Understanding the complex and dynamic nature of e-health systems assimilation: a system dynamics modelling approach

Patrick Shabaya,[1] Ismail Ateya,[1] Gregory Wanyembi[3]*

[1]Faculty of Information Technology; Strathmore University; [1]School of Computing and Informatics; Mount Kenya University

**pshabaya@strathmore.edu*

Abstract

Technology assimilation process allows organisations and individuals to integrate technologies into their user practices in a non-routine post-adoptive manner that enhances organisational outcomes. However, previous research in technology implementation shows an assimilation gap between organisational adoption and the full deployment of these technologies within work practices. Healthcare institutions suffer from low technology assimilation often associated with slow uptake on e-health systems. Technology assimilation is a dynamic and complex process and yet previous studies seem incognisant of this understanding and have mainly used variance models to conceptualise and study technology usage. Such studies have thus failed to acknowledge the impact of elements of feedback loops, delays and non-linearity inherent in technology assimilation on the use of technologies. This paper highlights the complex dynamic nature of technology assimilation process within a healthcare setting and proposes system dynamics as a complementary approach to model e-health systems assimilation. System dynamics is an approach used by researchers to gain decision insights into complex dynamic systems by inferring system behaviour from the structure of the system.

Keywords: *Dynamic Synthesis Method, e-Health Systems, System Dynamics, Technology Assimilation, Complex systems*

Introduction

Healthcare providers in developed economies have for a long time been using health information technologies (HITs) to improve the quality and reduce the cost of services they offer to their clients. Developing economies on the other hand have recently embraced HITs although their adoption and assimilation has remained a challenge to many healthcare institutions (Silva, Rodrigues, de la Torre Díez, López-Coronado, & Saleem, 2015).

HITs and specifically electronic health (e-health) systems facilitate sharing of information between different collaborators in the healthcare industry including clinicians, hospitals, insurance companies, pharmacies and patients. The use of HITs in healthcare has evolved over the years since their introduction in the late 1960s (O'Connor 2013).

Currently, there exit a diverse set of technologies that comprise health information technologies or e-health systems including clinical computer decision support systems

(CDSS), electronic health records systems (EHRs), e-Prescribing systems, telemedicine, practice management systems, radiology/diagnostic systems including picture archiving and communication systems (PACS), computer provider order entry systems (CPOE) and laboratory information systems (Black et al., 2011; Castro, 2014).

The objective of these systems has always been to provide the clinician with accurate quality information about the patient and health problem at hand, and alternative tests and treatments for that problem, preferably at the point of care for better decision making (Coltin & Aronow, 1995).

The benefits of e-health systems will only be realised if the systems are fully adopted and assimilated within organisational work practices (Armstrong & Sambamurthy, 1999; Baird et al., 2017). Healthcare institutions have however, been slow with the uptake and assimilation of e-health systems, a problem often associated with the complex social nature of healthcare systems (Hoque et al., 2017, p. 1).

Previous studies in e-health have focused at the adoption stage of the systems implementation process (Hwabamungu & Williams, 2010; Venkatesh et al., 2011) with only a few going beyond adoption into assimilation (Baird et al., 2017; Greenhalgh et al., 2017).

Research in technology assimilation has used the variance theory to identify predictor antecedents of assimilation across stages of technology implementation (Hossain, Quaddus, & Islam, 2016; Zhu, Kraemer, & Xu, 2006). A few other studies have however applied process theory focusing on a deeper understanding of the actual process used to assimilate the technologies into work practices (Baird et al., 2017; Gallivan, 2001; Orlikowski, 2008).

Cooper and Zmud (1990) investigated the implementation of a Management Resource Planning (MRP) system and found out that 73% of the organisations adopted the system but only 27% managed to assimilate it. In another study by Fichman and Kemerer (1999), 42% of the organisations had adopted software development CASE tools while only 7% of them assimilated the tools into their work practices. More recent research shows a widening assimilation gap across technologies (Claybaugh, Ramamurthy, & Haseman, 2015; Venkatesh, Zhang, & Sykes, 2011; Xu, Ou, & Fan, 2015)

The process of e-health assimilation is complex involving deliberate learning through experimentation, interpretation and routinization, requiring adequate resources and commitment from the top management in order to realise (Baird et al., 2017; Feng & Hu, 2010; Swanson, 2004).

This is a dynamic process that changes over time whose independent factors interact and influence each other towards assimilation. However, in spite of the prevailing technology assimilation gap, there is still insufficient empirical research in the area of healthcare provider assimilation of e-health systems (Baird et al., 2017; Spinellis & Giannikas, 2012).

In order to improve understanding of the complex nature of technology assimilation, this paper argues for a paradigm shift towards the use of systems thinking philosophy. This philosophy involves the use of simulation and modelling through system dynamics techniques (Kanungo, 2003).

The paper is organised into four sections; the first section provides the required context for health information systems, the second section explores the complex and dynamic nature of e-health systems assimilation, the third section discuses key theoretical and empirical studies of e-health systems assimilation. The last and fourth section presents the dynamic synthesis method and proposes a causal loop diagram as a conceptual model to study e-health systems assimilation.

Health Information Technologies

According to Castro, a health information technology (HIT) device includes hardware and or software that is used to electronically create, maintain, analyse, store, or receive information to aid in the diagnosis, cure, mitigation, treatment, or prevention of disease and that is not an integral part of (1) an implantable device, or (2) an item of medical equipment (Castro, 2014, p. 5).

HIT compromises different technologies including 1) practice management, electronic health record systems (EHRs), computerized provider order entry (CPOE) systems, pharmacy systems, electronic medication administration records (e-MAR), clinical documentation systems, clinical decision support system (CDSS), laboratory information systems and radiology/diagnostic imaging systems (Black et al., 2011; Castro, 2014). Table 1 provides a summary of these systems.

The term e-health has also been used synonymous with health information technologies but lacks a definitive definition due to the diverse technologies involved and contexts in which the technologies operate. In trying to understand the meaning of e-health systems, Pagliari et al.(2005) identified 36 possible definitions for the term e-health while Oh, Rizo, Enkin, and Jadad, (2005) had identified 51 definitions.

This paper adopts the e-health systems definition proposed by the World Health Organisation (WHO) where e-health is defined as “the leveraging of information and communication technology (ICT) to connect providers, patients and governments; to educate and inform healthcare professionals, managers and consumers; to stimulate innovations in care delivery and health systems management, and to improve healthcare system” (Hoque et al., 2017, p. 1).

According to Deluca and Enmark, e-health systems are defined within three domains including; a) business e-health systems also known as practice management systems which include financial and administrative transactions used to conduct the daily operations of healthcare processes, b) clinical e-health systems whose transactions involve the collection, transmission and analysis of electronic health-related data and c) consumer e-health systems that combine business and clinical e-health while incorporating the consumer (i.e. patient) in health activities (Deluca & Enmark, 2000).

This paper focuses on clinical e-health systems because the adoption and use of clinical e-health systems is low especially by physicians (DesRoches et al., 2008; Venkatesh et al., 2011), and these systems are under investigated (Greenhalgh et al., 2017). The e-health clinical systems encompass a number of technologies that support healthcare services including data storage management & retrieval systems shown in table 1 (Black et al., 2011).

Table 1: Sub-systems that make up the health information technology (HIT) system

Type of healthcare information technology	Uses/components/functions	Author
Practice management systems	Used for administrative and patient billing	(Black et al., 2011; Castro, 2014)
Electronic health record systems (EHRs)	A longitudinal collection of patient-centric health care information available across providers, care settings, and time. May contain other sub-systems including clinical documentation, tests and imaging results, computerised provider order entry systems and clinical decision support systems	(Akanbi et al., 2012; Black et al., 2011; Sherer, Meyerhoefer, & Peng, 2016)
Electronic medical records (EMRs) systems	Similar to EHRs although often conceived as being local to an organisation and only containing standard clinical data	(Ajami & Bagheri-Tadi, 2013)
Picture archiving & communication systems (PACs)	Information systems used for the acquisition, archival, and post-processing distribution of digital images	(Black et al., 2011)
Computerised provider order entry systems (CPOEs),	Typically used by clinicians to enter, modify, review, and communicate orders; and return results for laboratory tests, radiological images, and referrals	(Black et al., 2011)
ePrescribing systems	Clinical information systems that are used by clinicians to enter, modify, review, and output or communicate medication prescriptions	(Black et al., 2011)
Clinical computerised	Clinical information systems that integrate clinical and demographic	(Black et al., 2011)

decision support systems (CDSS)	patient information to provide support for decision making by clinicians	
Patient health systems	an electronic application through which individuals can access, manage and share their health information in a private, secure and confidential environment	(Health & Services, 2006)

The use of e-health systems attract perceived advantages including improved quality of patient care and safety, reduced costs and improved efficiency, access to medical records in remote locations, easy and faster retrieval of information, easy in flagging abnormal results, eliminates hand written prescriptions thus reduces errors, simultaneous access to patient records by multiple users and ability to perform data quires for improved decision making (Akanbi et al., 2012).

EHRs also facilitates comprehensiveness, uniformity and standards, secure, reduced demand for space and completeness thus overcomes indecipherable content often found in manual systems (Coltin & Aronow, 1995).

The Complex Dynamic Nature of e-Health Assimilation

Technology assimilation has been conceptualised in diverse ways including 1) technology assimilation as a variable measured through the breadth and depth of organisational usage (Liang, Saraf, Hu, & Xue, 2007; Ranganathan, Dhaliwal, & Teo, 2004), 2) technology assimilation as a sequence of stages that culminate into full deployment and routinization of the technology within organisational activities (Hossain et al., 2016; Zhu et al., 2006), 3) technology assimilation as a post adoption process that integrates the adopted technology into end user work practices (Armstrong & Sambamurthy, 1999; Purvis, Sambamurthy, & Zmud, 2001) and 4) technology assimilation as a process of "learning-by-doing" where users of the technology iteratively experiment, interpret and routinize the technology towards making it an integral part of their work practices (Swanson, 2004).

The diverse conceptualisations of technology assimilation points to a lack of consensus on a definitive meaning of this term. However, Swanson (2004) provides a cognitive process view of technology assimilation and argues that this is the natural process that unfolds over time as users experiment, interpret and routinize the technologies into their work practices.

This conceptualisation has been supported by many other researchers using process models that offer a deeper understanding of the technology assimilation process (Baird et al., 2017; Gallivan, 2001; Rao & Rahul, De, 2014; Trudel et al., 2017).

Technology assimilation in this paper thus adopts a cognitive definition and focuses on the need for organisations to build relevant competencies to effectively use a technology over time through a process of "learning by doing" (Swanson, 2004). This is a more inclusive approach which encourages researchers to consider not only the factors of technology assimilation for the different conceptualisations, but to equally consider the interactions between these factors, the unintended consequences due to these interactions and possible delays inherent in the development of IT competencies required for assimilation (Sterman, 2000; Swanson, 2004).

The Oxford learners' dictionary defines the term "complex" as a system consisting of many different and connected parts, for example, "a complex network of water channels" while the term "dynamic" is defined as a "force that stimulates change or progress within a system or process" usually brought about by the interaction between the components of the system (Hornby, Gatenby, & Wakefield, 1963).

The above definitions resonate well with that of Sterman (2000) who defines complexity of a system as being inherent in the relationships or interactions between components that make up the system. According to Sterman (2000) all social systems, of which information systems are a part, are complex and suffer from the "counterintuitive behaviour" whereby an attempt to solve a problem often creates unintended consequences that may make the situation worse than it was previously.

According to Jacucci et al. (2006), the complexity theory guides a deeper understanding of complex systems where complexity is defined as an emergent property of systems made of large numbers of self-organizing agents that interact in a dynamic and non-linear fashion.

Dynamic complex systems are thus characterised by four key properties; namely; interactions between the different actors of the system; dependency on time; an internal complex structure that is subjected to feedback relationships; and delays in the behavioural reactions from the interactions. Such complex systems lack a direct and close cause – effect relationship common in a reductionist variance theory (Jacucci et al., 2006).

Similarly, a recent study by Merrill, Deegan, Wilson, Kaushal, and Fredericks (2013) defined complex systems as those that exhibit dynamic behaviour that include non-linear relationships; variable quantities that accumulate and deplete over time; delays from information or material processes; and or exhibit active feedback processes.

This is true with e-health assimilation where potential organisations first need to accumulate resources and sufficient absorptive capacity leading to full deployment of the technologies (Attewell, 1992). Cohen defined absorptive capacity as the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends (Cohen & Levinthal, 1990, p. 128).

In order for organisations to assimilate e-health systems, they need to overcome the impact of external pressure from partners to share information, the need to learn and adapt to or adapt the technology to their needs and to overcome the stress associated with using new technologies within increasing work backlogs (Baird et al., 2017).

Conceptualising e-health systems assimilation as a process of "learning by doing" in itself is the acknowledgement that the process is complex because learning is a complex process that exhibits all the characteristics of complex systems. Learning takes time to accomplish and may involve both single loop and double loop learning (Armstrong & Sambamurthy, 1999; Baird et al., 2017; Fichman & Kemerer, 1997; Purvis et al., 2001).

In single loop learning, organisations use feedback from the environment to improve their process but their mental models are not transformed. In double loop learning, the feedback acquired is used to change the mental models of employees thus improves the way the technology is assimilated within their work practices (Sterman, 2000).

The complex nature of technology assimilation process is also revealed in the structuration process of individual actions used to understand assimilation as influenced by institutional meta-structures. Structuration process of signification, domination and legitimation is a complex emergent phenomenon involving individual cognitions and behaviours which are shaped by institutional meta-structures" (Rai, Brown, & Tang, 2009).

According to Purvis and colleagues, users have to overcome the many challenges associated with learning and understanding how to reconceptualise their work process activities (Purvis et al., 2001, p. 131). This involves the structuring of individual actions as supported by the meta-structuring actions of top management and IT champions within the organisation.

Technology assimilation is thus as a result of "the dynamic interplay amongst workers, work processes, work structures, work tasks, and the technologies—an interplay embedded within multiple institutional contexts" (Purvis et al., 2001, p. 131).

Complexity of technology assimilation process may also be identified through the theories of organisational behaviour which portray organisations as complex and dynamic systems (Senge & Sterman, 1992). Technology assimilation within organisations is often associated with change which might be emergent, planned or episodic in nature (Orlikowski, 1996).

The complexity in this case is inherent in the social-technical nature of the change due to interaction between the social technical components including tasks, structures, actors and technology (Lyytinen & Newman, 2008).

The social-technical process of technology adoption and assimilation within such organisations mutually transform both the organisation and technology alike thus resulting into a complex process of assimilation (Jacucci et al., 2006; Rao & Rahul, De, 2014). The process model developed by Gallivan (2001) acknowledges the complex and dynamic nature of technology assimilation through feedback loops where learning that occurs in one unit may influence future adoption and assimilation behaviour elsewhere in the organisation.

The model also acknowledges system non-linearity where the outcomes of technology assimilation are non-deterministic such that it is not possible to tell if the outcome will occur and if it occurred, the user interpretations always end up being different.

Researchers have also specifically acknowledged the complexity of healthcare systems describing them as multiple complex and non-linear systems made up of relationally dependent sub-systems whose outcomes are unpredictable and with a large number of dynamically changing variables (Marshall et al., 2015).

According to Robert, Greenhalgh, MacFarlane, and Peacock (2009), the different determinants that influence healthcare innovations adoption and assimilation interact in a complex manner. Although the process of e-health assimilation is complex and dynamic in nature, empirical studies about technology assimilation have downplayed this complexity and have thus continued to apply linear models in studying assimilation.

Empirical Studies in e-health Systems Assimilation

An e-health system connects medical informatics, public healthcare services and business through associated technologies such as the Internet. A successful medical information system implementation involves the adoption and sustained use in serving healthcare needs of all the stakeholders (Hwabamungu & Williams, 2010).

However, literature shows adoption and assimilation of healthcare systems to be a challenge such that a good number of e-health projects experience high failure rates and low scalability (Greenhalgh et al., 2017; Heeks, 2006; Trudel et al., 2017). A study by PriceWaterhouseCoopers as cited by Venkatesh et al. (2011) showed that only a third of doctors in the United States of America use the technology available to them while less than 5% of them use all the powerful features available in these solutions.

Extant of literature on technology assimilation identifies a number of determinants for technology assimilation summarized in table 2. Studies in e-health systems assimilation show similar patterns in the determinants of e-health assimilation including top management support, relative advantage, complexity, competence or knowledge (Robert 2009; Panzano, 2012).

In a 3 year longitudinal study of e-health systems implementation by a large hospital in the United States of America, Venkatesh et al (2011) found out that the social ties among practicing doctors negatively influenced implementation of e-health systems. On the other hand, paraprofessionals and administrative staff willingly shared information about their work and were thus more willing to use e-health systems.

Venkatesh et al. (2011), noted that the low adoption and use of e-health systems was associated with a low perception of the relative advantage of the technology, lack of adequate training and support in managing the change process as well as the attitude of the different stakeholders involved in the healthcare industry.

Table 2: Past studies showing determinants of technology assimilation

Identified factors of Assimilation	Author(s)
Top management involvement and support	(Chatterjee, Grewal, & Sambamurthy, 2002; Xu et al., 2015), (Agarwal, Tanniru, & Wilemon, 1997; Dong, Neufeld, & Higgins, 2009; Gallivan, 2001), (Armstrong & Sambamurthy, 1999; Chatterjee et al., 2002; Claybaugh et al., 2015; Rai et al., 2009).
Organisational capabilities, competencies or absorptive capacity	(Armstrong & Sambamurthy, 1999; Claybaugh et al., 2015; Deng, Doll, & Cao, 2008; Liang et al., 2007; Roberts, Galluch, Dinger, & Grover, 2012).

Availability of adequate and appropriate resources	Gallivan 2001 and Baird 2017
Organisational readiness	(Rai et al., 2009), (Hoque et al., 2017; Uwizeyemungu & Raymond, 2011; Zhu et al., 2006)
Characteristics of the innovation including complexity and compatibility	(Cho & Kim, 2001; Xu et al., 2015), (Claybaugh et al., 2015; Feng & Hu, 2010; Venkatesh et al., 2011; Xu et al., 2015)
Attitude of end users	(Feng & Hu, 2010; Gallivan, 2001; Rao & Rahul, De, 2014)
Internal and external environmental pressures to use	(Liang et al., 2007; Rao & Rahul, De, 2014; Wang, 2008; Xu et al., 2015; Zhu et al., 2006)
Historical context of technology	(Land, 2010; Rao & Rahul, De, 2014)

Baird et al. (2017) used an action research approach to carry out a longitudinal 3 year study of ten small clinics that used e-health systems in the USA. Their study identified the ability of doctors and nurses to reflect and learn in practice to highly contribute to the assimilation of e-health systems.

In another study, Sulaiman and Wickramasinghe (2010) used the TOE model and identified IT infrastructure, IT governance, IT enabled intangibles, managerial obstacles and availability of hospital experts as key determinants of e-health systems assimilation.

In an earlier study, Reardon and Davidson (2007) used the concept of organising vision to confirm that through organisational learning, increased importance of EMR (relative advantage) positively influences assimilation while difficulty in implementation (complexity) negatively influenced assimilation.

Application of System Dynamics Approach in Technology Assimilation

Technology assimilation as defined earlier in this paper refers to the post-adoption process where a technology diffuses and gets routinized in the organisational functions through a process of “learning by doing” (Swanson, 2004).

A system is defined as a set of interrelated components working together to attain a specified goal i.e. “a complex whole, the functioning of which depends on its parts and the interactions between those parts” (Jackson, 2003 p.29). Unlike the traditional reductionist approach used in variance models where researchers test the impact of individual independent variables on the dependent variable and aggregate outcomes, systems thinking takes a pluralist view about systems.

The focus is on how components within the whole system interact with one another in order to make a single holistic system (Sterman, 2000). In systems thinking, the behaviour of a system is greater than that of the sum of the parts that make up the system. Systems thinking therefore involves understanding the interdependencies or interrelationships within complex systems.

The term dynamics refers to the “interactive system or process especially one involving competing or conflicting forces” (Stevenson, 2008). Thus, system dynamics is a process that is highly interactive made up of competing or conflicting forces. Dynamic systems often connote two characteristics; feedback loops and delays or lags.

Feedback loops indicate a relationship where A influences B, and in turn B influences A, either directly or indirectly (Sterman, 2000). The feedback loops form the core of system dynamics philosophy and captures the concept of non-linearity, an indication that a given effect is not always proportional to the cause of the effect. Feedback loops are of two types; the negative or balancing (B) loop and the positive or reinforcing (R) loop.

The balancing loop is often referred to as goal seeking because a departure from the reference point produces action tending to return the system toward the equilibrium position (Forrester, 1968). In a reinforcing (R) loop, the action on the system increases the system state to produce more action. For instance, Figure 1, represents the counter-intuitive theory; which asserts that in complex systems, when people seek to solve a problem they often make it worse (Sterman, 2000, p. 5).

In Figure1, an increase in the intensity of assimilation problems will lead to an increase in short term solutions (+) hoping to address this problem. An increase in short term solutions will temporarily resolve the issues that cause the problem thus reducing the intensity of the assimilation problem (-) and this brings the system to a stable state of equilibrium.

However, over a period of time (delays), the short-term solutions fail to fully address the issues arising and unintended consequences occur. The unintended consequences increase over time and may lead to an even bigger increase in the intensity of the assimilation problem (+). If left unchecked, the reinforcing effects in the system may grow exponentially and eventually cause the system to fail.

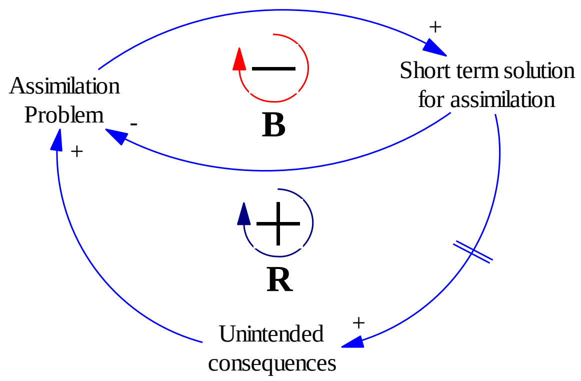


Figure 1: Basic diagram showing a counterintuitive behaviour for complex systems

This concept of feedback loops makes it difficult for researchers to predict outcome of any of the factors independent of their interaction (Kanungo 2003). The second characteristic of system dynamics connotes system delays or lags often associated with the fact that the actual assimilation of systems will not always start immediately a system is adopted but instead takes time for users to accept and internalize system functionality prior to assimilation.

The dynamic nature of technology assimilation makes the process theory more suitable for this study because it acknowledges the fact that variables in a system interact with each other and change over time. System dynamics (SD) can thus operationalize process theory for complex systems to incorporate feedback into the use model and thus avoid the black box syndrome inherent in variance theory (Kanungo, 2003).

A powerful tenet of system dynamics approach is the fact that the complexity of a problematic behaviour is easily captured by the underlying feedback structure of that behaviour. In order to investigate dynamically complex problems, system dynamics methodology (SDM) maps the complex structure of the system to the dynamic behaviour of the real world leading to a reliable policy decision making process (Sterman, 2000).

Unlike the statistical rational models, SD allows modellers to incorporate soft variables in the model including top management support, user competence and relative advantage among others (Zawedde, 2016).

Research Method

The extant of literature shows a death of empirical studies that recognise the complex and dynamic nature of e-health systems assimilation and the need for a pluralist approach to study this phenomenon. This paper fronts a knowledge based view to e-health assimilation in support of process modelling by Baird et al. (2017) and Swanson (2004).

In recognizing the complex nature of assimilation as a learning process, the authors propose system dynamics (SD) as an alternative to model e-health assimilation. The objective of the SD approach is to provide managers with a technique to understand the structure of complex systems and thus intervene and improve problematic situations. The best way to improve system performance is to discover and represent mental models of the decision makers within the system (Sterman, 2000).

The research method chosen for this on-gong study is the Dynamic Synthesis Methodology (DSM) which incorporates case study with system dynamics (SD) because the issue at hand; e-health assimilation, is complex and abstract. DSM allows a researcher to first gain an understanding of the problem through a case study prior to modelling.

The process of developing a system model using DSM progresses through a sequence of five main stages which although appear to be sequential, are highly iterative as shown in Figure 2 (Williams, 2000). Limited literature and lack of quantitative data on assimilation of e-health systems within healthcare institutions meant that the researchers first adopt a field study approach involving healthcare institutions that have adopted and assimilating e-health systems.

Stage 1 of the DSM methodology focuses on problem articulation (boundary selection) which identifies the issue of concern or purpose of the model, while stage 2 is meant to define a dynamic hypothesis of the problem identified. The issue of concern in this context is the slow uptake and assimilation of e-health systems used by doctors and other paraprofessionals within a healthcare institution (Baird et al., 2017; Venkatesh et al., 2011).

Two ways in which information is elicited to define a dynamic hypothesis is through reference modes and or time horizon. According to Sterman (2000), the reference mode for diffusion of any technology over time is defined by the shape of an “S” curve. The dynamic hypothesis for an e-health system assimilation will thus be defined by the shape of the “S” curve.

The target stakeholders include those in charge of IT in the institution, expert e-health users including doctors, paraprofessionals and administrative staff. The large private hospitals in Nairobi City in Kenya were selected for this study because they have installed and used these systems for at least more than 3 years. A total of 36 participants are targeted for this study including 12 doctors, 16 paraprofessionals and 8 administrative staff.

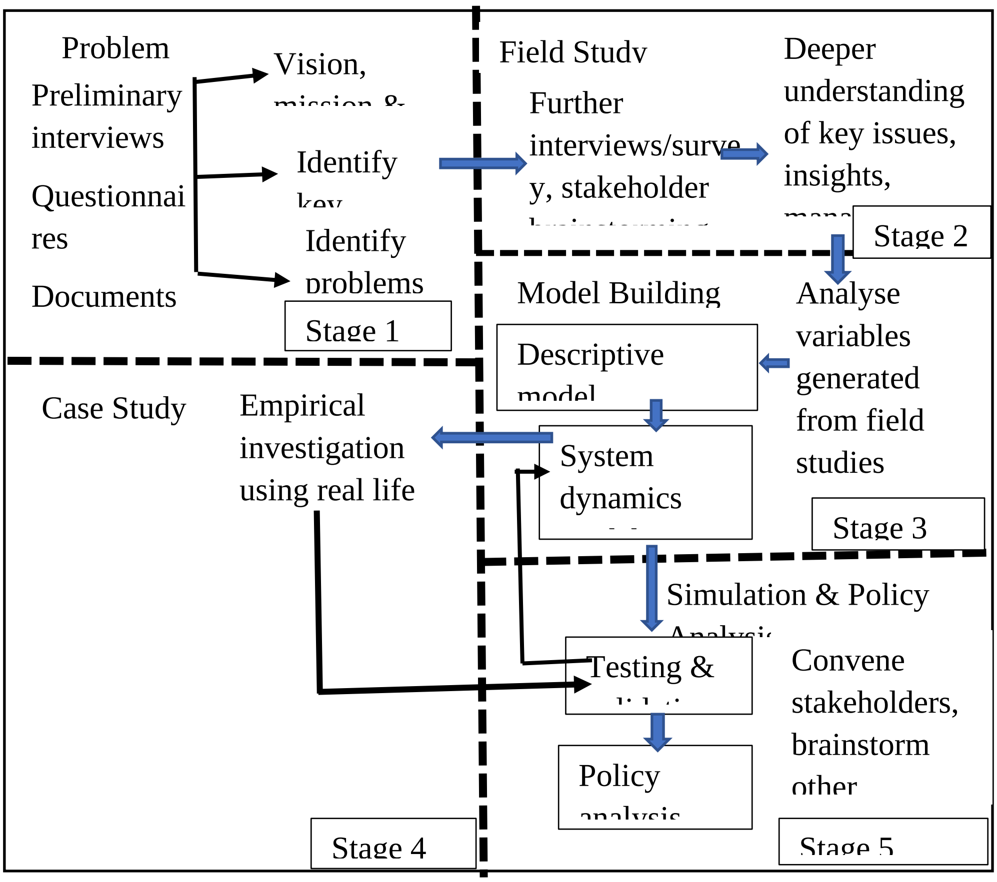
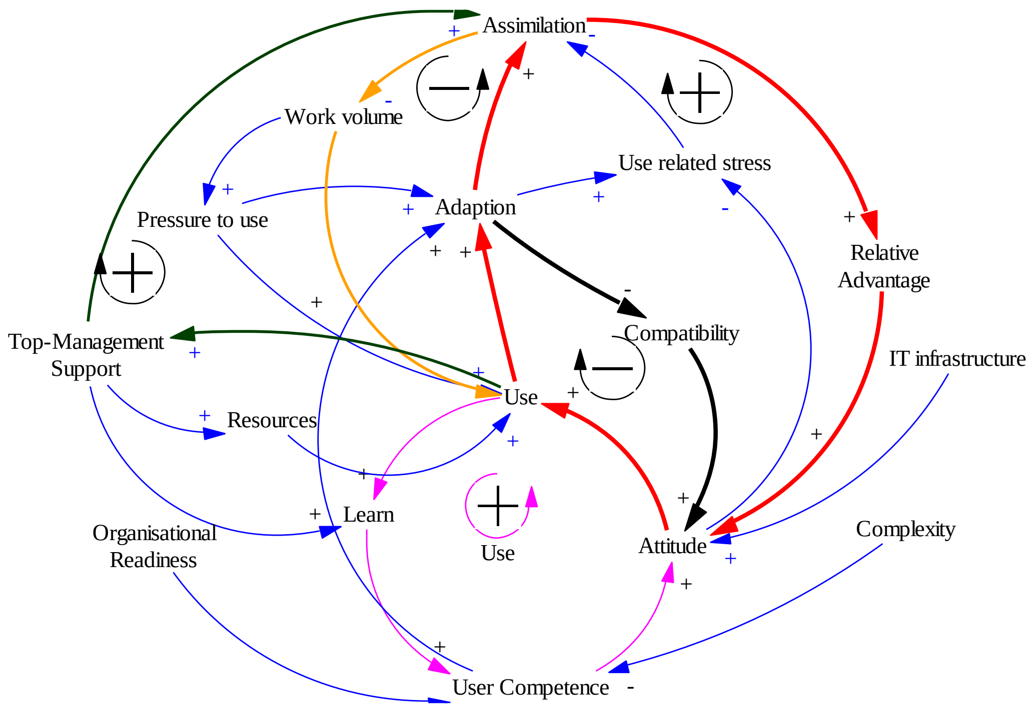


Figure 2: The Dynamic Synthesis Methodology (DSM) Process (Source: Williams, 2000).

Conceptual Model

In an attempt to understand how technology use influences productivity of an organisation, Kanungo (2003) developed an system dynamics causal model with five subsystems including information systems (IS)-use, IS-related task, IS-use related stress, computer self-efficacy, and individual productivity.

In a similar thread, Liu, Li, & Tian (2010) developed an SD information systems diffusion model comprising of IS use, volume of business to handle, pressure to use IS, technical factors and levels of diffusion. Building from an extensive review of literature, including models developed by Kanungo (2003) and Liu et al. (2010), this paper proposes the e-health assimilation causal model shown in Figure 3.



.

Figure 3: The Causal Loop diagram for e-health Systems Assimilation

The key sub-systems in the e-health system assimilation process of Figure 3 include the e-health use sub-system, the e-health adaptation, work volume to handle sub-system, top management support and the assimilation sub-system.

User experimentation with the technology is represented by the use sub-system while interpretation is covered within the adaptation sub-system such that after a user experiments with a technology (routine use) their interpretation leads to adaptation and innovative use of the system (Leonard-Barton, 1988; Orlikowski, 1996).

The e-health systems assimilation is thus directly and positively influenced by increased top management support and adaption to the e-health system or changes to organisational practices but negatively influenced by use related stress.

An increase in the “work volume to handle” will increase e-health routine use which leads to an increase in system or practice adaptation which in turn increases assimilation that finally reduces “work volume to handle”. This is a balancing loop that shows when “work to handle” increases, users use more of the technology and find ways to adapt and use it innovatively in order to reduce the “work to handle” and create a stable state.

The causal loop diagram for e-health assimilation represents the system dynamic hypothesis comprising five loops of which two are balancing loops and three reinforcing loops. Interaction between other components within the assimilation process are shown in Figure 3 such that a (+) sign shows that an increase in the cause parameter increases the effect due to that parameter while a (-) sign shows increasing the cause reduces the effect.

Conclusion

This paper presented a review of the extant literature on technology assimilation to help define the concept of technology assimilation and to discuss the dynamic and complex nature of technology assimilation within organisational settings.

The literature showed a focus on use of cross sectional surveys that apply variance models to identify antecedents of technology adoption and assimilation within organisations. Only a few of the studies apply process theory to investigate how technology is assimilated in organisations.

In order to accommodate the complex nature of technology assimilation, this paper proposed the use of a hybrid pluralist methodology that combines case study and system dynamics approaches in order to capture feedback, delays and non-linearity in the interactions between components of e-health assimilation.

The paper has however only focused on the first two steps of SDM to demonstrate how e-health systems may be assimilated within organisations.

References

1. Agarwal, R., Tanniru, M., & Wilemon, D. (1997). Assimilating information technology innovations: Strategies and moderating influences. *IEEE Transactions on Engineering Management*, *44*(4), 347–358.
2. Ajami, S., & Bagheri-Tadi, T. (2013). Barriers for adopting electronic health records (EHRs) by physicians. *Acta Informatica Medica*, *21*(2), 129.
3. Akanbi, M. O., Ocheke, A. N., Agaba, P. A., Daniyam, C. A., Agaba, E. I., Okeke, E. N., & Ukoli, C. O. (2012). Use of electronic health records in sub-Saharan Africa: progress and challenges. *Journal of Medicine in the Tropics*, *14*(1), 1.
4. Armstrong, C. P., & Sambamurthy, V. (1999). Information Technology assimilation in firms: The influence of senior leadership and IT infrastructures. *Information Systems Research*, *10*(4), 304–327.
5. Attewell, P. (1992). Technology diffusion and organizational learning: The case of business computing. *Organization Science*, *3*(1), 1–19.

6. Baird, A., Davidson, E., & Mathiassen, L. (2017). Reflective Technology Assimilation: Facilitating Electronic Health Record Assimilation in Small Physician Practices. *Journal of Management Information Systems*, *34*(3), 664–694.
7. Black, A. D., Car, J., Pagliari, C., Anandan, C., Cresswell, K., Bokun, T., … Sheikh, A. (2011). The impact of eHealth on the quality and safety of health care: a systematic overview. *PLoS Medicine*, *8*(1), e1000387.
8. Castro, G. M. (2014). Classification of Health Information Technology-Related Contributing Factors to Patient Safety Events (PhD Thesis).
9. Chatterjee, D., Grewal, R., & Sambamurthy, V. (2002). Shaping up for e-commerce: Institutional enablers of the organizational assimilation of web technologies. *MIS Quarterly*, 65–89.
10. Cho, I., & Kim, Y.-G. (2001). Critical Factors for Assimilation of Object-Oriented Programming Languages. *Journal of Management Information Systems*, *18*(3), 125–156.
11. Claybaugh, C. C., Ramamurthy, K., & Haseman, W. D. (2015). Assimilation of enterprise technology upgrades: a factor-based study. *Enterprise Information Systems*, *11*(2), 250–283.
12. Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 128–152.
13. Coltin, K. L., & Aronow, D. B. (1995). Using Information Technology To Improve the Quality of Health Care. In *Bringing Health Care Online: The Role of Information Technologies*. US Congress Office of Technology Assessment.
14. Cooper, R. B., & Zmud, R. W. (1990). Information Technology Implementation Research: A Technological Diffusion Approach. *Management Science*, *36*(2), 123–139.
15. Deluca, J. M., & Enmark, R. (2000). E-health: the changing model of healthcare. *Frontiers of Health Services Management*, *17*(1), 3.
16. Deng, X., Doll, W. J., & Cao, M. (2008). Exploring the absorptive capacity to innovation/productivity link for individual engineers engaged in IT enabled work. *Information & Management*, *45*(2), 75–87.
17. DesRoches, C. M., Campbell, E. G., Rao, S. R., Donelan, K., Ferris, T. G., Jha, A., … Shields, A. E. (2008). Electronic health records in ambulatory care—a national survey of physicians. *New England Journal of Medicine*, *359*(1), 50–60.
18. Dong, L., Neufeld, D., & Higgins, C. (2009). Top management support of enterprise systems implementations. *Journal of Information Technology*, *24*(1), 55–80.
19. Feng, Y., & Hu, Q. (2010). Understanding Individual Level ERP Assimilation: A Multi-Case Study. In *43rd Hawaii International Conference on System Sciences*. Hawaii.

20. Fichman, R. G., & Kemerer, C. F. (1997). The assimilation of software process innovations: An organizational learning perspective. *Management Science*, *43*(10), 1345–1363.

21. Fichman, R. G., & Kemerer, C. F. (1999). The illusory diffusion of innovation: An examination of assimilation gaps. *Information Systems Research*, *10*(3), 255–275.

22. Forrester, J. W. (1968). Industrial dynamics—after the first decade. *Management Science*, *14*(7), 398–415.

23. Gallivan, M. J. (2001). Organizational adoption and assimilation of complex technological innovations: Development and application of a new framework. *ACM Sigmis Database*, *32*(3), 51–85.

24. Greenhalgh, T., Wherton, J., Papoutsi, C., Lynch, J., Hughes, G., A'Court, C., … Shaw, S. (2017). Beyond adoption: a new framework for theorizing and evaluating nonadoption, abandonment, and challenges to the scale-up, spread, and sustainability of health and care technologies. *Journal of Medical Internet Research*, *19*(11).

25. Health, U. D. of, & Services, H. (2006). Personal health records and personal health record systems. *A Report and Recommendations from the National Committee on Vital and Health Statistics*.

26. Heeks, R. (2006). Health information systems: Failure, success and improvisation. *International Journal of Medical Informatics*, *75*(2), 125–137.

27. Hoque, M. R., Bao, Y., & Sorwar, G. (2017). Investigating factors influencing the adoption of e-Health in developing countries: A patient's perspective. *Informatics for Health and Social Care*, *42*(1), 1–17.

28. Hornby, A. S., Gatenby, E. V., & Wakefield, H. (1963). *The advanced learner's dictionary of current English* (Vol. 965). Oxford University Press London.

29. Hossain, A., Quaddus, M., & Islam, N. (2016). Developing and validating a model explaining the assimilation process of RFID: An empirical study. *Information Systems Frontiers*, *18*(4), 645–663.

30. Hwabamungu, B., & Williams, Q. (2010). m-Health adoption and sustainability prognosis from a care givers' and patients' perspective. In *Proceedings of the 2010 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists* (pp. 123–131). ACM.

31. Jackson, M. C. (2003). *Systems thinking: Creative holism for managers*. University of Hull, UK: John Wiley & Sons Ltd,.

32. Jacucci, E., Hanseth, O., & Lyytinen, K. (2006). Introduction: Taking complexity seriously in IS research. *Information Technology & People*, *19*(1), 5–11.

33. Kanungo, S. (2003). Using systems dynamics to operationalize process theory in information systems research. *ICIS 2003 Proceedings*, 38.

34. Land, F. (2010). The use of history in IS research: an opportunity missed? *Journal of Information Technology*, *25*(4), 385–394.

35. Leonard-Barton, D. (1988). Implementation as mutual adaptation of technology and organization. *Research Policy*, *17*(5), 251–267.

36. Liang, H., Saraf, N., Hu, Q., & Xue, Y. (2007). Assimilation of enterprise systems: The effect of institutional pressures and the mediating role of top management. *MIS Quarterly*, 59–87.

37. Liu, Y., Li, H., & Tian, S. W. (2010). Modeling Government Credit Information Systems Diffusion in China: A System Dynamics Approach. In *PACIS* (p. 173).

38. Lyytinen, K., & Newman, M. (2008). Explaining information systems change: a punctuated socio-technical change model. *European Journal of Information Systems*, *17*(6), 589–613.

39. Marshall, D. A., Burgos-Liz, L., IJzerman, M. J., Osgood, N. D., Padula, W. V., Higashi, M. K., … Crown, W. (2015). Applying dynamic simulation modeling methods in health care delivery research—the simulate checklist: Report of the ispor simulation modeling emerging good practices task force (pp. 5–16).

40. Merrill, J. A., Deegan, M., Wilson, R. V., Kaushal, R., & Fredericks, K. (2013). A system dynamics evaluation model: implementation of health information exchange for public health reporting. *Journal of the American Medical Informatics Association*, *20*(e1), e131–e138.

41. Oh, H., Rizo, C., Enkin, M., & Jadad, A. (2005). What is eHealth?: a systematic review of published definitions. *World Hosp Health Serv*, *41*(1), 32–40.

42. Orlikowski, W. J. (1996). Improvising organizational transformation over time: A situated change perspective. *Information Systems Research*, *7*(1), 63–92.

43. Orlikowski, W. J. (2008). Using technology and constituting structures: A practice lens for studying technology in organizations. In *Resources, co-evolution and artifacts* (pp. 255–305). Springer.

44. Pagliari, C., Sloan, D., Gregor, P., Sullivan, F., Detmer, D., Kahan, J. P., … MacGillivray, S. (2005). What is eHealth (4): a scoping exercise to map the field. *Journal of Medical Internet Research*, *7*(1).

45. Purvis, R. L., Sambamurthy, V., & Zmud, R. W. (2001). The assimilation of knowledge platforms in organizations: An empirical investigation. *Organization Science*, *12*(2), 117–135.

46. Rai, A., Brown, P., & Tang, X. (2009). Organizational assimilation of electronic procurement innovations. *Journal of Management Information Systems*, *26*(1), 257–296.

47. Ranganathan, C., Dhaliwal, J. S., & Teo, T. S. H. (2004). Assimilation and Diffusion of Web Technologies in Supply-Chain Management: An Examination of Key Drivers

and Performance Impacts. *International Journal of Electronic Commerce*, *9*(1), 127–161.

48. Rao, R. A., & Rahul, De. (2014). Technology assimilation through conjunctures–a look at IS use in retail. *Information Systems Frontiers*, *17*(1), 31–50.
49. Reardon, J., & Davidson, E. (2007). Do Perceptions of An Organizing Vision Influence Physicians Assimilation of Electronic Medical Records’. *AMCIS 2007 Proceedings*, 15.
50. Robert, G., Greenhalgh, T., MacFarlane, F., & Peacock, R. (2009). Organisational factors influencing technology adoption and assimilation in the NHS: A systematic literature review. *Report for the National Institute for Health Research Service Delivery and Organisation Programme*. Retrieved from http://www.netscc.ac.uk/hsdr/files/project/SDO_FR_08-1819-223_V01.pdf
51. Roberts, N., Galluch, P. S., Dinger, M., & Grover, V. (2012). Absorptive capacity and information systems research: Review, synthesis, and directions for future research. *MIS Quarterly*, *36*(2).
52. Senge, P. M., & Sterman, J. D. (1992). Systems thinking and organizational learning: Acting locally and thinking globally in the organization of the future. *European Journal of Operational Research*, *59*(1), 137–150.
53. Sherer, S. A., Meyerhoefer, C. D., & Peng, L. (2016). Applying institutional theory to the adoption of electronic health records in the US. *Information & Management*, *53*(5), 570–580.
54. Silva, B. M., Rodrigues, J. J., de la Torre Díez, I., López-Coronado, M., & Saleem, K. (2015). Mobile-health: A review of current state in 2015. *Journal of Biomedical Informatics*, *56*, 265–272.
55. Spinellis, D., & Giannikas, V. (2012). Organizational adoption of open source software. *Journal of Systems and Software*, *85*(3), 666–682.
56. Sterman, J. D. J. D. (2000). *Business dynamics: Systems thinking and modeling for a complex world*. Massachusetts Institute of Technology: Jeffrey J. Shelsfud.
57. Stevenson, A. (2008). *Oxford english dictionary* (Vol. 30).
58. Sulaiman, H., & Wickramasinghe, N. (2010). Critical Issues in Assimilation of Healthcare Information Systems. In *PACIS* (p. 176). Retrieved from http://www.pacis-net.org/file/2010/2598.pdf
59. Swanson, E. B. (2004). How is an IT innovation assimilated. *IT Innovation for Adaptability and Competitiveness*, 267–287.
60. Trudel, M.-C., Marsan, J., Paré, G., Raymond, L., de Guinea, A. O., Maillet, É., & Micheneau, T. (2017). Ceiling effect in EMR system assimilation: a multiple case study in primary care family practices. *BMC Medical Informatics and Decision Making*, *17*(1), 46.

61. Uwizeyemungu, S., & Raymond, L. (2011). Information technology adoption and assimilation: Towards a research framework for service sector SMEs. *Journal of Service Science and Management*, *4*(02), 141.

62. Venkatesh, V., Zhang, X., & Sykes, T. A. (2011). "Doctors do too little technology": a longitudinal field study of an electronic healthcare system implementation. *Information Systems Research*, *22*(3), 523–546.

63. Wang, P. (2008). Assimilating IT innovation: The longitudinal effects of institutionalization and resource dependence. *ICIS 2008 Proceedings*, 21.

64. Williams, D. (2000). Dynamic synthesis: A theoretical framework for research in requirements engineering process management. *Operational Research Society*.

65. Xu, W., Ou, P., & Fan, W. (2015). Antecedents of ERP assimilation and its impact on ERP value: A TOE-based model and empirical test. *Information Systems Frontiers*, *19*(1), 13–30.

66. Zawedde, A. (2016). Modeling the dynamics of requirements process improvement. Technische Universiteit Eindhoven.

67. Zhu, K., Kraemer, K. L., & Xu, S. (2006). The process of innovation assimilation by firms in different countries: A technology diffusion perspective on e-business. *Management Science*, *52*(10), 1557–1576.