP developed by Saaty (Tzeng & Huang, 2011). Saaty concluded that "AHP is a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales" (Saaty, 2008). Using this hierarchical construction, an intricate decision-making problem can be broken down into many simple problems (Salmeron & Herrero, 2005). This method was considered as the reference method in the present study.

Analytical hierarchy structure

The goal was first defined and a literature review was carried out to find factors and subfactors using PubMed, Google Scholar, Scopus, and Ovid. The keywords applied to the search were hospital information system evaluation factor, evaluating framework for HIS, indicator for HIS evaluation, assessment of HIS, and health information system assessment. All relevant literature was reviewed and the most significant factors were extracted. From among the most frequently cited factors, human, organization, and technology were selected as the main factors. Using the finding of past studies and the opinions of researchers and experts, the subfactors of these main factors were chosen as the subfactors, sub-subfactors, and sub-sub-subfactors of the present study (Delone & McLean, 1992; Delone & McLean, 2001; Yusof et al 2008; Hamborg et al 2004; Hübner-Bloder & Ammenwerth, 2009; Littlejohns et al 2003; Farzandipour et al 2011; Hussain, 2014; Kimiafar et al 2014; Ahmadi et al 2014; Ehteshami et al 2013; Yu P, 2010; Bossen et al 2013; Wager et al 2005). A summary of the final factors influencing HISs evaluations are shown in Table 1. After selection of the factors, the hierarchical framework was set up (Figure 1).

Development of study questionnaire

The hierarchical structure was used to design 28 paired comparisons as questions. The questionnaire had two main sections. The first section included information about the purpose of the study and questions eliciting demographic information from the participants. The second section comprised comparison questions. The intensity score of importance for the Saaty scale used was: equal (1), moderate (3), strong (5), very strong (7) and extreme (9) (Saaty, 2008; Saaty & Vargas, 1994).

The validity of the questionnaire was verified based on the recommendations of four medical informatics experts before the questionnaires were distributed. To assure the reliability of the questionnaire, the test-retest method was employed by the four

Table 1: Factors, subfactors and sub-sub-subfactors influencing HISs evaluations

Main Factors	Subfactors	Sub-subfactors	Sub-Sub-subfactors	References
Human	Role & Task	Vendors	Customer Service	8-10, 12, 15-17
			Training	
			Qualified staff	
		Users	Level of use	8-10, 14
			Goals	
	User Satisfaction	Flexibility	-	10, 16, 23, 24
		Usefulness	-	
Organization	Cost & Benefits	Profit	-	8-10, 12, 13
		Total costs of the HIS sys	-	
	Environment	Competition	-	8-10
		Government	-	
	Structure	size	-	8-10, 12
		Workflow	-	
Technology	Security	Physical Security	-	8-10, 16, 17, 25
		Technical Security	-	
	Usability	Error tolerance	-	8-12, 15, 16, 22
		Controllability	-	
		Learning suitability	-	
		Self-descriptiveness	-	
		Reversibility	-	

Table 2: Demographic data for questionnaire

ID	Gender	Age		Final Degree	Experience		
		30-40	40-50		Less than 4 years	Between 4 to 8 years	More than 8 years
ID1	Male	-	46	PHD- Postdoc	-	-	✓
ID2	Female	-	41	PHD	-	-	✓
ID3	Male	34	-	PHD	-	✓	-
ID4	Female	36	-	PHD	-	-	✓
ID5	Male	32	-	MS	-	✓	-
ID6	Female	38	-	PHD	-	-	✓
ID7	Female	31	-	MS	-	✓	-
ID8	Male	34	-	PHD	-	✓	-
ID9	Female	35	-	PHD	-	✓	-
ID10	Female	34	-	PHD	-	✓	-

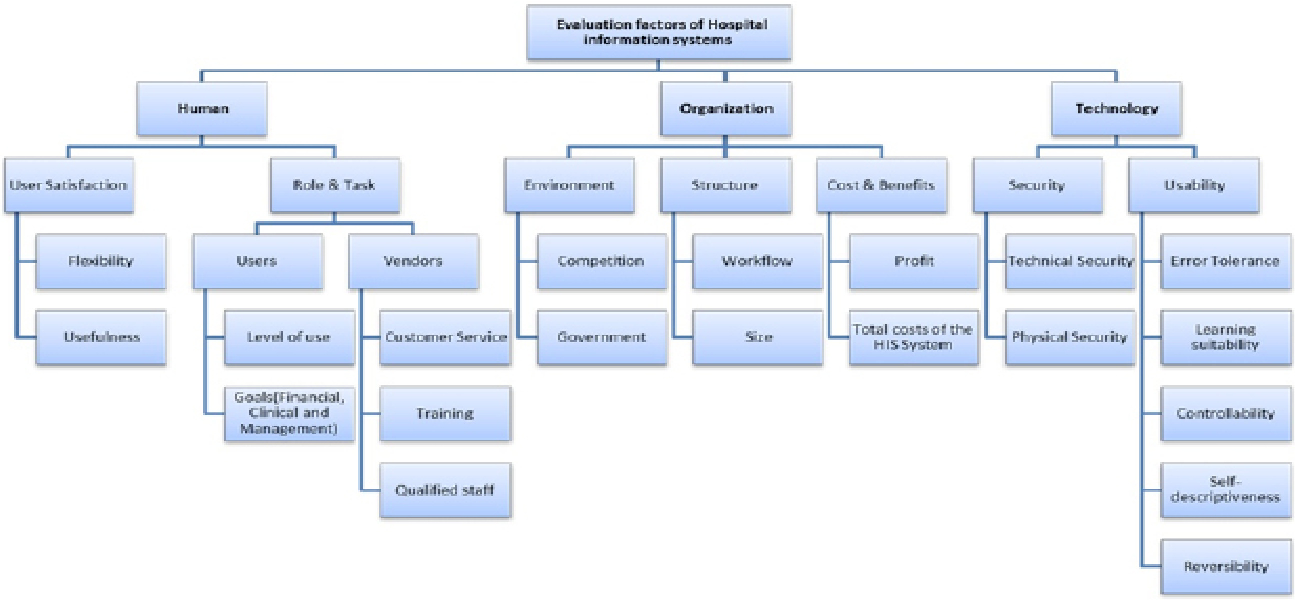

Figure 1: Hierarchical structure of hospital information system evaluation factors

Figure 2: Priorities with respect to weights for main factors

health information management specialists who were asked to complete the questionnaire a second time one week later. The intra-class correlation coefficient of reliability was analyzed using SPSS software, which verified the test-retest reliability (0.8). The full questionnaire is shown in Supplementary Table 1.

Participants

Saaty stated that a small number of participants are adequate for the analysis of the AHP (Saaty & Vargas, 1994); thus, the 13 questionnaires were sent to experts in health information management and medical informatics over a period of 15 days. Ten of the questionnaires were returned. Email and face-to face methods were used for data collection. In both methods, a sufficient description of the questionnaire and instructions on how to complete it were given to the participant.

Calculation of local weights of each comparison matrix

Saaty presented four methods to calculate the local weight: row sum, column sum, arithmetic mean, and geometric mean. To calculate the geometric mean, the local weight of the rows of the matrix was calculated and then normalized (Saaty, 2008; Saaty & Vargas, 1994). Expert Choice software was used to calculate and normalize the geometric mean of each row of the comparison matrix.

Consistency ratio

The consistency ratio (CR) was evaluated to control the validity response of the participant for the paired comparisons and overall consistency. The validity of the respondents will be

Table 3: Evaluation matrix with respect to the main factors

	Human	Organization	Technology	Weight
Human [a]	1	0.524	3.201	0.55
Organization [a]	1.907	1	1.172	0.256
Technology [a]	0.312	0.852	1	0.194

[a] Consistency ratio =0.01.

confirmed if the inconsistency rate is ≤0.1 (Saaty, 2008; Saaty & Vargas, 1994). The CRs in this study were calculated using Expert Choice and all of them were less than 0.1.

Results

Six of the participants were female (60%). The mean age of participants was 36 years. This fell into the 30-40 years age group (8 participants) who showed the highest prevalence (80%). Most of participants had a PhD (frequency of 8 persons; 80%); (Table 2). Table 3 shows the comparison matrix for the test criteria. The most important indicator was the human factor, with a weight of 0.55, followed by organization with a weight of 0.256 and technology with a weight of 0.194 (Figure 2). Table 4 shows the weights of all factors, subfactors, and sub-sub-subfactors. The security factor, with a weight of 0.617, had the most points, followed by user satisfaction (0.587). Work flow, with a weight of 0.872, was the most important sub-subfactor. The lowest weight was recorded for learning suitability (0.125).

Discussion

It appears that HIS evaluation has changed from a technical perspective to a human and organizational perspective; in

Table 4: Ranking weights of factors, subfactors and sub-sub-subfactors in HIS evaluation

Main Factors	Local Weights	Subfactors	Local Weights	Sub-subfactors	Local Weights	Sub-Sub-subfactors	Local Weights	Overall Weights	Overall Ranks
Human [b]	0.55	Role & Task [b]	0.413	Vendors [d]	0.264	Customer Service	0.512	0.031	11
						Training	0.202	0.012	18
						Qualified staff	0.286	0.017	14
				Users [a]	0.736	Level of use	0.321	0.054	8
						Goals	0.679	0.114	3
		User Satisfaction [b]	0.587	Flexibility	0.607	-	-	0.196	1
				Usefulness	0.393	-	-	0.127	2
Organization [b]	0.256	Cost & Benefits [b]	0.472	Profit	0.532	-	-	0.064	6
				Total costs of the HIS sys	0.468	-	-	0.057	7
		Environment [b]	0.149	Competition	0.634	-	-	0.024	12
				Government	0.366	-	-	0.014	16
		Structure [b]	0.378	size	0.173	-	-	0.016	15
				Workflow	0.872	-	-	0.084	4
Technology [b]	0.194	Security [b]	0.617	Physical Security	0.314	-	-	0.037	9
				Technical Security	0.686	-	-	0.082	5
		Usability [c]	0.383	Error tolerance	0.184	-	-	0.013	17
				Controllability	0.234	-	-	0.018	13
				Learning suitability	0.125	-	-	0.009	20
				Self-descriptiveness	0.14	-	-	0.01	19
				Reversibility	0.317	-	-	0.034	10

other words, from objective to subjective issues (Sadoughi et al 2013). The present study found that human factors were the most important in the HIS evaluation framework. Geremy et al. emphasized human factors as a central base for HIS evaluation and reported that systems without user interaction had lower failure rates than systems run by humans (Gremy et al 1999).

User satisfaction, as a subfactor of human factors, was the most important. This finding is similar to the results of many studies and indicates that user satisfaction is an essential aspect of the measurement of HIS success (Yusof et al 2008, Aggelidis & Chatzoglou, 2012]. Berg used a socio-technical approach to HIS evaluation to introduce role and task as subfactors of human factors (Berg, 1999). In the proposed ranking, the most important human sub-subfactor was user role and task. This confirms the utmost importance of systems users in evaluation. Yusof et al. developed a human organization technology fit (HOT) framework, and suggested structure and environment factors for evaluating the organizational aspects of their models (Yusof et al 2008). Cost and benefits was a factor added in the current study and consequently ranked first among the subfactors of organizational factors. Economic factors have a strong role in the success and failure of HISs (Sadoughi et al 2013). In spite of concerns about IS investment and return on investment, introducing HIS will help relieve these matters; therefore, the benefit of evaluation of HIS can be a step toward better acceptance of the system by stakeholders of the systems. Workflow as a factor in HIS evaluation was investigated by Berg (Berg, 1999) and received the highest score among organizational sub-subfactors in the current research.

Technical aspects placed third among other factors. Security was the most important subfactor of all subfactors, which shows that research participants were concerned about the security of the HIS. It could also be considered as a technical subfactor to be evaluated in the IS success model (Sadoughi et al 2013). Zikos et al. reported the adequacy of data security as an indicator of IS success (Zikos et al 2010). Aggelidis and Chatzoglou evaluated security as a subfactor of information quality, which plays a role in the success of HISs (Aggelidis & Chatzoglou, 2012). Yen identified usability factors as a major obstacle to the adoption of health information technology. They proposed a three-level model for health IT usability evaluation (Yen & Bakken, 2012). Hamborg et al. suggested a questionnaire based on a usability evaluation for HISs (Hamborg et al 2004). Reversibility received the highest score among usability subfactors in the current study with a weight of 0.317.

Conclusion

SThe reviews of the relevant studies published about evaluation of HISs are described in the present study. Different methods and frameworks were used for HIS evaluation. It was found that MCDM methods are useful in HISs to rank and score different aspects of the frameworks. Evaluation of more essential factors increase the efficiency of the evaluation process by reducing costs and the time needed for the evaluation by focusing on target factors.

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