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Integrating RFID with Healthcare Information Systems: Toward Smart Hospitals

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Abstract: Radio Frequency Identification (RFID) is the use of radio waves to read and capture information stored on a tag attached to an object is currently regarded as one of the most promising technologies in terms of its use, pervasiveness, market demand and commercial availability. RFID is perceived as critical technology for many purposes and applications such as improving the efficiency and effectiveness of business operations and improving customer service. This research is aimed at developing an incorporated view of a theoretical frame work to identify factors that affect RFID adoption in health care and providing an empirical analysis of the effect of organizational, environmental and individual factors on the diffusion of RFID within the health care industry.

Key words: RFID, healthcare, IT adoption, user factors, demand, applications

INTRODUCTION

Radio Frequency Identification (RFID) is currently considered as one of the most promising technologies in the health care (Ahmadi *et al*., 2017; Adhiarna *et al*., 2013). RFID is a generic term that refers to the use of waves and radio frequency wireless communications to transmit, label and automatically identify people or objects (Sharma *et al*., 2007). An RFID system will usually have three components: tags, readers and middleware. RFID supports data processing in business activities and it is always connected to an enterprise application system. RFID has become so popular that we are ‘‘witnessing the forward progress of an unstoppable technology adoption that has a huge impact on various industries” (Chong *et al*., 2015) including, services, supply chain manufacturing and healthcare industry.

Among these healthcare is a significant growing sector for RFID applications it will have a global market of $2.03 billion by 2018 (Cao *et al*., 2014; Zhou and Piramuthu, 2010). Despite the growing implementation of RFID in health care services, limited empirical research has been conducted to evaluate the potential of RFID within the healthcare sector (Wamba *et al*., 2013). This is astonishing given that health care organizations encounter many major challenges including inaccurate pharmaceutical stock, inability to track medical equipment such as beds and surgical tools, difficulty of tracking patient locations, etc.

Researchers indicated that such challenges could be overcome by using RFID technologies (Chong *et al*., 2015). For example patient safety incidents, administration of incorrect drugs, medical errors including mislabeled blood samples, drug quantities and transfusion using the wrong blood type. In addition, the fast-growing health care needs with increasing life expectancy and rising health care costs, health care organizations face ever increasing challenges such as maintaining continuous service while under increased pressure to deliver high-quality patient care, researcher and environment requirements, shortage of medical staff and increasing rates of medical errors (Yazici, 2014; Reyes and Jaska, 2007).

Despite the promising trends and potential out comes of RFID use health care organizations have not fully embraced and or recognized RFID technology. In many cases, health care practitioners are unable to justify their large investments on RFID technology. Carr *et al*. (2010) indicated that despite the promise of RFID technology in the literature, health care organizations are still in the early stages of adopting this technology. The benefits of auto-identification systems including both tangible and intangible pay-offs and possible application mechanisms, are generally not widely known or not justifiable (Matta *et al*., 2012). Yao *et al*. point to the scarcity of RFID adoption in healthcare and the lack of publications and empirical studies that examine the adoption of RFID in health care in comparison to those in other settings such as manufacturing and logistics and supply chain management (Chong *et al*., 2015). Therefore, this study attempts to achieve the following objectives:

- Identify the most critical factors and their dimensions of RFID adoption in health care sector
- Provide a measurement framework of RFID technology and adoption factors that can be used in future research in measuring technology adoption in organizations

MATERIALS AND METHODS

Research framework and hypotheses: Existing RFID literature provides the foundation for developing the research frame work by identifying factors that are deemed to be crucial for RFID adoption. The current research frame work was formulated through the results of an extensive view and theoretical examination of the related existing literature on IT adoption in health care in general and RFID research in particular. The researcher used the most frequently cited dimensional factors from the established adoption theoretical studies and when necessary the items used were tailored to suite RFID context in this study as illustrated in the study model. The frame work incorporates three different models: TOE, DOI and HOT-fit. Factors related to and barriers preventing RFID adoption are categorized into five main dimensions technology, organization, environmental, economic and human (user) factors. It is believed that the five aforesaid dimensions are well suited to studying RFID adoption by healthcare organizations. Therefore, the following hypotheses were tested in this study as illustrated in Fig. 1.

- H_1: technological factors are associated with RFID adoption in health care organizations
- H_2: organizational factors are significant determinants of RFID adoption
- H_3: environmental factors are significant determinants of RFID adoption
- H_4: economic factors are significant determinants of RFID adoption
- H_5: human factors are significant determinants of RFID adoption

Research approach: The study was conducted in six government hospitals in the UAE in different cities. The names of the hospitals were omitted for integrity reasons and based on our agreement with the hospital's administration. The hospitals surveyed in this study have completed their electronic health record system implementation and currently use some limited RFID technology applications in some functional areas and these hospitals are in the process of considering the deployment of RFID to other functional areas.

Prior to data collection, hospitals were contacted by email to explain the aim of the study and to solicit their cooperation. The survey was then sent by email to a person in each hospital to be distributed to all employees and professional staff in the hospitals. In total, 191 surveys were returned to the researcher out of which 182 questionnaires were used in the data analysis and the results reported in this study.

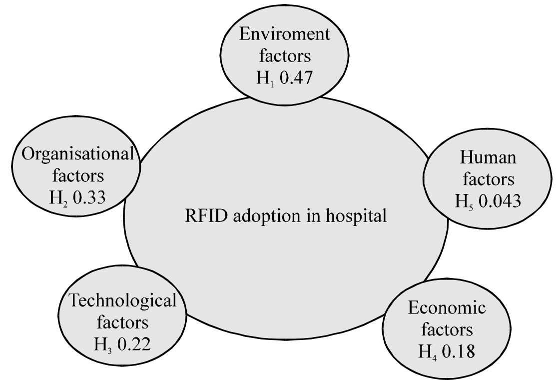

Fig. 1: Research model

RESULTS AND DISCUSSION

Analysis and findings: The model estimation was carried out using a structured equation model approach. According to the two-step approach recommended by researchers (Tabachnick and Fidell, 2007) in the first step the measurement model was analyzed for its validity. This was followed by the structural equation model to test the hypothesizes in the research model as discussed below.

Reliability was examined through the determination of Cronbach's coefficient alpha (β). The results reported in Table 1 indicate the presence of satisfactory Cronbach alpha scores which ranged from 0.81 for the technological factors to 0.91 for the economic factors, demonstrating thus high construct reliability (Tabachnick and Fidell, 2007).

Discriminant validity was assessed using the square root of the Average Variance Extracted (AVE) for each factor the factors are different if the AVE for the factors is greater than their shared variance (Tabachnick and Fidell, 2007). As shown in Table 1, the diagonal values in parentheses represent the square root of the AVE. All AVE values are greater then the off-diagonal values (shared variance) in the corresponding rows and columns.

Convergent validity was examined by three criteria all item loadings are significant composite reliability more than 0.70 while the AVE scores of all factors must exceed the threshold value of 0.50 (Tabachnick and Fidell, 2007). All factor loadings for this study exceeded the recommended value of 0.70 and the AVE values ranged from 0.78-0.90 indicating that convergent validity was satisfied.

Tests of the research model: The structural model was applied to examine the hypotheses proposed in this research. The fit of the data and measurement model was

Table 1: Reliability, validity and hypothesis testing results

Factors/Hypothesis	AVE	1	2	3	4	5	6	Alpha α	Path coefficient β	t-values	Hypothesis support
Environment factors	0.89	**(0.94)***						0.86	0.47	7.35**	Yes
Organizational factors	0.83	0.77	**(0.89)***					0.84	0.33	4.48**	Yes
Technological Factors	0.87	0.64	0.58	**(0.92)***				0.81	0.22	3.65**	Yes
Economic Factors	0.78	0.58	0.56	0.67	**(0.87)***			0.91	0.18	2.46**	Yes
Human factors	0.90	0.66	0.49	0.56	0.52	**(0.95)***		0.87	0.43	7.20**	Yes
Adoption decision	0.89	0.53	0.39	0.47	0.39	0.45	**(0.93)***	0.83	0.33	4.48**	Yes

*The diagonal values in bold are the squre root of the averaged variance extracted between the constructs and their measures; **Off-diagonal values are the correlations between the different constructs

Table 2: Goodness-of-fit for the measurement and structural models

Criteria/Indices	Recommended value	Measurement model	Structural model
Chi-square (χ^2)	-	307.65	301.10
Degree of freedom	-	182.00	185.00
χ^2/df	>2	1.69	1.62
GFI	>0.90	0.94	0.93
NFI	>0.90	0.91	0.92
NNFI	>0.90	0.93	0.93
CFI	>0.90	0.92	0.92
RMSEA	>0.08	0.83	0.83

measured using a Chi-square Goodness-of-Fit Index Model (GFI). All the goodness-of-fit measures fall into acceptable ranges with scaled χ^2/df = 1.60, CFI = 0.92, GFI = 0.94, NFI = 0.91 and RMSEA = 0.083 as listed in Table 2. The goodness-of-fit statistics indicate that the overall structural model is acceptable, hence, the proposed combined model provides a good fit with the data.

The goodness-of-fit indices for the structural model were χ^2/df = 1.62, CFI = 0.92, GFI = 0.93, NFI = 0.92 and RMSEA = 0.83. Thus, the integrated model provided a good fit with the data about RFID use in health care. The results of the hypotheses test, path coefficients (β) and t-values for all factors are summarized in Table 1.

The findings indicate that environmental, organizational, economic, technological and human factors significantly affect the decision to adopt RFID in health care organizations (β = 0.47, t = 809). Technological factors were found to be the most significant among the study factors in terms of effect on the decision to adopt RFID (β = 0.47, t = 7.35, $p<0.05$). Environment factors exhibited a significant but small effect on organizational decisions toward adopting RFID (β = 0.18, t = 2.46). As expected, human factors were found to significant and to play a crucial role in affecting employees and decision makers towards adopting RFID in their hospitals. The findings reveal a strong relationship between these factors and organizational decisions to adopt RFID in healthcare organizations (β = 0.43, t = 7.20).

CONCLUSION

The study empirically supports the applicability of the incorporation of three IT adoption models including TOE, DOI and HOT-fit frame works in understanding organizational decisions surrounding RFID adoption. The synthesized frame work provides a good starting point for analyzing and considering suitable factors that can affect organization innovation-adoption decisions in health care organizations.

IMPLICATIONS

The findings showed that it is important to consider factors from individual user differences and the HOT-fit model to understand health care professional's adoption of RFID. These factors have different influences on the adoption of RFID and therefore different implications for RFID implementation. For example, different perception of RFID benefits among medical staff such as physicians and nurses, could influence their propensity to use RFID. That is medical staff are looking for RFID to provide different operational and process solutions based on their research requirements and task needs. These individual factors must be considered at the early stages of RFID projects and before rolling out the implementation of RFID in hospital and clinical settings. The findings indicated that organizational factors such as top management and financial resources are significant determinants of RFID adoption.

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