1-1-2007

# Drivers of Wireless Technology in Healthcare: An Indian Study

Raj Gururajan
*University of Southern Queensland*, gururaja@usq.edu.au

# DRIVERS OF WIRELESS TECHNOLOGY IN HEALTHCARE: AN INDIAN STUDY

Raj GURURAJAN
Faculty of Business
University of Southern Queensland
Toowoomba, Australia 4350
email: gururaja@usq.edu.au

## 1. ABSTRACT

*The outcomes of clinical usefulness as a driver of wireless technology for Indian healthcare are reported here. Using both qualitative and quantitative techniques, 30 physicians were interviewed and 200 health professionals were surveyed. The outcomes established that in addition to technology factors, other factors such as clinical factors, administration factors and communication factors play a crucial role in determining the uptake of wireless technology for healthcare. These factors were further validated using a PLS model.*

## 2. INTRODUCTION

In the last few years, high expectations, technological developments, and effective and efficient services have been shown to be prerequisites for improvements in the healthcare domain (Rogoski, 2005). Latest trends in the healthcare sector include the design of more flexible and efficient service provider frameworks aimed at providing health services to all stakeholders. In order to implement such frameworks, wireless technology is increasingly being used in the healthcare sector (e.g. data management automation). A decrease in the cost of wireless devices and improved awareness of the benefits that ensue by using related wireless applications are two of the contributing factors towards the increased use of wireless technology in this sector (Gururajan, R., Quaddus, M. et al., 2005). Even though the future of this technology and its usability is promising, its adoption is still in its infancy, which is attributed to the complex and critical nature of the healthcare environment. In the current competitive and complex business environment, technology developments have played a critical role in delivering high quality of care (Reinecke, 2004). However, there is limited knowledge and empirical research on the effectiveness and adoption of wireless technology in general, and in the Indian healthcare system in particular.

Recent research has established that investment in emerging Information Technology (IT), including Information Systems (IS), can lead to productivity gains only if they are accepted and effectively used by respective stakeholders. Consequently, acceptance and utilization of IT/IS in the healthcare environment have been central themes in the information systems literature. Therefore, the fundamental focus of this research is to investigate and examine the influence of internal and external determinants on the usefulness of wireless technology. Further, this research also assesses how its acceptance contributes to the adoption of wireless technology. We believe that this research is the first of its kind attempted in the Indian healthcare domain and it employs empirical evidence to explore the impact of wireless technology and its usefulness in the Indian healthcare system. The Indian healthcare domain is at the forefront in adopting the latest medical technologies and applications, as evidenced by media reports and, as such, it constitutes an excellent context for validating existing adoption theories and extending them.

The main contribution of this research includes the identification of a set of drivers and barriers to using wireless technology in a given Indian healthcare setting. In addition to this, for the first time, a

set of clinical factors influencing the adoption of wireless technology has been identified and validated using a second order regression model.

# 3. LITERATURE REVIEW

The concept of wireless technology in healthcare is discussed in many studies (Dyer, 2003; Hu et al., 2002; Sausser, 2003; Simpson, 2003; Wisnicki, 2002). For example, Wisnicki (2002) provides details of how broadband technology, an essential component of wireless technology, can be used in healthcare. While prior studies agree that wireless applications have the potential to address the endemic problems of healthcare, very limited information can be found about the determinants of such applications (Gururajan, Raj et al., 2005; Gururajan et al., 2004). In general, the majority of the works reviewed are descriptive about the benefits of wireless handheld devices in healthcare in general, and medicine in particular. There is only a small number of studies that provide evidence-based information concerning these devices in healthcare (Fischer et al. 2003; Sax et al. 2005). Furthermore, five major studies in the area of healthcare (evaluated by (Spil & Schuring, 2006) testing the Technology Acceptance Model (TAM) produced findings which were inconsistent with the body of knowledge in non-healthcare settings. With 'Perceived Ease of Use' and 'Perceived Usefulness' as the major TAM attributes, these studies found that in the health environment, 'Perceived Usefulness' is an important attribute in technology adoption, while 'Perceived Ease of Use' was found to have no effect (Spil & Schuring, 2006). This is different to findings reported in non-health IS studies, where both attributes were found to be reliable technology adoption predictors. Therefore, further empirical investigation is required to explain the reasons why this variation exists in healthcare. In addition, there is a need to explore if further attributes exist which may influence the adoption of wireless applications in the healthcare environment.

### TAM IN HEALTHCARE CONTEXT

In healthcare literature, the discussion on wireless technology falls into three periods. For example, studies prior to and including 2000 discussed the status of wireless technology and the possible role the technology can play in healthcare. Studies between 2000 and 2003 discussed how wireless technology can be deployed in healthcare and the potential benefits the technology can bring to healthcare. It should be noted that these studies were only ‘discussion’ type studies. Majority of these studies did not provide any empirical evidence as to the use or acceptance of wireless technology in healthcare domains. Studies from 2004 till current date have collected data to establish the usefulness of wireless technology in healthcare. These studies, to some extent have focussed on the PDAs as these devices have been found to be useful in nursing domain for clinical data management.

The studies between 2000 and 2003 discussed a number of potentials of wireless technology in clinical domains. For example, how broadband technology can be used in healthcare was discussed by (Wisnicki, 2002), ability to address prevailing healthcare staff crisis by adopting intelligent solutions using agent and wireless technology that can identify the need and match the need with available resources in a timely and efficient manner was outlined by (Davis, R., 2002), better compliance with the rigorous regulatory framework was highlighted by (Wisnicki, 2002), reduction in medication errors and hence the benefits that can be realised was discussed by (Turisco, 2000), provision for greater flexibility and mobility of healthcare workers in performing their work was portrayed by (Athey & Stern, 2002), effective management of the increasingly complex information challenges and improved access to those information from anywhere at anytime was discussed by (Stuart & Bawany, 2001). Our review clearly identified that all these studies were only implying the potential of wireless technology and did not provide any empirical evidence.

While prior studies agreed that wireless applications have the potential to address the endemic problems of healthcare, very limited information can be found about the determinants of such wireless applications in order to establish the adoption of technology in a given healthcare context (Gururajan

et al., 2005; Gururajan et al., 2004). During the period of 2004 – 2006, studies emerged in the area of technology acceptance, specifically focussing on the acceptance of wireless technology in healthcare domains. These studies were empirical in nature and were testing the available models of technology acceptance or a variation in order to ascertain whether previous models hold good for a new technology in a specific domain. These studies were reported in a book titled 'E-Helth Systems Diffusion and Use', published by Idea Group Publishing in 2006 (Spil & Schuring, 2006). These studies are summarised below:

Predicting Internet Use: Applying the Extended Technology Acceptance Model to the Healthcare Environment (Chismar & Wiley-Patton, 2006) – This study empirically established that only perceived usefulness is significant and ease of use was not significant.

The dynamics of IT adoption in a major change process in health delivery (Lapointe et al., 2006) – This study established that TAM as devised by (Davies et al., 1989) is not adequate for health systems because adoption/resistance factors may be group related as opposed to the fundamental basis of TAM which is individualistic, influence of intra and inter organisational factors, linkages to cultures, environmental factors as well as the complexity of the environment.

Introducing electronic patient records to hospitals: Innovation adoption paths (Suomi, 2006) – This study found that relative advantage, strong network externalities available, rich availability of information through different communication channels are key factors for innovation and adoption. It should be noted that these are not discussed in the TAM models.

User acceptance and diffusion of innovations summarised (Spil & Schuring, 2006) – This summary established that perceived usefulness is a predictor of technology acceptance in healthcare. Ease of use was not found to be significant.

Understanding physicians' use of online systems: an empirical assessment of an electronic disability evaluation system (Horan et al., 2006) – This study found that in order to diffuse technology in an organisation, it is important to ascertain physicians' behaviour, their workflow practices and their perceptions regarding the value of specific information systems.

In essence, the recent studies appear to be indicating that the current models of technology acceptance or its derivatives are not suitable to predict the adoption factors of wireless technology in healthcare environment. Strong support can also be derived from three specific studies that have tested TAM models in healthcare. The first study conducted by (Jayasuriya, 1998) established that ease of use was not significant in a clinical domain. The second study by (Chau & Hu, 2002) echoed similar sentiments. The third study by Hu et al. (Hu et al., 1999) also found similar findings.

Further, recent studies conducted by (Howard et al., 2006) also established that ease of use was not significant while determining factors of adoption in a clinical domain in regard to wireless technology. Further, (Ivers & Gururajan, 2006) also found that there are other factors beyond the TAM models influencing the acceptance of technology.

Interviews conducted with 30 Queensland nursing staff members by (Gururajan, R., Moloney, C. et al., 2005) revealed that clinical usefulness of wireless technology is far more significant than ease of use factor as established in TAM. Another focus group discussion with the Western Australian senior health managers by (Gururajan, R., Quaddus, M. et al., 2005) also indicated that aspects of clinical usefulness such as integration of clinical data may be a significant factor than the ease of use factor. (Howard et al., 2006) also identified clinical usefulness is far more influencing than the ease of use factor while determining factors of adoption of wireless technology in the Indian healthcare domain.

However, the recent findings that the ease of use factor not showing strong significance in healthcare domain while determining wireless technology adoption warrants explanation as this is different to

many other reported studies in the generic IS domain where both attributes (ease of use and perceived usefulness) were reported to be reliable predictors.

This variation requires further empirical investigation in order to explain the reason behind this variation specific to healthcare. Therefore, there is a need to identify attributes that assist in the adoption of wireless applications in healthcare environment. We argue that the initial validity of TAM was predominantly established by testing the model with students as surrogates in a generic software application domain. This environment is very different to the healthcare environment, where the skills are at different levels. Further, the healthcare environment is complex, sensitive and time critical. These could be some of the reasons why TAM did not perform as expected in healthcare settings.

In addition, in the recent variant of TAM, namely, UTAUT, Venkatesh et al ((Venkatesh et al., 2003) reviewed eight prominent models of user acceptance and managed to create a unified view. The unified model comprised of seven constructs. The first four – performance expectancy, effort expectancy, social influence and facilitating conditions – were theorised to be direct determinants. The last three – attitude towards technology, self efficacy and anxiety – were theorised to be indirect. All the seven constructs were found to be significant determinants of technology usage by Venkatesh et al ((Venkatesh et al., 2003).

In terms of attitude, Venkatesh et al. (Venkatesh et al., 2003) defined it as an individual's overall affective reaction to using a system. The model depicts four constructs relating to this determinant – attitude towards behaviour, intrinsic motivation, affect towards use and affect. (Spil & Schuring, 2006) verified that in three cases the relation between attitude and behavioural intention is significant. Therefore, this determinant cannot be indirect. If there is significance between attitude and behaviour intention, then there is a direct relationship.

Therefore, there appears to be a basis to identify factors that contribute to the adoption of technologies in healthcare settings. Given that wireless technologies have started making in-roads in healthcare, the overarching purpose of the research is to identify the factors that influence the adoption of wireless technology in the Indian healthcare system. The rationale of the purpose is justified by the fact that India is a leader in software technologies, especially medical applications. Further, India is emerging as 'health tourism', due to the advancement in medical technology and reduction in cost in offering high quality health services—as highlighted by various print media. However, our initial review of available literature indicated that this area is under-researched. Collectively, these aspects led to the following research question:

- What are the determinants for the adoption of wireless technology by physicians in the Indian healthcare system?

The first stage of this study is focused on answering the research question qualitatively and the second stage on answering the research question quantitatively. Details as to how the research question was answered are provided in the research methodology section below.

# 4. METHODOLOGY

An examination of existing IS studies indicated that there is a necessity for a suitable research method. Most of the reviewed studies follow a quantitative approach which involves an instrument being administered onto a domain with perhaps a lesser understanding of the domain issues. For this study it was felt that if technology issues are to be studied with respect to a specific domain, then user involvement with the technology issues forms a major part in establishing the adoption (or inhibiting) factors. By necessity, this would occur prior to administering quantitative instruments (e.g. survey). This, in turn, requires an understanding of research philosophy, values of inquiry that would guide the

study, and the choice of relevant research techniques required to conduct the investigation in order to answer the research questions.

Further, there appears to be limited information available in the Indian IS domain to guide the principles of this study. This study is relatively new and, hence, requires a rigorous justification as to the choice of research methods employed. We also believe that due to aspects associated with various regulatory issues impacting the Indian health system, unique factors of technology acceptance, as well as usefulness, may emerge. Our initial meetings with Indian physicians also suggested that there is a divide in terms of technology usage between private and public hospitals, where private hospitals are rich in technology use and public hospitals are not. On the other hand, in many traditional studies in IS, either quantitative or, to some lesser extent, qualitative methods are used—but not both. In recent years this has been cited as a weakness (see (Mingers, 2001) for a detailed argument on this). Taking this into account, this study investigates the suitability of both approaches in order to answer the research question.

We recognise that the foundation for any research will be grounded on the researcher's fundamental philosophical view of the world (Myers, 1997). The choice of tools, including research techniques, instruments, and methods such as qualitative and quantitative, are not inherently linked to a particular philosophical position, as these positions are generic in nature. It is the contextual framework within which they are applied that provides consistency to an inquiry. While the choice of tools and methods are not linked to the philosophical view, the articulation—which is commonly the process of explaining choices of research methods and its related choice of research instruments—helps determine the philosophical disposition. This is usually achieved by asking questions on the beliefs, perceptions, experiences, advantages and disadvantages in order to determine this disposition. This may even include a researcher's personal experience within that domain, or their expertise in explicating the information using any approach that may be suitable to that domain. This has prompted us to follow a qualitative approach as the first phase of the study. We argue that this approach facilitates direction to the second phase of the study where quantitative evidence can be collected to establish causality between the dependent and the independent variables.

The research question dictates the need for quantitative research methods, while the behavioural component of the same investigation dictates qualitative research methods. The rationale for this approach is based on the notion that behavioural components require a thorough understanding of how users apply wireless technology in a given setting in order to understand behavioural issues. To extract 'tacit' aspects, this is best accomplished by applying a qualitative approach. A quantitative instrument can then be developed to extract the quantitative aspects, such as the opinion scores.

Health professionals view the term 'wireless technology' in different ways, either as a product or a process. The combined domain of wireless technology and healthcare is relatively new in the Indian IS domain. While IS studies have discussed the impact of Information & Communication Technology (ICT) tools and associated behavioural intentions on healthcare users, limited information can be found as to how the combination of wireless technology and healthcare settings would influence users who are already conversant with novel and advanced medical technologies (Spil & Schuring, 2006). The workplace or organizational factors that influence such combinations are yet to be explored in detail. Such an exploration has close association with the choice of research method as these methods pave the way for proper inquiry into the factors that determine technology acceptance in a given setting. On this basis, the suitability of one research method over another has to be carefully weighed. Consequently, this study identified an exploratory approach to be suitable for the initial investigation. This approach is particularly favourable in confirming the direction of the study, variables chosen for the study, and in helping refine the literature. The exploratory study can also possibly eliminate some variables, while providing opportunities for including emerging variables.

***Qualitative Data Collection***

As argued, for the first stage of this research the investigators used a qualitative approach to collect initial sets of themes for the adoption of wireless technology in the Indian healthcare system. For this purpose, 30 physicians operating in Indian healthcare were identified randomly. These physicians were interviewed by an independent member (external to the team) who identified the attributes for the adoption of wireless technology by physicians in the Indian healthcare system. This approach was deliberate to address criticisms of 'bias' in the interview process. Further, due to linguistic issues, we required a person with proficiency in both Indian language and English. The interview questions were derived from existing literature. The first stage of the data collection concentrated on Indian hospitals with some form of wireless technology already in use. The physicians were also chosen based on their wireless technology awareness or working experience. They were drawn from both private and government hospitals. The interviews were conducted over a 45-60 minute period and recorded using a digital recorder. Once they were recorded, the interviews were transcribed.

***Quantitative Data Collection***

This study developed a survey instrument from the interview data. The main reason for this digressed attitude was that previously tested instruments in the technology domain were not relevant to healthcare setting and were found to be inadequate in answering the research question. The data from the interviews were used to develop specific ranges of questions to gather a more detailed view from the wider population. This survey instrument was pilot tested to capture the information reflecting the perceptions and practice of those adopting the wireless technology in the Indian healthcare system. Particularly, it focussed on what internal and external environmental factors affect the adoption of wireless technology and the extent of this influence. The survey was then distributed to over 300 physicians randomly chosen from the telephone book and a total of 200 responses were received. The survey responses were then entered into a spreadsheet file. A Visual Basic interface was written to generate numerical codes for various elements of the survey for data analysis using SPSS. The coded spreadsheet file was then copied onto a SPSS file format.

## 5. DATA ANALYSIS

Qualitative data was analysed using the NVivo (version 7) application, which helped identify the initial themes from the interviews. Quantitative data were analysed using SPSS, which helped identify the factors and their correlation for the adoption of wireless technology in the Indian healthcare setting.

***Qualitative Data Analysis***

Qualitative data was manually coded to extract themes that had an impact on wireless technology acceptance as stated by the physicians. In total, 63 themes were extracted from the interviews. The initial themes include awareness, cost factors, advantages and disadvantages, medical errors, information sharing, current state of technology, usefulness and role of wireless technology, and technology awareness. On the basis of the interviews and the literature review, the themes were classified into drivers and inhibitors as shown in the following table. This list of drivers and inhibitors was expected to provide a direction for the development of the survey instrument for the collection of quantitative data to capture the wider community views and to generalize the outcome of the research. This grouping is presented in Table 1.

**Table 1: The factors driving and inhibiting wireless technology adoption in healthcare**

| Drivers | Barriers |
|---|---|
| • Save-time<br>• Improve-clinical-workflow<br>• Efficiency-in-communication | • Legal barriers<br>• Administrative purpose<br>• Communication with physicians |

| | |
|---|---|
| • Delivery-of-high-qual-info<br>• Better-quality-of-service<br>• Save-effort<br>• Improve-clinical-performance<br>• More-contact-time-with-patients<br>• Improved-delivery-of-information<br>• Reduce-overall-cost<br>• Positive-impact-on-patient-safety<br>• Reduce-inaccuracies<br>• Improve-public-image<br>• Reduce-medical-errors<br>• Easy-access-to-data<br>• Attract-more-practitioners<br>• Reduce-workload | • Patient education<br>• Communication with colleagues<br>• Obtain lab results<br>• Note taking<br>• Electronic medical records<br>• Device usage barrier<br>• Benefit evaluation barrier<br>• Resource barrier<br>• Electronic prescribing |

The content of the Table 1 is consistent with findings of previous studies conducted by Gururajan et al. (2004; 2005). This prompted conducting a quantitative study in order to establish causality among dependent and independent variables, as well as external validity and generalisability.

***Quantitative Data Analyses***

In order to ensure statistical reliability, suitable tests were run on the entire instrument, as well as selected group of variables. For example, the reliability test returned a Cronbach alpha value of 0.965 for the instrument indicating high reliability (Zikmund, 1994). We ran this test because the instrument was generated from the interview data and, hence, it was necessary to establish statistical reliability. In addition, reliability tests were also run for three factor groupings, namely, drivers, inhibitors of adoption and other technology factors. The reliability tests returned values of 0.941, 0.447 and 0.536, respectively, indicating that the data were suitable for factor analysis testing.

As a second step, survey data were analysed for factor analysis using SPSS. It is evident from the table below that two factor component matrix identified drivers and the barriers for the adoption of wireless technology in the Indian healthcare setting. This finding is consistent and aligned with the findings of the qualitative data collection stage (i.e. first stage) of this research.

**Table 2: The factors driving and inhibiting wireless technology adoption in healthcare from data analysis of survey result**

| Drivers | Loading values | Barriers | Loading values |
|---|---|---|---|
| improve-clinical-workflow | .798 | poor technology barrier | .605 |
| tech-support | .764 | time for training barrier | .572 |
| delivery-of-high-qual-info | .760 | tech expertise barrier | .554 |
| save-time | .757 | benefit evaluation barrier | .503 |
| better-quality-of-service | .749 | legal barriers | .465 |
| save-effort | .743 | solutions barrier | .444 |
| improved-delivery-of-information | .732 | system migration barrier | .442 |
| efficiency-in-communication | .730 | technical support barrier | .436 |
| more-contact-time-with-patients | .725 | lack of support barrier | .352 |

| | | | |
|---|---|---|---|
| improve-clinical-performance | .702 | device access barrier | .316 |
| more-training | .699 | device comfort barrier | .248 |
| improve-public-image | .695 | funding barrier | -.225 |
| easy-access-to-data | .692 | security as barrier | .224 |
| positive-impact-on-patient-safety | .679 | device usage barrier | .208 |
| reduce-inaccuracies | .659 | | |
| reduce-workload | .657 | | |
| reduce-medical-errors | .650 | | |
| reduce-overall-cost | .634 | | |
| attract-more-practitioners | .600 | | |
| Org-culture | .464 | | |

The drivers were further tested for factor groupings. The analysis resulted in Table 3.

**Table 3: The factors driving wireless technology adoption in healthcare from data analysis of survey result**

| | Organizational | Management | Clinical |
|---|---|---|---|
| save-effort | .716 | | |
| reduce-overall-cost | .708 | | |
| reduce-inaccuracies | .703 | | |
| save-time | .667 | | |
| easy-access-to-data | .659 | | |
| attract-more-practitioners | | .769 | |
| improve-public-image | | .680 | |
| tech-support | | .680 | |
| reduce-workload | | | .817 |
| improve-clinical-performance | | | .797 |

The driving factors of adoption yielded three categories of factors, namely, 'organisational', 'management' and 'clinical'. The organisational components include wireless technology drivers that can generate specific benefits for organisations. The management components represent the benefits that healthcare managers can realise using wireless technology. The clinical components encompass clinical drivers of using wireless technology.

A similar factor model was generated for the inhibitors. The model resulted in Table 4:

**Table 4: The factors inhibiting wireless technology adoption in healthcare from data analysis of survey result**

| | Technology | Resource | Usage |
|---|---|---|---|
| poor technology barrier | .625 | | |
| time for training barrier | .582 | | |
| solutions barrier | .575 | | |
| benefit evaluation barrier | .528 | | |
| tech expertise barrier | .527 | | |
| system migration barrier | .511 | | |

| | | | |
|---|---|---|---|
| funding barrier | | -.749 | |
| resource barrier | | -.690 | |
| technical support barrier | | | .542 |
| device usage barrier | | | .519 |

Similar to the drivers, the inhibitors also resulted in three specific categories. The 'technology' category includes technology factors that inhibit wireless adoption in the Indian healthcare. The 'resource' category encompasses resource barriers that are currently being encountered in the healthcare setting. Finally the 'usage' category is comprised of inhibiting factors, which are associated with usage issues.

In addition to the two factor groups, namely drivers and inhibitors, we also identified a third. We named this 'clinical usefulness' and its components are shown in Table 5 below.

**Table 5: The factors 'clinical usefulness' of wireless technology adoption in healthcare from data analysis of survey result**

| | General Communication | Clinical Communication | Records Management |
|---|---|---|---|
| Obtain lab results | .837 | | |
| Administrative purpose | .770 | | |
| Electronic prescribing | .670 | | |
| Medical database referral | .632 | | |
| Patient education | | .727 | |
| Communication with colleagues | | .707 | |
| Communication with patients | | .676 | |
| Drug administration | | .596 | |
| Communication with physicians | | .548 | |
| Electronic Medical Records | | | .764 |
| Generating exception list | | | .738 |
| Note taking | | | .617 |
| Disease state management | | | .563 |

This factor group yielded three components. The first component deals with the general communication aspects facilitated by wireless technology in healthcare settings. The second component refers to clinical communication using wireless technology. The third component is specific to records management. In summary, the data analyses yielded three specific categories of factors which can affect the adoption of wireless technologies in the healthcare setting. These comprise adoption drivers, inhibitors, and clinical usefulness.

***Hypotheses Formulation and Testing***

Based on the evidence collected, the three sets of factors, namely, drivers, barriers and clinical usefulness, contribute to the acceptance of wireless technology in healthcare. We hypothesise that the drivers positively impact clinical usefulness, whereas the barriers have a negative impact on it. While the drivers and barriers include factors beyond the technology aspects, their respective influences are

restricted to the clinical domain as this is where the usefulness of wireless technology can be experienced. Therefore, the following two hypotheses were generated for testing:

H1: Drivers of wireless technology positively impact clinical usefulness.

H2. Barriers to wireless technology negatively impact clinical usefulness.

A Partial Least Square (PLS) model was developed in order to test the hypotheses. The rationale for using PLS includes: PLS is used for confirmatory factor analysis (CFA); the pattern of loadings of items on the latent constructs is explicit; PLS provides strong convergent and discriminant validity; p-value of t-value is significant (over 0.50 level) for constructs; and measurement items load highly on theoretically assigned factors and not highly on other factors.

## 6. PLS MODEL DEVELOPMENT

In order to develop the PLS model, a PLS Graph prototype was used. Initially, the individual drivers, barriers and clinical usefulness were tested for CFA scores and these were found to be reliable. When the CFA was found to be satisfactory, a model was built with clinical infuences as dependent variable on drivers and barriers. The factors of these three constructs were linked using PLS Graph software and the model was run. The final outcome is shown in Figure 1 below.

Figure 1 shows that the factor loading (the number on the path: for example, for the construct Drivers, the 'esydataccs' has 0.763) and the factor weight (the number in the parantheses: for example, 0.101) for almost all factors are reliable. The drivers and clinical usefulness load very highly (over 0.8 for most of the items), indicating a high reliability. Further, all variables have a t-value of over 1.96 to indicate high convergent validity.

Upon construct validation, a simple PLS (consolidated) model was developed to test the hypotheses. The model consists of clinical usefulness as the dependent variable, and drivers and barriers as independent variables. The model was run with PLS Graph program and the screenshot shown in Figure 2 displays the values along the link from Drivers to Clinical Usefulness, and Bariers to Clinical Usefulness. As hypothesised, drivers exhibited a positive loading (0.097) and the barriers exhibited a negative loading (-0.384). The number below the circle Clinical Usefulness is the construct $R^2$, which is calculated and displayed for each dependent variable. The lower the $R^2$, the minimum the error in the model. In the model the R2 values for the dependent variable 'Clinical Usefulness' is 0.167. This is not high and hence the error is minimal. This is shown in Figure 2.

## 7. IMPLICATIONS

Clearly, wireless technology can be used to facilitate access to clinical information and communications between clinicians, maximise clinician time, increase patient safety, and accomplish the strategic and business goals of health organisations. Taken together, these factors have a direct impact on clinical usefulness and its effectiveness. However, achieving clinical usefulness with wireless handheld devices can be a challenge and has several implications.

Firstly, the highest security standards must be achieved. This includes direct end-to-end data encryption, authentication, authorisation, maintenance of audit logs and session management (Chen et al. 2004). While high security standards are essential, their implementation is likely to affect usability. For example, the download and encryption of patient information from the server where it is stored into a wireless handheld device may not be prompt. Sax et al. (2005) argue that clinicians may experience increasingly longer time lags when they carry out increasingly more complex procedures. This is likely to adversely affect clinical usefulness and, hence, decrease user acceptance.

Closely associated with security is also the issue of patient confidentiality, which is of significant importance and concern. Although wireless handheld devices have locking security features and password protection functions which activate during periods of inactivity, the frequent use of these functions during the clinicians' busy daily schedules may have an impact on clinical usefulness.

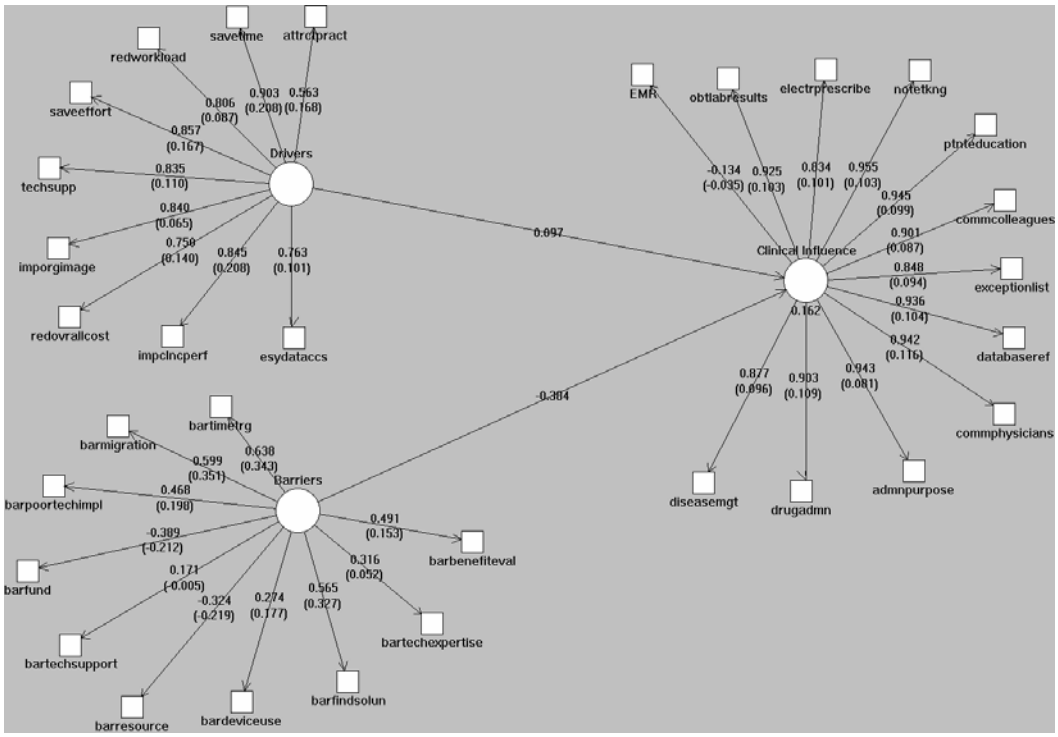


**Figure 1: PLS Model of adoption of wireless technologies in Indian healthcare**

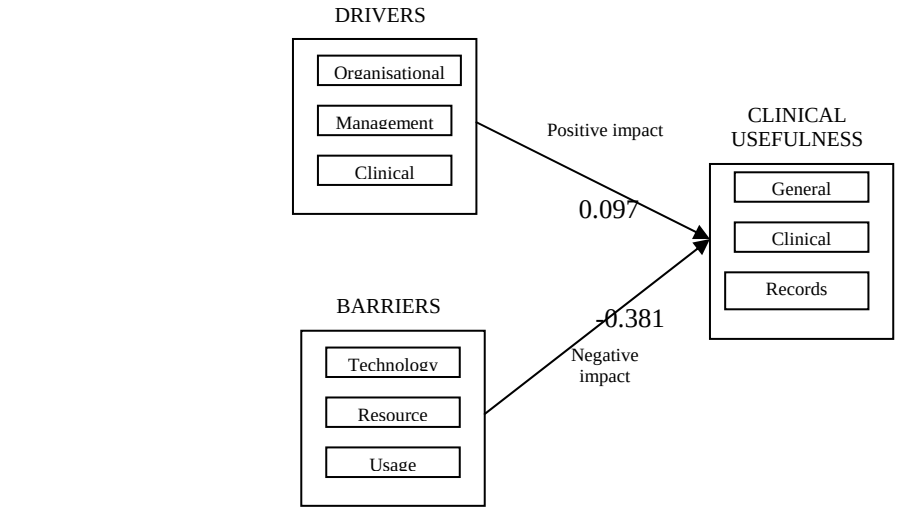


**Figure 2: Result of Model Testing**

Secondly, the design of an effective human-computer interface, while challenging, constitutes a key factor for the acceptance of the technology and its routine use by healthcare workers (Chen et al. 2004). This is an important development consideration as the relevant information should be easy to navigate and read, and has to be presented in an organised fashion when required within the resource

limitations (e.g. screen size and bandwidth) of a wireless handheld environment. Usability factors are not only likely to constitute an acceptance barrier, but can also be the cause of medical errors. Bates et al. (2001) argue, 'While it may be easy and common to blame operators for accidents [or errors], investigation often indicates that an operator "erred" because the system was poorly designed' (p. 301). Therefore, medical errors can also occur due to poor usability. Taken together, these factors would contribute to reduce medical errors. By implication, it is important to involve users in the design of the wireless applications, thereby maximising their clinical usefulness.

Thirdly, simply acquiring and implementing wireless technology alone would be insufficient to accomplish clinical usefulness and, subsequently, drive adoption and diffusion. Wireless technology should be integrated with process improvement and organisational change. Process improvement requires the optimisation of clinical processes and should be supported by technology, rather than driven by it (Smith 2004). Ultimately, this is likely to generate significant patient outcomes and financial improvements with health organisations.

Fourthly, as suggested by the empirical evidence collected in this study, cost constitutes an important factor which will affect the integration and, subsequently, the success of wireless handheld devices in the healthcare setting (Sax et al. 2003). Typically costs include the software, the server, upgrades of healthcare organisations' existing networks and legacy systems, the costs of the handheld units themselves, as well as maintenance and support. While existing research in this area argues that such technology has the potential to decrease charting time and medical errors and enhance patient care quality, there is no evidence that comparisons of costs before and after the implementation of wireless technology have been made. This suggests that further research is required, but also, most importantly, it shows that, indirectly, costs have the potential to affect clinical usefulness and threaten widespread adoption.

## 8. FUTURE RESEARCH

This research is an exploratory study to identify clinical influences of wireless technology applicable to the Indian healthcare system. While we obtained data on perceived opinions, we were not able to actually measure the usefulness of wireless technology in a clinical setting. Currently, we are conducting a project that would enable us to measure clinical influences of using wireless technology in an objective manner. We expect that this new project will provide us with some insights into the efficiency gains of using wireless technology and the challenges people encounter in using this technology.

This study is confined to the Indian healthcare setting, which limits the generalisability of its findings. However, this study is also the first of its nature and, as a result, it has prepared the groundwork for further research which can confirm (or refute) whether our findings are applicable to other settings. We are also collecting data using the same instruments in Australia, Taiwan and India. We anticipate the data collection to be completed by December 2006. This exercise, we hope, will enable to us extend our notion to broader populations.

## 9. REFERENCES


Athey, S., & Stern, S. 2002. The impact of information technology on emergency health care outcomes. RAND Journal of Economics, 33(3), 399 - 388.

Bates, D.W., Cohen, M., Leape, L.L., Overhage, M., Shabot, M.M. & Sheridan, T. 2001. 'Reducing the Frequency of Errors in Medicine Using Information Technology', Journal of the American Medical Informatics Association, 8 (4), pp. 299-308

Chau, P. Y. K., & Hu, P. J.-H. 2002. Investigating healthcare professionals' decision to accept telemedicine technology: An empirical test of competing theories. Information and Management, 39, 297-311.

Chen, E., Mendoca, E.A., McKnight, L.K., Stetson, P.D., Lei, J. & Cimino, J.J. 2004. 'PalmCIS: A Wireless Handheld Application for Satisfying Clinician Information Needs', Journal of the American Medical Informatics Association, 11 (1), pp. 19-28

Chismar, W. R., & Wiley-Patton, S. (2006). Predicting Internet Use: Applying the Extended Technology Acceptance Model to the Healthcare Environment. In T. A. M. Spil & R. W. Schuring (Eds.), E-Health Systems Diffusion and USe: The Innovation, the USer and the USE IT Model. London: Idea Group Publishing.

Davies, F. D., Bagozzi, R. P., & Warshaw, P. R. 1989. User acceptance of computer technology: A comparison of two theoretical models. Communications of the ACM, 35(8), 982-1003.

Davis, R. 2002. Pursue front end solutions to revenue problems. Healthcare Financial Management, 56(8), 30 - 36.

Davis, S., & Bostrom, R. 1993. Training end users: An experimental investigation of the roles of the computer interface and training methods. M I S Quarterly(March), 61-85.

Dyer, O. 2003. 'Patients will be reminded of appointments by text messages', British Medical Journal, 326 402 , 281.

Dyer, O. 2003. Patients will be reminded of appointments by text messages. British Medical Journal, 326(402), 281.

Fischer, S., Stewart, T.E., Mehta, S., Wax, R. & Lapinsky, R. 2003. 'Handheld Computing in Medicine', Journal of the American Medical Informatics Association, 10 (2), pp.139-149.

Gururajan, R. et al. 2004. 'Necessity for a new technology acceptance model to predict adoption of wireless technology in healthcare', paper presented at the Let's Make a Difference with Health ICT, HIC Conference, 25-27 July .

Gururajan, R. et al. 2005. 'Drivers and Barriers to adoption of wireless handheld system in WA healthcare: Selected views', paper presented at the HIC 2005, Melbourne.

Gururajan, R., Moloney, C., & Kerr, D. 2005. Drivers for wireless handheld technology: views from Queensland nurses. Paper presented at the Australian Business & Behavioural Sciences Association (ABBSA) Conference, Cairns, Australia.

Gururajan, R., Quaddus, M., Fink, D., Vuori, T., & Soar, J. 2005. Drivers and Barriers to adoption of wireless handheld system in WA healthcare: Selected views. Paper presented at the HIC 2005, Melbourne.

Gururajan, R., Toleman, M., & Soar, J. 2004, 25-27 July. Necessity for a new technology acceptance model to predict adoption of wireless technology in healthcare. Paper presented at the Let's Make a Difference with Health ICT, HIC Conference.

Horan, T. A., Tule, B., & Hilton, B. N. (2006). Understanding physician use of online systems: An empirical assessment of an electronic disability evaluation system. In T. A. M. Spil & R. W.Schuring (Eds.), E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model. London: Idea Group Publishing.

Howard, A., Gururajan, R., Hafeez-Baig, A., & Howard, S. 2006. Clinical Usefulness of Wireless Technology in Healthcare: An Indian Study. Paper presented at the The Australasian Conference on Information Systems, University of South Australia.

Hu, P. J., Chau, P. Y. K., & Liu Sheng, O. R. 2002. Adoption of telemedicine technology by health care organisations: An exploratory study. Journal of organisational computing and electronic commerce, 12(3), 197-222.

Hu, P. J., Chau, P. Y. K., & Tam, K. Y. 1999. Examining the technology acceptance model using physician acceptance of telemedicine technology. Journal of Management Information Systems, 16(2), 91-112.

Ivers, B., & Gururajan, R. 2006. Management issues in telecommunications: videoconferencing & telehealth. Paper presented at the International Conference on Recent Trends in Information Systems Proceedings, India.

Jayasuriya, R. 1998. Determinants of microcomputer technology use: Implications for education and training of health staff. International Journal of Medical Informatics, 50, 187-194.

Lapointe, L., Lamothe, L., & Fortin, J. (2006). The dynamics of IT adoption in a major change process in healthcare delivery. In T. A. M. Spil & R. W. Schuring (Eds.), E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model. London: The Idea Group Publishing. London: Idea Group Publishing.

Mingers, J. 2001. 'Combining IS research methods: Towards a pluralist methodology', Information Systems Research, 12 (3) , 240-259.

Mingers, J. 2001. Combining IS research methods: Towards a pluralist methodology. Information Systems Research, 12(3), 240-259.

Myers, M. D. 1997. Qualitative research in Information Systems. MIS Quarterly, 21(2), 241-242.

Reinecke, I. 2004. 'Managing Information in Health', Melbourne National Health Information Summit.

Reinecke, I. (2004). Managing Information in Health. Melbourne National Health Information Summit.

Rogoski, R. 2005. 'Wireless by Design', Health Management Technology January , 1-7.

Sausser, G. D. 2003. Thin is in: web-based systems enhance security, clinical quality. Healthcare Financial Management, 57(7), 86-88.

Sax, U., Kohane, I. & Mandl, K.D. 2005. 'Wireless Technology Infrastructures for Authentication of Patients: PKI that Rings', Journal of the American Medical Informatics Association, 12 (3), pp. 263-268.

Simpson, R. L. 2003. The patient's point of view -- IT matters. Nursing Administration Quarterly, 27(3), 254-256.

Smith, C. 2004. 'New Technology Continues to Invade Healthcare: What are the Strategic Implications/Outcomes?', Nursing Administration Quarterly, 28 (2), pp. 92-98.

Spil, T. A. M., & Schuring, R. W. 2006. E-Health system Diffusion and Use. Hershey: IDea Group Publishing.

Stuart, D., & Bawany, K. (2001). Wireless Services: United Kingdom (Operational Management Report No. DPRO-90741): Gartner.

Suomi, R. (2006). Introducing electronic patient records to hospitals: Innovation adoption paths. In T. A. M. Spil & R. W.Schuring (Eds.), E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model

Turisco, F. 2000. Mobile computing is next technology frontier for health providers. Healthcare Financial Management, 54(11), 78 - 82.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. 2003. User Acceptance of Information Technology: Toward A Unified View. MIS Quarterly, 27(3), 425-478.

Wisnicki, H. J. 2002. Wireless networking transforms healthcare: physician's practices better able to handle workflow, increase productivity (The human connection). Ophthalmology Times, 27(21), 38 - 41.

Zikmund, W. 1994. Business research methods. International edn. , Orlando, FL: The Dryden Press.