DANP-based method for determining the adoption of hospital information system

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Abstract: The primary purpose of this study is to identify the essential factors that are significantly driving or hindering the decision to adopt a hospital information system (HIS). This study proposes the initial theoretical model that integrates Technology Organisation Environment (TOE) framework, Human Organisation Technology (HOT) fit model and institutional theory. The initial model consists of four main dimensions and 13 variables, which are the most frequently used in prior literature and essential for the investigation of HIS adoption. The data were collected from healthcare experts who have full knowledge of HIS. Accordingly, the recently developed DANP (Decision Making Trial and Evaluation Laboratory (DEMATEL) based Analytic Network Processes (ANP)) method is employed for assessing interdependency and give weights to dimensions and criteria. As per the expert's knowledge and experience, the results indicate that perceive technical competence, compatibility, top management support, and vendor support are found to be the most essential variables for the successful adoption of HIS.

Keywords: hospital information system; public hospitals; TOE framework; HOT-fit model; institutional theory; DANP method.

Reference to this paper should be made as follows: Shahzad, K., Jianqiu, Z., Zubedi, A., Xin, W., Wang, L. and Hashim, M. (2020) 'DANP-based method for determining the adoption of hospital information system', *Int. J. Computer Applications in Technology*, Vol. 62, No. 1, pp.57–70.

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1 Introduction

The advancement of Information Systems (IS) has changed the environment in every field of life. Consequently, the healthcare delivery system is also changing rapidly all over the world due to the development of IS. These innovations are providing various benefits in healthcare organisation with the intention to minimise medical error, reduce cost, assist the search for medical solutions and help in decision making (Ahmadi et al., 2017; AlSobeh et al., 2019; Shahzad et al., 2018). These innovations are creating the path for the integration among the medical field experts within the organisation globally (Sepucha et al., 2016). On the other hand, the patients are complaining that there is need to pay more attention to them during the medical treatment (Kassirer, 2000); Shieh et al., 2010). Therefore, the patients are demanding electronic services from the hospitals, but the response rate from healthcare providers is prolonged (Shieh et al., 2010). Until 2009, even in the USA, only 17% of hospitals have functional Computerised Physician Order Entry (CPOE) in place (Maslove et al., 2011).

The hospital can improve the quality and performance of the medical services through the precise adoption of information technologies. Therefore, for the development of Information Technologies (IT) both public and private hospitals are investing tremendously in order to get variants outcomes in its response (Shahzad et al., 2018). Among these IS, Hospital Information System (HIS) is a comprehensive system which is designed to integrate all information systems to manage the financial, clinical and administrative aspects of a hospital (Ahmadi et al., 2015). The hospital can get many benefits from the adoption of HIS, ranging from administration systems to medical systems (Esfahani et al., 2018). The implementation of HIS can enhance the patient care and provide comprehensive information for decision making. Moreover, in clinical practice, there are some limitations which can be addressed with the implementation of HIS (Esfahani et al., 2018; Liang et al., 2017; Nilashi et al., 2016). Currently, the priorities of IT are to upgrade in-patient clinical systems, minimise medical error through HIS implementation in the hospital (Esfahani et al., 2018).

A study conducted in Shaukat Khanum Memorial Cancer Hospital, and Research Centre (Pakistan) stated that the adoption of HIS could improve the quality of performance of the hospitals, error reduction and enhance the quality of patient care (Sultan et al., 2014). Malik and Khan (2009) discussed the case of the Pakistan Institute of Medical Science (PIMS), which is a public hospital where the strong vision of top management has implemented HIS. Sultan et al. (2014) concluded that after the implementation of HIS, the relative advantage is very high in perspective of cost reduction.

Various studies have been conducted in the arena of HIS. Numerous studies explored the influencing factors according to the culture and environment of Malaysian public hospitals (Ahmadi et al., 2015, 2017; Ahmadian et al., 2014; Nilashi et al., 2016). Esfahani et al. (2018) investigated influencing elements according to the culture and environment of Iranian public hospitals. However, there is no comprehensive theoretical assessment of the implementation of HIS has been done in Pakistan public sector hospitals, while HIS has many potential outcomes which are highlighted. In Pakistan, the rate of HIS adoption is slow, and literature on HIS is very limited (Mali and Khan, 2009). The challenges in the implementation of HIS in public hospitals are related to Environment, Human, Technology and Organisation issues. So, the main goal of this study is to evaluate the influences of Environment, Human, Technology and Organisation context on HIS adoption in the light of Human, Organisation, and Technology (HOT) fit model and Technology, Environment and Organisation (TEO) framework. Furthermore, the existing literature of HIS use the combination of ANP and DEMATEL for prioritising factors (Ahmadi et al., 2015, 2017; Ahmadian et al., 2014; Esfahani et al., 2018). The combination of these two methods can be divided into four types, but DEMATEL-based ANP (DANP) has the benefit of all other three types (Gölcük, and Baykasoğlu, 2016). Hence, according to our knowledge, for the evaluation of HIS adoption, no one uses this method while this method has benefits of all other methods. So, we employ the DANP method for the assessment of factors affecting the adoption of HIS in Pakistan public hospitals.

1.1 Research questions and objectives

The research questions of this study which will guide us and give the way to accomplish our primary goals, are as follows: (a) What theoretical model is appropriate that can be proposed for HIS adoption in Pakistan? (b) What are the essential factors that can influence the decision for the adoption of HIS? (c) What is the Multi-Criteria Decision Making (MCDM) model precise to weigh the elements for the adoption of HIS in Pakistan public sector hospitals?

The research objectives of this study are (1) to explore which theoretical model is appropriate that can be proposed for HIS adoption in Pakistan (2) to investigate the essential factors that can influence the decision to adopt HIS. (3) To explore which MCDM model is precise to weigh the elements for the adoption of HIS in Pakistan public sector hospitals.

2 Literature review

2.1 Hospital information system (HIS)

HIS usually refers to IS which is an integrated system that contains many IS including reporting IS, laboratory test and medical examination system, inpatient IS, nursing IS, outpatient IS, and so on (Hsiao et al., 2011). According to Shahzad et al. (2018), HIS is a computerised system whose purpose is to create the paperless environment that covers all operations of the hospitals including financial, clinical and administrative.

2.2 Current status of HIS

The arena of HIS adoption has measured by many research scholars. Schoen et al. (2009) conducted a study in US hospitals and rigorously evaluated the adoption status of electronic health records (EHR). According to their results, only 17–35% of hospitals have EHR during 2005–2007. In 2006, according to the American Hospital Association (AHA), only 11% of hospitals had EHR in place. Later, the AHA survey indicated that the status of EHR adoption in 2008 and 2009 was 9% and 12%, respectively. Till 2009, in the USA, only 17% of hospitals have functional Computerised Physician Order Entry (CPOE) in place (Maslove et al., 2011). It clearly shows that there is a low adoption rate even in US hospitals.

In the case of developing countries, few studies identified issues related to HIS adoption (Idowu et al., 2008; Lucas, 2008). They stated that clarity of the software functionality, complexity in the system, internet connectivity, inadequate electric supply, lack of government interest in IT adoption and lack of adequate funding are core issues in HIS implementation. Hsiao et al. (2009) and Sulaiman (2011) discussed the cases of Thailand and Taiwan and demonstrated that the HIS adoption in these countries is still in the early phase. Moreover, the rate of HIS acceptance by physicians is also low. In Malaysia, 22 out of 137 public hospitals have successfully implemented the HIS (Ahmadi et al., 2017). In the case of Pakistan, Malik and Khan (2009) and Sultan et al. (2014) explained the success story of HIS implementation in both public and private hospitals. They also demonstrated that the adoption rate of HIS in Pakistan is meagre.

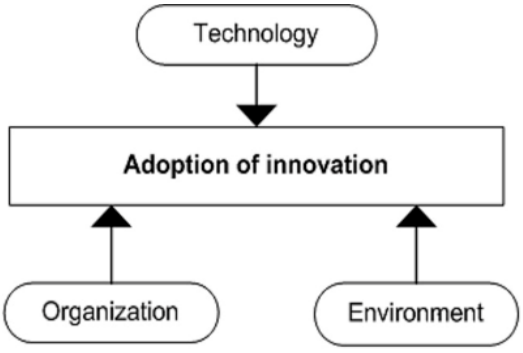
2.3 IS adoption theories

There are many studies that have been done on technology adoption, and innovation across various IS domains. Parker and Castleman (2009) stated that in information journals at least 128 articles had been published on technology adoption and innovation during the period of 2003–2008. Therefore, the theories in this domain have some differences in practice, but the objectives have similarities (Esfahani et al., 2018; Straub, 2009).

2.3.1 TOE framework

Tornatzky et al. (1990) developed the TOE framework. TOE framework explains three characteristics of the organisation that could be barriers or drivers in the adoption and implementation of new technology (see Figure 1). The technological aspect includes all internal and external technologies that belong to an organisation. This dimension consists of both existing technologies and technologies to be implemented. Organisation characteristics are related to the resources and features of an organisation which includes infrastructure, organisation size, human resources, financial resources and top management of an organisation. Environmental characteristic is the arena wherein an organisation runs its business. This dimension consists of all environment-related factors such as competitors and government policies.

Figure 1 TOE framework



The use of TOE framework gives deep insight in IS adoption in the realm of healthcare industry regarding HIS adoption (Esfahani et al., 2018; Lian et al., 2014; Lin et al., 2012). The significant number of scholars (Chang et al., 2007; Chong and Chan, 2012; Lian et al., 2014; Lin et al., 2012; Liu, 2011) stated that TOE framework is handy for establishing the theoretical basis for exploring IS adoption behaviour in the healthcare industry. For instance, Liu (2011) demonstrated that TOE framework is useful for understanding of telecare adoption and Chang et al. (2007) used TOE framework to explore the essential factors in the adoption of e-signature within a hospital. Additionally, Ahmadi et al. (2015, 2017), Esfahani et al. (2018), Nilashi et al. (2016) and Shahzad et al. (2018) described that TOE framework is handy for analysing and understanding the adoption of HIS. According to the above

mentioned debate, this study will apply the TOE framework for better understanding of essential factors that influence the adoption of HIS in public sector hospitals of Pakistan.

2.3.2 Institutional theory

Organisations have to face different external influences for instance competitors, legal requirements, conventions, and cultural differences because they do not work in a vacuum. So, we couldn't overlook the institutional pressure when we are discussing technological adoption. The institutional pressure was presented by DiMaggio, and Powell (1983). DiMaggio and Powell concluded that there are three types of institutional pressure with respect to the environment which influences the process of innovation in an organisation. These three institutional pressures are mimetic, coercive and normative.

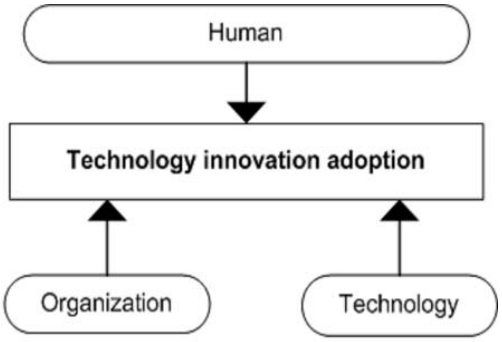
The institutional pressure that insists on an organisation to copy the technology or pattern of those organisations which are working in the same arena is called mimetic pressure (Yang et al., 2013). Coercive pressure related to the cultural assumptions of the society. It is exerted when an organisation dependent on another organisation in the shape of stakeholders. These stakeholders can be agencies, consumers, contractors, trade unions and government (DiMaggio and Powell, 1983). They can generate coercive pressure to fulfil their demands. Third pressure presented by DiMaggio and Powell is normative pressure. Organisations meet this pressure when they want to start a new business, and they have to learn distinct types of business norms and values. Based on the aforementioned discussion, this study will evaluate the essential factors which are affecting the adoption of HIS in light of institutional theory.

2.3.3 HOT-fit model

Various studies in the context of health information technology adoption mentioned that there is a lack of fitness in the human, organisation and technological (HOT) context (Ahmadi et al., 2017; Marques et al., 2011; Yang et al., 2013). To fulfil this gap, Yusof et al. (2008a, 2008b) analysed the adoption of health information system and presented essential dimensions in this regard. These dimensions can comprehensively evaluate the influencing factors in the adoption of a system.

Based on these dimensions, they developed the latest research model in the context of organisational, human and technological elements (see Figure 2). They recommended that their model is very flexible and can be implemented to assess and evaluate the development of a system life cycle in both developing and developed countries.

Figure 2 HOT-fit model



Yusof et al. (2008a, 2008b) demonstrated that to evaluate the IS adoption both researchers and practitioners can apply the HOT-fit model for better understanding in the healthcare sector. Various prior studies related to HIS have stressed on the technological issue because it is directly related to HIS success or failures (Ahmadi et al., 2015; Coiera, 2015; Lian et al., 2014; Marques et al., 2011; Shahzad et al., 2018). Kilsdonk et al. (2017) mentioned that HOT-fit model is the most suitable model for the adoption of the healthcare information system. Based on the above-mentioned discussion, this study is going to apply the HOT model in this study for identifying and evaluating the essential factors which are influencing the decision to adopt HIS.

3 Development of theoretical framework

This work will consider four dimensions for the assessment of multi-criteria decision-making model that influence the adoption of HIS. Each dimension of the framework has several sub-elements which are widely used in prior literature (Table 2). All the variables along with all dimensions are taken based on the institutional theory, HOT fit model and TOE framework. Figure 3 illustrates the conceptual framework. All these variables are mentioned and explained in Table 1.

Table 1 Description of variables

Dimension/variables	*Explanation*	*References*
	Human	
Perceived technical competence	Perceive technical competence means the capabilities of IS employees is an organisation.	(Lian et al., 2014)
Employees IS knowledge	Lin et al describe it as the sufficient knowledge to adopt an innovation.	(Lin et al., 2012)
	Technology	
Relative advantage	Relative advantage is about the technology innovation which is perceived better than its predecessor.	(Rogers Everett, 1995)
Compatibility	Roger Everett describes the term compatibility as the existing experience, values, and needs of a firm are well-suited with the innovative technology.	(Rogers Everett, 1995)
Complexity	Roger Everett defines the complexity as the technology innovation which is considered difficult to use and understand.	(Rogers Everett, 1995)
Security concern	Lin et al. describe security concern as the security of patient's data.	(Lin et al., 2012)

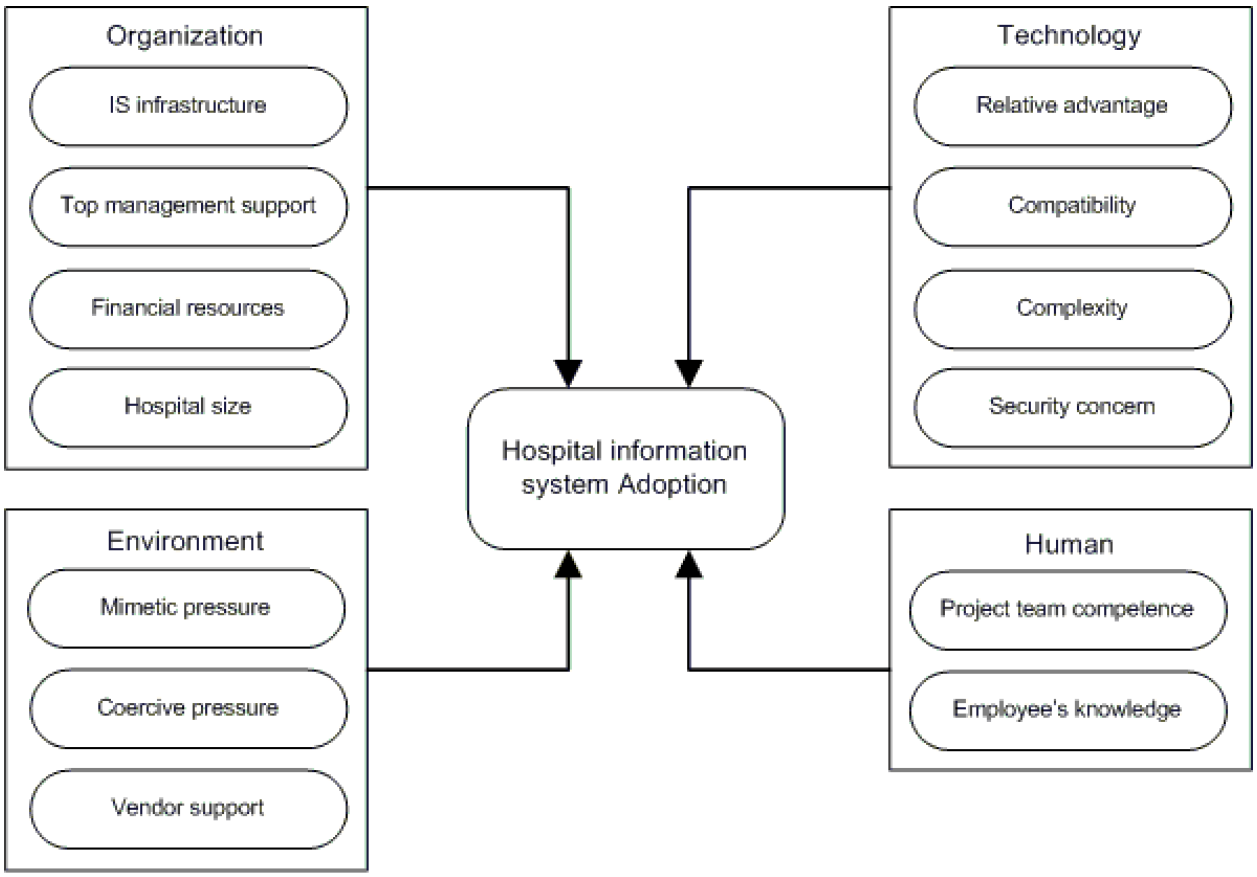
Table 1 Description of variables (continued)

Dimension/variables	*Explanation*	*References*
	Organisation	
IS infrastructure	IS infrastructure can be described as the existing resources of telecommunication and database in an organisation?	(Ahmadi et al., 2015)
Top management support	Top management support can be explained as the upper management of an organisation that can understand the function and nature of HIS and support the implementation of HIS.	(Shahzad et al., 2018)
Financial resources	Financial resources can be defined as the funding available for the implementation, installation, and maintenance of the technological innovation.	(Shahzad et al., 2018)
Hospital size	Chang et al. describes hospital size as the availability of resources to adopt an innovation in a large hospital is more as compared to a small hospital.	(Chang et al., 2007)
	Environment	
Coercive pressure	Coercive pressure develops by legal effects which are employed by structures on which the leading firm is relying.	(Yang et al., 2013)
Mimetic pressure	The institutional pressure that insists on an organisation to copy the technology or pattern of those organisations which are working in the same arena is called mimetic pressure.	(Shahzad et al., 2018)
Vendor support	Liu et al. defines the term vendor support as the support which is provided by HIS supplier or vendor for the implementation of HIS.	(Liu, 2011)

Table-2 Summary of variables with adoption theories and HTOE dimensions

			Context/Variables												
			Human		*Technological*					*Organisational*			*Environmental*		
Author	*Type of innovation*	*Adopted theories*	*Perceived technical competence*	*Employees IS knowledge*	*Relative advantage*	*Compatibility*	*Complexity*	*Security concern*	*IS infrastructure*	*Top management support*	*Financial resources*	*Hospital size*	*Coercive pressure*	*Mimetic pressure*	*Vendor support*
(Hsiao et al., 2009)	MNIS	DOI+HOT					✓			✓			✓	✓	✓
(Sherer et al., 2016)	EHR	Institutional theory											✓	✓	✓
(Marques et al., 2011)	Medical record system	TOE+HOT	✓									✓			
(Lian et al., 2014)	Health cloud computing	TOE+HOT	✓		✓	✓	✓	✓		✓	✓		✓	✓	
(Liu, 2011)	Telecare	TOE			✓	✓				✓					✓
(Hung et al., 2010)	Hospital CRM system	DOI		✓	✓		✓		✓			✓			
(Chang et al., 2007)	e-signature	TOE					✓	✓			✓	✓			✓
(Lin et al., 2012)	HL7	DOI	✓			✓		✓		✓		✓	✓	✓	✓
(Klöcker et al., 2014)	E-health	Institutional theory											✓	✓	
(Yang et al., 2013)	Vital signs monitoring system	DOI+TOE			✓	✓	✓			✓	✓	✓			✓
(Ahmadi et al., 2017)	HIS	TOE+HOT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(Shahzad et al., 2018)	HIS	TOE			✓	✓	✓			✓	✓		✓	✓	
(Ahmadi et al., 2015)	HIS	TEO+HOT	✓		✓	✓	✓		✓	✓		✓	✓	✓	✓
(Esfahani et al., 2018)	HIS	TOE+HOT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
(Ahmadi et al., 2018)	HIS	RTD+HOT		✓							✓	✓	✓	✓	
			6	4	7	7	8	5	4	8	6	9	8	8	9

Figure 3 Research framework



4 Research methodology

4.1 The selection of multiple-attribute decision making (MADM) method

Decision making is a complex activity, and every human and organisation has to deal with this situation very often. Therefore, the implementation of HIS is also a complex MADM process. MADM deals with such problems in different ways (Liu, 2018; Rawashdeh et al., 2017; Wang et al., 2018). Many MADM methods have been established for resolving MADM problems, for instance, Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), VIKOR and TOPSIS. Majority of these methods assume that measures are independent of each other but practically in various problems, this statement is not accepted (Gölcük and Baykasoğlu, 2016). Therefore, a comprehensive technique is required to resolve these problems.

In this perspective, the combination of ANP and DEMATEL is considered the most appropriate method to solve these problems (Gölcük and Baykasoğlu, 2016). Various studies in the healthcare domain have been used in this combination (Ahmadi et al., 2015, 2017; Esfahani et al., 2018). The combination of these two methods can be divided into four types, but DANP has the benefit of all other three types (Gölcük and Baykasoğlu, 2016). Hence, according to our knowledge, for the assessment of HIS adoption, no one uses this method while this method has benefits of all other approaches. So, we will employ the DANP technique for the evaluation of factors affecting the adoption of HIS in Pakistan public hospitals.

4.2 Data collection

For the collection of data, a questionnaire was designed based on HTOE (TOE and HOT) framework. The questionnaire consists of 0-4 influencing scale in which 0 means no influence and 4 means high influence. The data were collected from the hospitals of three major cities of Pakistan namely Islamabad, Lahore, and Faisalabad. According to Ar and Kurtaran (2013), AHP is technically valid, and there is no need for large sample size, and ANP is not different as it is a special case of AHP. Many scholars in the domain of healthcare have employed the combination of DEMATEL and ANP; they used such a small sample size for MCDM model implementation (Ahmadi et al., 2015, 2017; Esfahani et al., 2018). Therefore, the data were collected from 21 experts in the hospitals who have in-depth knowledge of HIS (as mentioned in Table 3). Although they were experts of the HIS for getting a better response before the collection of data, a brief introduction of dimensions and variables was given to the respondents of this study.

Table 3 Sample characteristics

Measures	*Category*	*No(#)*	*Percentage*
Gender	Male	17	81
	Female	4	19
Age	<30	6	28
	30–40	9	43
	41–50	4	19
	>51	2	10
Education	Bachelor's degree	5	24
	Master's degree	12	57
	Higher	4	19
Role of respondents	Chief executive officers	2	10
	Chief information officers	4	19
	Chief technology officer	4	19
	Senior clinician (Professors)	11	52
Experience (Years)	1–3	2	10
	4–6	4	19
	7–9	8	38
	<10	7	33

4.3 DANP method

This study seeks to evaluate essential factors for adopting HIS, which comprise multiple dimensions and criteria. To identify the influencing weights of these criteria, in traditional ANP to get the normalisation matrix each entry is divided by corresponding column sum, so every column attains unity. This method assumes that each cluster has the same weights. On the other hand, the influence between clusters may be different in degree. However, the ANP assumption is not reasonable. Hence, DANP addresses this limitation and uses DEMATEL for influencing matrix Tc and Td. So, the DEMATEL method is employed for establishing Influencing Network Relationship Map (INRM) for dimensions and each criterion. After DEMATEL method, the DANP is employed to get the weights of dimensions and each criterion by using total influencing matrix.

The DEMATEL method steps (1–4) are used to build network relationship map and steps (5–9) are used to get weights of DANP by using influencing matrix. These steps are summarised below.

4.3.1 Application of DEMATEL for INRM

Step 1: Calculating the direct influence matrix

Based on expert knowledge, evaluation of dimensions and factors has done through pairwise comparison by using the scale 0–4. The scale 0–4 represent the degree of influence of one factor *i* to another factor *j* in which 0, 1, 2, 3, 4 are indicating 'no,' 'very weak,' 'weak,' 'strong' and 'very strong' influence respectively. If they consider that element *I* influences element *j*, then we will denote this by k_{ij}. So, the direct influencing matrix can be attained.

$$K = \begin{bmatrix} k_{11} & \cdots & k_{1j} & \cdots & k_{1n} \\ \vdots & & \vdots & & \vdots \\ k_{i1} & \cdots & k_{ij} & \cdots & k_{in} \\ \vdots & & \vdots & & \vdots \\ k_{n1} & \cdots & k_{nj} & \cdots & k_{nn} \end{bmatrix}$$

Step 2: Normalisation of direct influencing matrix

The normalised matrix *Y* is obtained through the equations (1) and (2) by using matrix *K*.

$$Y = vK \tag{1}$$

$$v = \min\left\{\frac{1}{\max_i \sum_{j=1}^{n} k_{ij}}, \frac{1}{\max_j \sum_{i=1}^{n} k_{ij}}\right\} \tag{2}$$

Step 3: Obtains total influence matrix

After getting *Y*, by using equation (3) we can get the total influencing matrix. In equation (3), *I* indicate the identity matrix.

$$Tc = Y + Y^2 + Y^3 + \cdots = Y\left(I - Y\right)^{-1} \tag{3}$$

Step 4: Analyse the outcomes

We define *h* and *g* be $1 \times n$ and $n \times 1$ vectors representing the sum of column and sum of the row in the total relationship matrix *Tc*. Vectors *g* and *h* are calculated by equations (4) and (5), respectively. Now the row sum *gi* will demonstrate the total direct and indirect impact of factor *i* that exert on other factors. Likewise, the column sum *hj* will represent the total influence of factor *j* that exert by other factors. When $i = j$, then the sum $(i + j)$ denote the importance of criteria such as total influence received and given by factor *i*. Similarly, the difference shows the net impact that factor *I* gives to a system.

$$T_C = \left[T_C^{ij}\right]_{n\times n}, i, j \in \{1, 2, 3, \ldots, n\}$$

$$g = \left[\sum_{j=1}^{n} t_c^{ij}\right]_{n\times 1} = \left[t_c^{i}\right]_{n\times 1} = \left(g_1, \ldots, g_i, \ldots, g_n\right)' \tag{4}$$

$$h = \left[\sum_{i=1}^{n} t_c^{ij}\right]_{1\times n}' = \left[t_c^{i}\right]_{n\times 1} = \left(h_1, \ldots, h_i, \ldots, h_n\right)' \tag{5}$$

4.3.2 Application of DANP for calculating weights

Step 5: Normalizing the total influence matrix

At this stage, we normalised the total influencing matrix by using equations (6)–(10). Here, dimensions denoted by T_D while criteria denoted by T_C.

$$T_D^{\alpha} = \left[t_D^{\alpha ij}\right]_{m\times m} = \begin{bmatrix} t_D^{11}/g_1 & \cdots & t_D^{1j}/g_1 & \cdots & t_D^{1m}/g_1 \\ \vdots & & \vdots & & \vdots \\ t_D^{i1}/g_i & \cdots & t_D^{ij}/g_i & \cdots & t_D^{im}/g_i \\ \vdots & & \vdots & & \vdots \\ t_D^{m1}/g_m & \cdots & t_D^{mj}/g_m & \cdots & t_D^{mm}/g_m \end{bmatrix} \tag{6}$$

$$g_i = \sum_{j=1}^{m} t_D^{ij}, \quad i = 1,2,...,m \tag{7}$$

$$T_C^{\alpha} = \begin{bmatrix} T_C^{\alpha 11} & \cdots & T_C^{\alpha 1j} & \cdots & T_C^{\alpha 1m} \\ \vdots & & \vdots & & \vdots \\ T_C^{\alpha i1} & \cdots & T_C^{\alpha ij} & \cdots & T_C^{\alpha im} \\ \vdots & & \vdots & & \vdots \\ T_C^{\alpha m1} & \cdots & T_C^{\alpha mj} & \cdots & T_C^{\alpha mm} \end{bmatrix} \tag{8}$$

In the matrix T_C^{α}, $T_C^{\alpha ij}$ is a $m_i \times m_j$ sub-matrix in matrix T_C^{α}. We use $T_C^{\alpha 12}$ as an example to indicate how can we obtain it.

$$T_C^{\alpha 12} = \begin{array}{c} \\ C_{11} \\ \vdots \\ C_{11} \\ \vdots \\ C_{1m_1} \end{array} \begin{bmatrix} C_{21} & \cdots & C_{2j} & \cdots & C_{2m_2} \\ t_{11}^{12}/t_1^{12} & \cdots & t_{1j}^{12}/t_1^{12} & \cdots & t_{1m_2}^{12}/t_1^{12} \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{12}/t_i^{12} & \cdots & t_{ij}^{12}/t_i^{12} & \cdots & t_{im_2}^{12}/t_i^{12} \\ \vdots & & \vdots & & \vdots \\ t_{m_1 1}^{12}/t_{m1}^{12} & \cdots & t_{m_1 j}^{12}/t_{m1}^{12} & \cdots & t_{m_1 m_2}^{12}/t_{m_1}^{12} \end{bmatrix} \tag{9}$$

$$t_i^{12} = \sum_{j=1}^{m_2} t_{ij}^{12} \tag{10}$$

Step 6: Made an unweighted super-matrix W

By using equation (11), we get an unweighted super-matrix.

$$W = \left(T_C^{\alpha}\right)' \tag{11}$$

Step 7: Constructing a weighted super-matrix

T_D^{α} is implemented with the unweighted matrix W using equation (12) to build the weighted matrix W^{α}.

$$W^{\alpha} = T_D^{\alpha} W = \begin{bmatrix} t_D^{\alpha 11} \times W_{11} & \vdots & t_D^{\alpha 1i} \times W_{i1} & \vdots & t_D^{\alpha 1n} \times W_{n1} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha j1} \times W_{1j} & \vdots & t_D^{\alpha ji} \times W_{ij} & \vdots & t_D^{\alpha jn} \times W_{nj} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha n1} \times W_{1n} & \vdots & t_D^{\alpha ni} \times W_{in} & \cdots & t_D^{\alpha nn} \times W_{nn} \end{bmatrix} \tag{12}$$

Step 8: Attain the DANP

Limit the weighted supper matrix by increasing its power until it becomes a long-term stable super-matrix to attain influencing weights of each criterion.

$$W^* = \lim_{h \to \infty} \left(W^{\alpha}\right)^h \tag{13}$$

5 Description of the problems

5.1 Build INRM

DEMATEL is used to evaluate the causal influence on HIS adoption from each dimension and criterion. First, we calculate the arithmetic mean of all respondents and then by using equations (1)–(5) we get the influential relationship between dimension and criterion. Table 4 and Figure 4 are indicating the relationship between dimensions and criteria Based on results, we can rank these dimensions as environments > technology > human > organisation.

Table 4 and Figure 4 show that influencing factors top management support, relative advantage, compatibility, and security concern are the most imperative criteria. According to (*fi* – *gi*) the factors that are positive and affect others include employee's knowledge, project team competence, hospital size, mimetic pressure, IS infrastructure and financial resources. On the other hand, the remaining factors are affected by these factors.

5.2 Influential weights of criteria in HIS adoption

Based on total influencing matrix resulting from the DEMATEL technique, these values are used to calculate the unweighted super-matrix by using equations (6)–(11). Table 5 shows the unweighted super matrix W. Then weighted super-matrix is calculated by applying equation (11) which is shown in Table 6. Finally, limit the weighted super-matrix based on equation (12) by increasing its power until it becomes a long-term stable super-matrix to attain influencing weights of each criterion. Table 7 shows the weights of each dimension and criterion.

Table 4 Sum of influences given and received on dimensions and criteria

Dimension/criteria	*f*	*g*	*f* + *g*	*f* – *g*
Organisation	3.829	4.659	8.488	–0.830
O1-IS infrastructure	1.664	1.497	3.161	0.167
O2-Top management support	2.048	2.809	4.856	–0.761
O3-financial resources	1.869	1.802	3.671	0.067
O4-hospital size	1.368	1.056	2.424	0.312
Technology	4.294	4.133	8.427	0.161
T1-Relative advantage	2.316	2.455	4.771	–0.139
T2-combatibility	2.046	2.636	4.682	–0.590
T3-complexity	1.754	1.862	3.616	–0.108
T4-security concern	1.716	1.988	3.704	–0.272
Human	3.741	3.961	7.702	–0.220

Table 4 Sum of influences given and received on dimensions and criteria (continued)

Dimension/criteria	*f*	*g*	*f* + *g*	*f* – *g*
H1-perceive technical competence	2.050	1.224	3.274	0.826
H2-employee's knowledge	1.947	0.981	2.927	0.966
Environment	3.407	2.518	5.925	0.889
E1-mimetic pressure	2.040	1.817	3.857	0.223
E2-coercive pressure	1.701	1.802	3.503	–0.101
E3-vender support	1.613	2.203	3.816	–0.590

Figure 4 Influence network relation map (INRM)

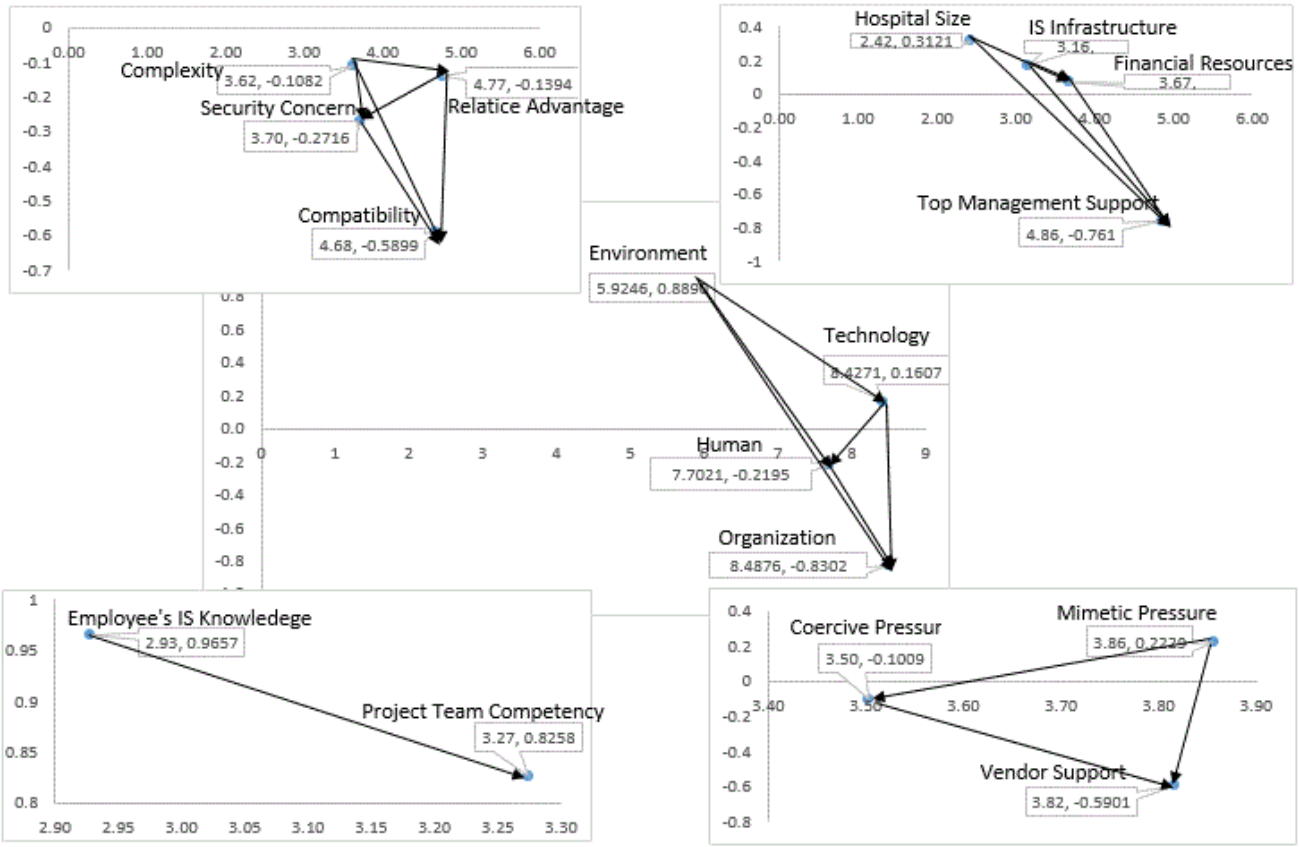


Table 5 Unweighted super-matrix

	O_1	O_2	O_3	O_4	T_1	T_2	T_3	T_4	H_1	H_2	E_1	E_2	E_3
O_1-IS infrastructure	.158	.255	.248	.234	.204	.240	.172	.183	.208	.184	.215	.193	.212
O_2-Top management support	.409	.301	.401	.350	.374	.386	.464	.427	.423	.439	381	.378	.374
O_3-Financial resources	.269	.278	.173	.318	.272	.233	.229	.257	.251	.241	.252	.257	.249
O_4-Hospital size	.163	.166	.179	.097	.151	.141	.135	.134	.119	.136	.152	.172	.165
T_1-Relative advantage	.287	.276	.294	.290	.203	.304	.302	.282	.283	.285	.249	.277	.248
T_2-Compatibility	.314	.299	.307	.314	.333	.201	.303	.333	.296	.293	.281	.271	.302
T_3-Complexity	.186	.211	.217	.182	.224	.247	.134	.228	.186	.201	.211	.233	.246
T_4-Security concern	.213	.214	.183	.214	.241	.248	.261	.157	.235	.221	.259	.219	.205
H_1-Project team competency	.537	.539	.561	.561	.575	.581	.591	.581	.401	.715	.502	.522	.554
H_2-Employee's knowledge	.463	.461	.439	.439	.425	.419	.409	.419	.599	.285	.498	.478	.446
E_1-Mimetic pressure	.315	.313	.310	.323	.302	.288	.354	.300	.300	.317	.237	.356	.384
E_2-Coercive pressure	.306	.330	.290	.284	.314	319	.318	.321	.303	.310	.372	.230	.298
E_3-Vendor support	.379	.357	.400	.392	.384	.392	.328	.379	.397	.373	.391	.414	.318

Table 6 The weighted super-matrix W^{α}

	O_1	O_2	O_3	O_4	T_1	T_2	T_3	T_4	H_1	H_2	E_1	E_2	E_3
O_1-IS infrastructure	.041	.066	.064	.060	.066	.078	.056	.059	.067	.059	.068	.061	.067
O_2-Top management support	.105	.077	.103	.090	.121	.125	.151	.139	.136	.142	.120	.119	.118
O_3-Financial resources	.069	.072	.044	.082	.088	.076	.074	.083	.081	.078	.079	.081	.079
O_4-Hospital size	.042	.043	.046	.025	.049	.046	.044	.043	.038	.044	.048	.054	.052
T_1-Relative advantage	.085	.081	.087	.086	.046	.069	.069	.064	.082	.082	.069	.077	.069
T_2-Compatibility	.093	.088	.091	.093	.076	.046	.069	.076	.086	.085	.078	.075	.084
T_3-Complexity	.055	.062	.064	.054	.051	.056	.031	.052	.054	.058	.058	.065	.068
T_4-Security concern	.063	.063	.054	.063	.055	.057	.059	.036	.068	.064	.072	.061	.057
H_1-Project team competency	.150	.151	.157	.157	.154	.156	.158	.156	.087	.156	.136	.141	.150
H_2-Employee's knowledge	.129	.129	.123	.123	.114	.112	.110	.112	.131	.062	.135	.129	.121
E_1-Mimetic pressure	.053	.052	.052	.054	.054	.052	.064	.054	.051	.054	.033	.049	.053
E_2-Coercive pressure	.051	.055	.049	.048	.056	.057	.057	.058	.052	.053	.051	.032	.041
E_3-Vendor support	.063	.060	.067	.066	.069	.070	.059	.068	.068	.064	.054	.057	.044

Table 7 Local and global weights of dimension and criteria

Dimension/variables	*Local weights*	*Global weights*	*Rank*
O-organisation	0.3022		1
O_1-IS infrastructure	0.2091	0.0632	7
O_2-Top management support	0.3951	0.1194	2
O_3-Financial resources	0.2505	0.0757	5
O_4-Hospital size	0.1453	0.0439	13
T-technology	0.2722		2
T_1-Relative advantage	0.2766	0.0753	6
T_2-Compatibility	0.2954	0.0804	4
T_3-Complexity	0.2072	0.0564	10
T_4-Security concern	0.2208	0.0601	9
H-human	0.2592		3
H_1-Project team competency	0.5521	0.1431	1
H_2-Employee's knowledge	0.4479	0.1161	3
E-environment	0.1665		4
E_1-Mimetic pressure	0.3129	0.0521	11
E_2-Coercive pressure	0.3093	0.0515	2
E_3-Vendor support	0.3778	0.0629	8

6 Results and discussion

This study has two outcomes. First, by using DEMATEL, we gain INRM. INRM has been explained briefly in Figure 4 and Table 4. It shows that dimensions are influencing each other. For instance, dimension E influences other dimensions T, H and O ($E \rightarrow \{T, H, O\}$; dimension T influences dimensions H and O (T $\rightarrow$ {H, O} and dimension H influences O (H $\rightarrow$ {O}). This relationship between dimensions will give understanding to the decision maker to make the decision according to the priority among dimensions. For instance, they should give more attention to E (environment) followed by T (technology), H (human) and O (organisation) for the successful adoption of HIS in Pakistan public hospitals.

Table 4 and Figure 4 also indicate that factor O4 influences factors O1, O2 and O3 (O4 $\rightarrow$ {O1, O2, O3}, factor O1 influences factors O3 and O2 (O1 $\rightarrow$ {O3, O2}, and factor O3 influences factor O2 (O3 $\rightarrow$ {O2}. Additionally, factor T3 influences factors T1, T4, and T2 (T3 $\rightarrow$ {T1, T4, T2}, factor T1 influences factors T4 and T2 (T1 $\rightarrow$ {T4, T2} and factor T4 influences factor T2 (T4 $\rightarrow$ {T4}). In human dimension factor, H1 influences factor H2. Moreover, environmental dimension factor E1 influences factors E2 and E3 (E1 $\rightarrow$ {E2, E3} and factor E2 influences factor E3.

Based on DEMATEL results for the adoption of HIS decision makers should make strategies by focusing on the environment because its $(f - g)$ value is 0.889 which is higher than other dimensions. In this way, we can say that the environment is the dispatcher. Therefore, the consequences of our study indicate that the environment and technology are

casues and human and organisation are effects. It means that environment and technology have a significant influence on other dimensions so more attention should be given to these dimensions for the successful adoption of HIS.

According to Table 4 and Figure 4, we can prioritise all criterion elements such as employee's knowledge > project team competence > hospital size > mimetic pressure > IS infrastructure > financial resources > coercive pressure > complexity > relative advantage > security concern > vendor support > compatibility and top management support. According to Table 4 and Figure 4, the factors which are positive and affect other factors include employee's knowledge, project team competence, hospital size, mimetic pressure, IS infrastructure and financial resources. On the contrary, the remaining factors are affected by others. Consequently, the healthcare professionals should take action according to the above priorities for the successful adoption of HIS.

The second and most significant results of this study are DANP influential weights which are demonstrated in Table 7. According to the results of DANP, the most important dimension is organisation (0.302) followed by technology (0.272), human (0.259) and environment (0.166). So, the healthcare professionals should give more importance to the organisation and human dimensions during the process to evaluate the decision to adopt HIS. However, human and environment have less influence on HIS adoption but professionals should consider these dimensions as well.

According to the human dimension, perceived technical competence is the most important criterion with the global weight of (0.1431). The finding of our study is consistent with prior studies (Ahmadi et al., 2015; Lian et al., 2014). This study result indicates that healthcare professionals should hire IT experts for the training of IS staff because there is a need to improve the technical competence of IS staff. Additionally, if a hospital's IT staff have technical competency and have sufficient experience and knowledge of HIS adoption then a hospital will be more confident to adopt HIS (Carayon, 2006; Lian et al., 2014). Previous studies of HIS identified that when a hospital wants to adopt IS innovation the capabilities of IS staff play a significant role (Lin et al., 2012; Liu, 2011). The second element of the human dimension is employees' IS knowledge with the global weight of (0.1161) which also found an important factor affecting the adoption of HIS. Previous literature also has similar results (Ahmadi et al., 2017; Hung et al., 2010). A study conducted in Pakistan public hospitals indicated that lack of employees' IS knowledge was a barrier to the implementation of HIS (Malik and Khan, 2009). The literature of HIS demonstrated that to gain benefits from technological innovation in a hospital they should rely on employees' IS knowledge and capabilities (Hung et al., 2010; Lin et al., 2012).

With respect to technological dimension, relative advantage, compatibility, complexity, and security concern are found to be significant with the global weight of (0.0753), (0.0804), (0.0564) and (0.0601), respectively. In addition, compatibility is the most important factor in technological domain. According to Shahzad et al. (2018), a hospital can easily adopt HIS if its existing technology is compatible with the adopted technology. So, the compatibility is positively impacting the adoption of an innovation. Prior literature is confirming our results (Hung et al., 2010; Shahzad et al., 2018; Yang et al., 2013). Consequently, we can say that there is a need to improve HIS compatibility with existing hospital software and hardware. Secondly, in this dimension relative advantage is also significant and has a positive impact on HIS. Prior studies have same results with our results (Hung et al., 2010; Lin et al., 2012; Shahzad et al., 2018; Yang et al., 2013). Therefore, relative advantage is the main interpreter of technological innovation in an organisation because if an innovation has a high relative advantage than it will influence organisations to adopt it. Sultan et al. (2014) analysed the relative advantage of HIS in a hospital of Pakistan by comparing cost and saving trend of projects before and after the implementation of HIS. They found that HIS has a substantial relative advantage in cost and saving perspective. Subsequently, this study emphasised the HIS implementation by realizing the high relative advantage. Third and fourth elements in the technological dimension are complexity and security concern which have a significant effect on HIS adoption. Our finding is consistent with other scholars (Lian et al., 2014; Nilashi et al., 2016; Shahzad et al., 2018). Complexity and security concerns are negatively impacting the adoption of HIS hence if the adopted technology has complexity as well as security concerns than the adoption will be complicated. So, we can say that low complexity and patient data security in HIS will enable the innovation adoption of HIS.

Aside from technological elements, organisational elements also affect the adoption of HIS. IS infrastructure, top management support, financial resources, and hospital size are the significant elements of organisational dimension with global weights of (0.0632), (0.1194), (0.0757) and (0.0439), respectively. According to study results, top management support is identified as the second most important variable of our study. The result is familiar from other studies (Lian et al., 2014; Liu, 2011; Shahzad et al., 2018). Hsiao et al. (2009) stated that if the top management of an organisation has sufficient experience and knowledge regarding HIS advantage and disadvantages, then their attitude will positively affect the adoption of HIS. According to Malik and Khan (2009), the implementation of HIS in PIMS is made possible due to the sharp vision of top management. IS infrastructure and financial resources are also found to be important in our study. In Pakistan, the most common source of health financing is general taxation so for the adoption of HIS hospitals have more concern about financial resources. Sulaiman (2011) demonstrated that government's funding is based on taxation, so the money is an issue for hospitals. So, this factor is important for the adoption of HIS. The fourth factor in organisational dimension is hospital size which has a significant effect on HIS adoption. Various scholars have the

same results (Ahmadi et al., 2015; Chang et al., 2007). The cause is that the small hospitals have fewer technical and financial resources as compare to large size hospital. Consequently, if the size of the hospital is large, then the chance of HIS innovation will be more as compared to small hospitals.

This study has mimetic pressure, coercive pressure and vendor support in the environmental dimension with the global weights of (0.0521), (0.0514) and (0.0629). Mimetic pressure from competitors and coercive pressure from governments are affecting the adoption of HIS. These results echo with other scholars (Lin et al., 2012; Shahzad et al., 2018; Sherer et al., 2016). Mimetic pressure might build when developing countries (competitors) are using HIS in their hospitals and gaining benefits from it and giving better facilities to patients. So, it will encourage hospitals to adopt HIS. Finally, Sherer et al. (2016) stated that for the implementation of HIS healthcare professionals should carefully focus on institutional pressure. Vendor support is the third variable of environmental dimension which is positively influencing the adoption of HIS. The finding is familiar from other studies (Chang et al., 2007; Esfahani et al., 2018). Vendor support plays a vital role in HIS implementation, for instance, Malik and Khan (2009) discussed the case of Pakistan public sector hospital where due to the lack of technical competence and expertise HIS implementation was very difficult but vendor support will make it possible and easy.

6.1 Contribution

This study has the following contributions in the field of healthcare. Firstly, in the case of Pakistan studies are available on HIS that are providing understanding related to HIS benefits and successful implementation of HIS. Therefore, no comprehensive integration model has been developed which gives suggestion and direction regarding the barriers and driving forces in the adoption of HIS in Pakistan public hospitals. Hence, this study has filled this gap by providing concise and comprehensive insight regarding the decision to adopt HIS in Pakistan public hospitals. Secondly, in case of developing countries according to some authors, there is a dearth of studies in integrated technologies especially healthcare sector such as HIS (Lin et al., 2012; Nilashi et al., 2016). On the other hand, according to Nilashi et al. (2016), HIS has become an important tool due to its unique benefits as it plays a significant role for the integration of all systems in a hospital. So, our study also contributed theoretically and practically in the perspective of developing countries and will provide comprehensive understanding related to HIS innovation adoption. Finally, many studies of HIS applied generic theories such as Diffusion of Innovation (DOI) theory (Hung et al., 2010; Lin et al., 2012), institutional theory (Klöcker et al., 2014; Sherer et al., 2016), TOE framework (Chang et al., 2007; Liu, 2011; Shahzad et al., 2018) and HOT-fit model (Maslove et al., 2011; Yusof et al., 2008b) separately. Hence, this study evaluates the factors of HIS adoption with the integration of TOE framework with HOT-fit model and institutional theory.

6.2 Future work

Although our study has contributed both theoretically and practically some limitations exist. These limitations should be considered in future work especially the prospective scholars who want to do similar work in this domain. First, this study collected data from 21 experts and end users so that there is call for future work to evaluate the HIS adoption process by using large sample size. Therefore, based on large sample size future work could be done by using Structural Equation Modelling (SEM) to empirically analyse the essential factors that influencing the HIS adoption. Second, this study is based on the survey so prospective scholars can conduct the study to investigate the inhibiting and driving forces in the adoption of HIS by using both survey and interview from the respondents. Finally, the results of our study are according to the culture and environment of Pakistan public sector hospitals, but these are not limited to Pakistan. Future work will be done in other developing countries for verifying the results of our study and giving more understanding about the adoption of HIS.

7 Conclusion

The purpose of this study was to comprehensively evaluate the variables that are influencing the adoption of HIS in Pakistan public hospitals. For this purpose, we rigorously analysed the literature of HIS and found some variables, which can affect and lead to achieving the adoption of HIS in Pakistan public hospitals. After finalising the variables, we discuss these variables with HIS experts, and according to their suggestion and opinions, we continue our study. For theoretical basis we use TOE framework, HOT-fit model and institutional theory. After identifying variables and adoption theories, we investigate all MADM methods and found recently established DANP method was suitable for this study. Therefore, DANP method was employed as an impressive method for the contribution in healthcare IS literature. The main findings of this study based on experts' opinions using DANP show that in human dimension perceived technical competency is recognised as the most important factor. In addition, experts believe that compatibility and the relative advantage are more important variables in technological dimension than others. With respect to organisational dimension, top management support and financial resources are found more significant as compared to others. Furthermore, in environment dimension experts agreed that vendor support is the most important criterion. Therefore, based on expert recommendation the results of our study reveal that the managers of the hospitals should not overlook these factors for the successful adoption of HIS. Consequently, the results of the current study provide the concise and comprehensive guideline to decision makers to

give importance to factors according to their weights and make strategies for the successful implementation of HIS. In the end, this study hopefully extended the knowledge towards the improvements of healthcare industry into theoretical perspective and also will give direction to prospective scholars for further assessment of HIS adoption.

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