A System Dynamics Model of eHealth Acceptance: A Sociotechnical Perspective

GETNET BOGALE FANTA
University of Pretoria, Department Engineering and Technology Management, South Africa
genetb@gmail.com (Corresponding)

LEON PRETORIUS
University of Pretoria, Department Engineering and Technology Management, South Africa
leon.pretorius@up.ac.za

LOUWRENCE ERASMUS
University of Pretoria, Department of Engineering and Technology Management, South Africa
l.erasmus@ieee.org

ABSTRACT

The majority of stakeholders recognize the importance of eHealth in providing support for the management of patient records. However in many cases it is shown that the end users did not fully accept eHealth technology when implemented in a naturalistic healthcare settings because of technical, social, economic or/and organizational factors.

The introduction of eHealth technology in healthcare facility results in the emergent and recursive interactions among new technology and existing social systems, technologies, and physical environments. These dynamic sociotechnical interactions are the major sources of unintended consequences during eHealth implementation that can sometimes undermine quality and safety, and can lead to implementation failure. Understanding the individual components of sociotechnical system and the interplay between them helps to expose the causes of particular eHealth implementation or use problems.

The usability problem of eHealth technology could result from the technical dimensions like human computer interaction, or the social dimension such as the users’ perception towards the usefulness of technology to achieve their operational goal. Moreover organizational policies, procedure and cultures are also believed to affect the use of eHealth technology within an adopting organization.

The dynamic complexity arises from sociotechnical interaction during the design, development, implementation and operation of eHealth technology within complex healthcare environment. The complex interactions and feedbacks occurring within a dynamic environment influence the acceptance of technology by end users. System dynamics is part of a research simulation method that may enhance the learning process in complex systems. This is then the research approach followed in this paper.

In this paper the Information System (IS) success, technology acceptance model (TAM) and sociotechnical models are used; moreover literatures that validate the models with empirical evidence are reviewed as part of an exploratory research method. A system dynamics approach is used seeking for the possibility to unlock the dynamic nature sociotechnical elements of eHealth acceptance. The study identified four sociotechnical dimensions for eHealth acceptance, namely technical, social, technology use and outcome dimensions and the interplay among the elements during the technology implementation and use. An iterative system dynamics modelling process to represent the complex interplay among sociotechnical elements
during eHealth implementation and use within healthcare facility is followed in this research. The proposed system dynamics model shows the dynamic interaction and critical feedbacks of the sociotechnical factors of eHealth technology implementation and use.

The sociotechnical framework for technology acceptance proposed in this study supports the effort of successful eHealth technology design, development, implementation, and operation by providing the additional insight into sociotechnical dimensions and their interaction during implementation and use of eHealth technology within healthcare facility to maximize the users’ acceptance.

**Key words:** Sociotechnical, eHealth, Technology Acceptance, Information System Success, System Dynamics.

**INTRODUCTION AND RESEARCH METHOD**

The vast majority of stakeholders recognized the importance of eHealth in providing support for the management of patient records. However the diffusion of Health Information Technology (HIT) solutions within healthcare remains limited. The process of effective technology diffusion is influenced by both technology adoption as well as acceptance (Fanta, Pretorius, & Erasmus, 2015).

The five stage innovation-decision process model that focuses on the diffusion of technology incorporates both the technology adoption and acceptance processes as well as decisions (Rogers 2003). Similarly, Venkatesh & Bala (2008) classification of the technology adoption intervention into pre-implementation and post-implementation categories corresponds to technology adoption and acceptance respectively. Technology acceptance usually takes place at an individual level; however, the adoption process and decisions can be either at the institutional level or at an individual level (Oliveira & Martins 2011).

The successful adoption of a Computerized Patient Record System (CPRS) in one paediatric office and failure in another paediatric office is an indication of the social structure influence to the successful implementation of technology (Reddy, Pratt, Dourish, & Shabot, 2003). Besides the contribution of technical flaws to the failure of HIT, the undesirables outcomes of sociotechnical interactions during HIT implementation significantly hinder its success (Harrison, Koppel, & Bar-Lev, 2007). Sauer (1994) also indicated that the social and behavioural factors are the main reasons of information systems failures may be more than the technical factors.

The social practices in the healthcare domain are highly institutionalized, as a result the sociotechnical elements play a prominent role in the implementation of HIT solutions (Reddy et al. 2003). The sociotechnical interaction is an interplay between new HIT and the adopting organisation’s existing sociotechnical conditions such as technologies, workflows, culture, and social interaction (Harrison et al. 2007). Petrakaki, Cornford, & Klecun (2010) argued that the “sociotechnical changing” is a continuous process but not static or district post and pre implementation “impacts” or notions of district change.

An exploratory research method is followed, based on reviewed academic literature and a system thinking approach leading to system dynamics. The key words ‘TAM’ and ‘IS success model’ are used on Google scholar and PubMed databases to identify literatures with empirical
As part of an exploratory study. The bibliographies of selected papers are also visited to identify studies that have empirically validated the models.

In this paper, we seek for the possibility of understanding the dynamic relations between social and technical factors during eHealth implementation to facilitate acceptance by the end users. The brief discussion on technology acceptance and IS success models from literatures will be followed by analysis of social and technical factors that impact eHealth implementation. The sociotechnical models as well as the quantitative evidences of TAM and IS success model are reviewed to confirm the link between social and technical variables of the proposed sociotechnical model of technology acceptance. The proposed system dynamics model of eHealth acceptance aims to maximize the acceptance of technology by benefiting policy makers as well as stakeholders involved in the design, implementation, and operation of eHealth systems.

THEORETICAL BACKGROUND

Acceptance of technology

The acceptance and use of technology by the intended end users is one of the key success factors of information systems (IS) implementation (DeLone & McLean 1992; DeLone & McLean 2003; Michel-Verkerke, Stegwee, & Spil 2015). However, Seddon (1997) argued that IS success should be measured by its net benefit instead of the system use. Studies indicated strong association between system use and net benefit (DeLone & McLean 2003); hence, technology acceptance or system use is a necessary but not sufficient condition to the success of eHealth systems.

The two determinants, perceived usefulness and perceived ease of use, were hypothesized to be fundamental determinants of user acceptance of Information Technology in the technology acceptance model (TAM) as shown in Figure 1 (Davis 1989).

- **Perceived usefulness** is defined as “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989:320).
- **Perceived ease of use** refers to “the degree to which a person believes that using a particular system would be free of effort” (Davis, 1989:320).

In two studies involving 152 users and four applications programs, Davis (1989) argued *usefulness* had a greater correlation with usage behaviour than *ease of use*. The regression analyses further indicated that perceived ease of use may actually be a causal antecedent to perceived usefulness, rather than a direct determinant of system usage (Davis 1989).

![Figure 1: Technology Acceptance Model (Source: Davis, 1989 and Venkatesh & Davis, 2000).](image-url)
In subsequent study, Venkatesh & Davis (2000) used TAM as the starting point and incorporated additional theoretical constructs to capture social influence processes (subjective norm, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality, result demonstrability, and perceived ease of use) to propose TAM2. The data polled from four studies across the three time periods yielded a sample of 468, with a sample of 156 per each period, indicated that “unlike the social influence processes, the effect of cognitive instrumental processes remained significant over time” (Venkatesh & Davis, 2000:199). The study also concluded that subjective norm significantly affects the intention to use directly only when usage is mandatory and experience is in the early stages (Venkatesh & Davis, 2000:198).

By combining TAM2 and the model of the determinants of perceived ease of use, Venkatesh & Bala (2008) proposed an integrated model of technology acceptance - TAM 3. The perceived ease of use, subjective norm, image, and result demonstrability were identified as a significant predictors of perceived usefulness (Venkatesh & Bala, 2008). The study further indicated that perceived usefulness was the strongest predictor of behavioural intention during pre- and post-implementation (Venkatesh & Bala, 2008).

Venkatesh, Morris, Davis, & Davis (2003) reviewed eight user acceptance models and formulated the Unified Theory of Acceptance and Use of Technology (UTAUT) that integrates elements across the eight models. The UTAUT identified three direct determinants of intention to use (performance expectancy, effort expectancy, and social influence) and two direct determinants of usage behaviour (intention and facilitating conditions). In addition, the model confirmed four moderators of key relationship (gender, age, experience and voluntariness of use) as integral features of UTAUT (Venkatesh et al., 2003).

The potential of several technology acceptance and innovation diffusion models were analysed and Ward (2013) highlighted the weakness of the models to differentiate between the technological and human factors for acceptance of health related IT projects limited the models’ applicability in practice.

Information system success

The IS success factors are multi-dimensional elements covering a wide range of performances such as technical, human, financial and organizational factors (DeLone & McLean 2003; Seddon 1997; Petter et al. 2013; Al-Mamary et al. 2014; Al-Mamary et al. 2015). As depicted by DeLone & McLean (1992), the six distinct aspects of IS success are:

- **System quality**: Measures the desired characteristics of the IS itself (technical success).
- **Information quality**: Measures the IS output.
- **Use**: Recipient consumption of the output of an information system.
- **User satisfaction**: Recipient response to the use of the output of an IS.
- **Individual impact**: The effect of information on the behaviour of the recipient.
- **Organizational impact**: The effect of information on organizational performance.

The IS success model postulated by DeLone & McLean (1992) shows the interdependency of the six distinct dimensions within three process components; namely, the creation of a system, the use of the system, and the consequences of this system use. The ‘System Quality’ and ‘Information Quality’ belong to the ‘creation of system’ process dimension and are believed to affect both ‘Use’ and ‘User Satisfaction’. In a process sense, the ‘Use’ precedes ‘User Satisfaction’, however both can positively or negatively affect each other. The model also
indicates that ‘Information Use’ and ‘User Satisfactions’ are direct antecedents of ‘Individual Impact’; which eventually have some effect on ‘Organizational Impact’ (DeLone & McLean 1992).

After ten years, DeLone & McLean (2003) evaluated research studies which made use of their model. They specifically looked at the research efforts that applied, validated, challenged, and proposed enhancements to the original IS success model, and came up with an updated DeLone and McLean IS Success Model. *Service quality*, i.e., the measure of overall support delivered, was one of the inclusion in the updated model as the third quality dimension. To address the process versus causal concerns of the model as well as to resolve the difficulties of several interpretation of “use”, such as mandatory versus voluntary, informed versus uninformed, effective versus ineffective, the “intention to use” was introduced in the updated model (DeLone & McLean 2003). “‘Intention to use’ is an attitude, whereas ‘use’ is a behaviour.” (DeLone & McLean, 2003:23).

Furthermore, all the IS impact measures, such as work group impact, organizational impact, consumers impact, societal impacts, were grouped into a single category called “net benefit” (DeLone & McLean 2003). Figure 2 depicts the influence of net benefits on the intention to use, use and user satisfaction with feedback loops.

---

![Figure 2: Updated D&M IS Success Model (Source: DeLone & McLean, 2003).](image)

The three major categories proposed as important dimensions of management Information System (MIS) adoption in organizations are *technological, organizational* and *people* factors (Al-Mamary, Shamsuddin, & Aziati 2014). The *technological, social, organizational (environmental)* and *economic* factors are suggested to be four key factors for the sustainable implementation of eHealth systems (Fanta, Pretorius, & Erasmus, 2015).

The system, information and service qualities of IS success model address the technology features of a system hence grouped in the technological dimension. The individual perception (usefulness and ease of use) and social influence are the important factors that determine the social dimension of IS success (Petter et al. 2013). The Individual perception relates to the attitude, behaviour and personal demography of individuals towards using the IS (Petter et al. 2013). The social influence refers to the influence of peer groups or social networks on individual’s behaviour towards using technology (Petter et al. 2013).
The sociotechnical models

The interaction of people through technology to create a community results in a sociotechnical system (Whitworth & Sylla 2012). The sociotechnical system involves complex interaction among the social subsystems (people, tasks, relationships), technical subsystems (technologies, techniques, task performance methods, work settings) and their social and organizational aspects of a system (Baxter & Sommerville, 2011:4-5; Harrison, Koppel, & Bar-Lev, 2007). Hence the sociotechnical systems design (STSD) should consider these factors—people, machines and context—when developing complex sociotechnical systems (Baxter & Sommerville, 2011:5). In general, the sociotechnical perspective of eHealth implementation considers the interaction between the technical features of an eHealth system with the social features of a healthcare work environment (Ludwick & Doucette 2009).

The sociotechnical factors directly influence the eHealth implementation success (Ludwick & Doucette 2009). The five key characteristics of sociotechnical systems are (Baxter & Sommerville, 2011:5):

- Systems have interdependent parts.
- System adapts to and pursues goals in external environments.
- Internal environment of a system comprises separate but interdependent technical and social subsystems.
- There are more than one system of choices to achieve the system goals.
- System performance depends on the joint optimisation of the technical and social aspects of the system.

Figure 3 describes the emergence of four different sociotechnical system levels, namely hardware, software, human-computer interaction and sociotechnical (Whitworth & Sylla 2012).

Sittig & Singh (2010) proposed an 8-dimensional sociotechnical model aimed to address challenges in the design, development, implementation, use and evaluation of HIT within
complex healthcare environment. Table 1 shows the relationship between the four levels of sociotechnical systems and the 8 dimensions of sociotechnical systems.

The Interactive Sociotechnical Analysis (ISTA) framework recognizes the conditions characterizing complex adaptive systems – the sociotechnical interactions that are dynamic, emergent, hard to understand and often surprising (Harrison et al. 2007). The ISTA framework captures five common types of dynamic, emergent and recursive sociotechnical interaction among the new eHealth system, existing social systems, technologies, and physical environments to raise awareness of unanticipated consequences during eHealth implementation (Harrison et al. 2007).

### Table 1: The sociotechnical levels of 8 sociotechnical dimension

<table>
<thead>
<tr>
<th>Sociotechnical dimensions of HIT (Sittig &amp; Singh, 2010)</th>
<th>Sociotechnical system levels (Whitworth &amp; Sylla 2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware and software computing infrastructure.</td>
<td>X X</td>
</tr>
<tr>
<td>Clinical content</td>
<td>X</td>
</tr>
<tr>
<td>Human computer interface</td>
<td>X</td>
</tr>
<tr>
<td>People</td>
<td>X</td>
</tr>
<tr>
<td>Workflow and communication.</td>
<td>X</td>
</tr>
<tr>
<td>Internal Organizational policies, procedures, and cultures</td>
<td>X</td>
</tr>
<tr>
<td>External rules, regulations, and pressures.</td>
<td>X</td>
</tr>
<tr>
<td>System measurement and monitoring.</td>
<td>X</td>
</tr>
</tbody>
</table>

The five types of interactions addressed in the framework are (Harrison et al. 2007):
- New HIT changes existing social system.
- Technical & physical infrastructures mediate HIT use.
- Social system mediates HIT use.
- HIT-in-use changes social system.
- HIT-social system interactions engender HIT redesign.

### THE SOCIOTECHNICAL FRAMEWORK FOR TECHNOLOGY ACCEPTANCE

The TAM has been widely used and empirically tested to predict the user acceptance and use of Information Systems (Davis 1989); besides the IS success model has been applied in a wide range of research studies to empirically validate the success of Information Systems (DeLone & McLean 1992). Al-Mamary et al. (2014) categorized the three quality variables of the IS success model namely, system, information and services quality (DeLone & McLean 2003) as a key factors affecting IS acceptance in the technological dimension. The three quality factors are widely studied and empirical validated elements of IS Success model.

The implementation of new eHealth technology is believed to bring changes into an existing social system (Harrison et al. 2007). Moreover, Harrison et al. (2007) indicated that the social and technological features play a key role in mediating technology use. The technology end-users and their social network are the key IS success determinants with in the social dimension (Petter et al. 2013). The elements of the social dimension, individual perception (usefulness...
and ease of use) as well as social influence, are widely addressed and empirically tested in the studies that used the TAM.

The sociotechnical framework for technology acceptance has been developed as a result of literature reviews. The framework adapts the three qualities (system, information and service quality) factors from IS success model in the technological dimension; and the constructs of TAM in the social dimension. Moreover, TAM and IS success models are combined to develop the technology use dimension of the theoretical framework. Eventually, the net benefit element of IS success model is adapted to address the outcome section of the theoretical sociotechnical framework (see Figure 4).

The relationship among the elements of the theoretical framework are determined from the empirical evidence reported on literature reviewed in this paper that validated the TAM and IS success model. The summary of evidences are presented in the Tables 2 - 5.

![Figure 4: The Sociotechnical Framework for Technology Acceptance.](image)

**Table 2: Relationship between social dimensions and other sociotechnical elements.**

<table>
<thead>
<tr>
<th>Relationships</th>
<th>Significance</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Influence - Intention to Use</td>
<td>3/3 Supported</td>
<td>Venkatesh et al. 2003; Aggelidis &amp; Chatzoglou 2009; Holden &amp; Karsh 2010</td>
</tr>
</tbody>
</table>

**Table 3: Relationship between outcome dimension and Intention to use.**

<table>
<thead>
<tr>
<th>Relationships</th>
<th>Significance</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Benefit - Intention to Use</td>
<td>1/1 Strongly Supported</td>
<td>Petter &amp; Mclean, 2009</td>
</tr>
</tbody>
</table>
Table 4: Relationship between technology use dimensions and other sociotechnical elements.

<table>
<thead>
<tr>
<th>Relationships</th>
<th>Significance</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Satisfaction - Intention to Use</td>
<td>2/2 Support</td>
<td>Chang et al. 2011; Petter &amp; Mclean 2009</td>
</tr>
<tr>
<td>Intention to Use - Actual use</td>
<td>4/4 Supported</td>
<td>Venkatesh et al. 2003; Iivari 2005; Holden &amp; Karsh 2010; Venkatesh &amp; Bala 2008</td>
</tr>
<tr>
<td>Actual use - User Satisfaction</td>
<td>3/4 Supported</td>
<td>Iivari 2005; Hou 2012; Petter &amp; Mclean 2009</td>
</tr>
<tr>
<td></td>
<td>1/3 Not supported</td>
<td>Tilahun &amp; Fritz 2015</td>
</tr>
</tbody>
</table>

Table 5: Relationship between technological dimensions and other sociotechnical elements.

<table>
<thead>
<tr>
<th>Relationships</th>
<th>Significance</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Quality - Information Quality</td>
<td>2/2 Supported</td>
<td>Aggelidis &amp; Chatzoglou 2012; Gorla et al. 2010</td>
</tr>
<tr>
<td>System Quality - Ease of use</td>
<td>2/2 Supported</td>
<td>Pai &amp; Huang 2011; Aggelidis &amp; Chatzoglou 2012</td>
</tr>
<tr>
<td>Information Quality - Actual Use</td>
<td>2/3 Supported</td>
<td>Tilahun &amp; Fritz 2015; Petter &amp; Mclean 2009</td>
</tr>
<tr>
<td>Information Quality - Intention to Use</td>
<td>2/2 Supported</td>
<td>Iivari 2005</td>
</tr>
<tr>
<td>Information Quality - Usefulness</td>
<td>2/2 Supported</td>
<td>Pai &amp; Huang 2011; Moores 2012</td>
</tr>
<tr>
<td>Information Quality - Intention to Use</td>
<td>2/2 Supported</td>
<td>Chang et al. 2011; Petter &amp; Mclean 2009</td>
</tr>
<tr>
<td>Service Quality - Social Influence</td>
<td>2/6 Supported</td>
<td>Aggelidis &amp; Chatzoglou 2009; Garcia-Smith &amp; Effken 2013</td>
</tr>
<tr>
<td>Service Quality - Net Benefit</td>
<td>2/2 Supported</td>
<td>Tilahun &amp; Fritz 2015; Venkatesh et al. 2003; Chang et al. 2011</td>
</tr>
<tr>
<td>Service Quality - Actual Use</td>
<td>2/3 Supported</td>
<td>Tilahun &amp; Fritz 2015; Venkatesh et al. 2003; Petter &amp; Mclean 2009</td>
</tr>
<tr>
<td>Service Quality - User Satisfaction</td>
<td>2/4 Supported</td>
<td>Tilahun &amp; Fritz 2015; Garcia-Smith &amp; Effken 2013</td>
</tr>
<tr>
<td></td>
<td>2/4 Not supported</td>
<td>Aggelidis &amp; Chatzoglou 2012; Petter &amp; Mclean 2009</td>
</tr>
</tbody>
</table>

The sociotechnical framework for technology acceptance addresses the important dimensions of sociotechnical systems, their interplay and the feedback processes. The theoretical framework has been used as a basis to develop a system dynamics model.

**SYSTEM DYNAMICS MODEL**

System dynamics is an interdisciplinary approach to enhance the learning in complex systems (Sterman 2000). Causal loop diagram (CLD) and stock and flow diagram (SFD) are the basic diagrammatic tools of system thinking and system dynamics (Sterman 2000). The CLD an
important approach to represent an interdependency and the feedback processes of systems (Sterman 2000).

Figure 5: Conceptual causal loop diagram of the sociotechnical framework of technology acceptance.

Figure 6: Conceptual stock and flow diagram of the sociotechnical model of technology acceptance.
The conceptual CLD is depicted in Figure 5 for sociotechnical framework for technology acceptance developed in the previous section from literature studies. The balancing loop (social influence on use) in the CLD indicates the rejected users influence on individual and social dynamics and eventually on the intention to use. There are two reinforcing loops, the first (quality on satisfaction) shows the influence of technological quality dimensions on the user satisfaction and net benefit; whereas the other (benefit of use) depicts the dynamics of actual use and users’ satisfaction on the net benefit.

The conceptual SFD shown in Figure 6 demonstrates the dynamic process of sociotechnical elements and their interplay with different stocks and flows. The SFD in figure 6 has been developed considering in more detail the relationships indicated in the CLD from figure 5.

CONCLUSION

The study applied widely used and empirically validated models, TAM and IS success model, as well as sociotechnical models to propose the sociotechnical framework for eHealth acceptance. The theoretical framework has four major dimensions: technological, social, technology use and outcome dimension. The elements of technological dimension of the framework comprises system, information and service qualities as discussed on IS success model. The users’ perception of usefulness and ease of use together with social influence are adapted from TAM to build the social dimension of the sociotechnical model for technology acceptance. The intention to use, actual use and user satisfaction elements that are discussed in both TAM and IS success models are grouped under technology use dimension of the theoretical framework. Finally, the outcome dimension of the framework adapted net benefit from IS success model.

The relationship between the elements of sociotechnical framework for technology acceptance are determined from literatures that presented empirical evidence to validate the relationship among the elements of both TAM and IS success model. A system dynamics approach is used to explore the dynamic nature sociotechnical dimensions of eHealth implementations.

Although the use of extensively studied TAM and IS model is the strength of this study along with the review of literatures with empirical evidence to determine the link among the elements of the proposed theoretical model, this study is by no means without limitations. The literatures reviewed do not cover all studies that have empirically validated the TAM and IS success model. Moreover, the theoretical framework is not yet validated with empirical evidence. The future research study will use focus group discussions to enhance the proposed model and empirical studies will be carried out to validate the theoretical framework.

REFERENCES


