Techno-organizational factors of eHealth acceptance: A system dynamics model

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Abstract: The sustained use of eHealth is influenced by the dynamic and nonlinear interactions of technological, social, organizational and economic factors. However, most eHealth implementation frameworks are modelled linearly without capturing the complex relationship among elements of the ecosystem to ensure technology acceptance. The model-based theory-building research approach followed in this study aimed at enhancing the understanding of techno-organizational factors' influence on the acceptance of eHealth technology. A qualitative research approach and system dynamics modelling are applied to develop a system dynamic model of techno-organizational factors of eHealth acceptance. The 'average workforce turnover' showed a stronger influence on the simulated 'acceptance rate' of both eHMIS and SmartCare systems in the techno-organizational dimension. Therefore, retaining skilled workforces in the healthcare organization should be the focus in the techno-organizational dimension of sustainable eHealth implementation to increase the 'acceptance rate' of eHMIS and SmartCare in Ethiopia.

Keywords: Techno-organization; eHealth; SmartCare; ICT for health; digital health; EMR; eHMIS; technology acceptance; system dynamics modelling; simulation.

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1 Introduction

The ecosystem of sustainable eHealth implementation covers wider ranges of factors in technological, social, organizational and economic dimensions to promote meaningful and sustained use of information for decision making in healthcare settings (Musango and Brent, 2010; Hay, Duffy and Whitfield, 2014). According to the World Health Organization (WHO), eHealth refers to the use of Information and Communications Technology (ICT) for health (WHO, 2011). Organizational culture, structure, resources, work process flow, supportive policy and management support are the key elements of organizational factors in the process of eHealth implementation (Tsiknakis and Kouroubali, 2009; Aarts, Peel and Wright, 1998; Rippen et al., 2013).

The successful implementation of an eHealth system is influenced by the operating environment. The operation of the healthcare team is influenced by the resources, values and practices of the organization (Aqil, Lippeveld and Hozumi, 2009; Rippen *et al.*, 2013). The organizational culture and availability of resources play a key role in the successful implementation of eHealth (Aarts, Peel and Wright, 1998).

The organizational dimensions addressed in this study are linked to factors internal to the organization, i.e., factors under the organization's control (Aqil, Lippeveld and Hozumi, 2009; Gorla, Somers and Wong, 2010). Other environmental factors that influence eHealth implementation but outside the organizations' control (external environment) are not in the scope of this research study (Yusof *et al.*, 2008).

Most businesses operate dominantly in the complex domain that requires an understanding of the context of the operating environment and the nonlinear dynamic interaction among organizational elements (Snowden and Boone, 2007). Although the complexity of healthcare organizations is recognised by several research studies, the proposed solutions fail to address the dynamic and nonlinear interaction between organizational and technological factors (Cresswell and Sheikh, 2012).

The techno-organizational factors deal with the dynamic interactions between the technological and organizational elements of sustainable eHealth implementation. The lack of proper fit of technology to the operating environment results in the eHealth implementation failure (Rippen et al., 2013). This study aims to determine the effect of techno-organizational factors on the acceptance of eHealth technology. The system dynamic model of techno-organizational dynamics is developed from the focus group data, literature studies and review of eHMIS and SmartCare implementation documents.

The techno-organizational factors of sustainable eHealth implementation are explained in appropriate detail using system dynamics modelling technique. The empirical evidence from eHMIS and SmartCare cases are used to perform the model validation and verification tests to ensure the robustness the model. A qualitative interview and focus group data focusing on the techno-organizational factors of eHealth acceptance are discussed to answer the research question. The next section discusses the research methodology followed in this research study.

2 Research Methodology

This research is a model-based theory building study rooted in grounded theory. Methodologically, the study mainly applies qualitative research methodology which is a common methodology in the interpretive approach. Qualitative studies consider programs as dynamic and developing; they aim at describing the dynamic process and the holistic effects of the system elements (Patton, 2002). In this dominantly qualitative research approach, system dynamics modelling is applied to develop a nonlinear and dynamic model of techno-organizational factors of eHealth acceptance.

System dynamics simulation method is an interdisciplinary modelling approach that helps to understand the structure and dynamics of the complex system. Healthcare is recognised as a complex system. A system dynamics modelling and the case study research approach are combined to strengthening the learning process of the dynamic interaction among factors of technological and organizational factors. An iterative system dynamics modelling process is applied based on the findings of the literature review and data from the empirical evidence.

Electronic Health Management Information System (eHMIS) and SmartCare in Ethiopia were selected for the case study research. eHMIS routinely generates information of health indicators to support decision-making processes at each level of the health system to improve the performance of healthcare service delivery and thereby the health status of the population (FMOH, 2014a). SmartCare is an integrated EMR system to capture the electronic format of patients' medical record (Mweebo, 2014; Tilahun and Fritz, 2015).

Two focus group discussions were conducted with the project members of the Federal Ministry of Health (FMOH) partner organizations and the FMOH project teams in Ethiopia using a semi-structured instrument. Furthermore, data from the eHMIS database, eHMIS and SmartCare document archives, observations and informal discussion were used in this research study. Field notes and data from document review were analysed together with information from the focus group discussion using ATLAS.ti software. A rigorous coding process was used to analyse the transcripts of raw data using ATLAS.ti.

Vensim DSS Version 6.3D is used to model and simulate the system dynamics model. The variables captured from literature and focus group discussions are used to develop and test the system dynamics model. The summary of the techno-organizational factors of eHealth acceptance is presented in the next section.

3 Theoretical background

The key elements of the organizational dimension of eHealth implementation include organizational culture (Aqil, Lippeveld and Hozumi, 2009), organizational structure (Lluch, 2011), organizational leadership, (Cresswell and Sheikh, 2012; Bilbao-Osorio, Dutta and Bruno Lanvin, 2014), resources (Aqil, Lippeveld and Hozumi, 2009; Rippen et al., 2013), workflow process (Tsiknakis and Kouroubali, 2009; Lluch, 2011), and management support (Al-Mamary, Shamsuddin and Aziati, 2014). The implementation process of an eHealth system within a healthcare organization transforms the given inputs (determinants) into an output, i.e., the use of technology and information product (WHO, 2012).

The techno-organizational factors of sustainable eHealth implementation deal with subjects of user training to increase competency (Al-Mamary, Shamsuddin and Aziati, 2014); change management to ensure users oriented processes (Lluch, 2011); data management to improve data quality (WHO, 2012); stakeholders' engagement to increase technology acceptance (Cresswell and Sheikh, 2012; van Dyk et al., 2012); project management to effectively balance schedule, quality and budget (PMBOK, 2013) and organizational communications for effective exchange of timely and accurate information (PMBOK, 2013).

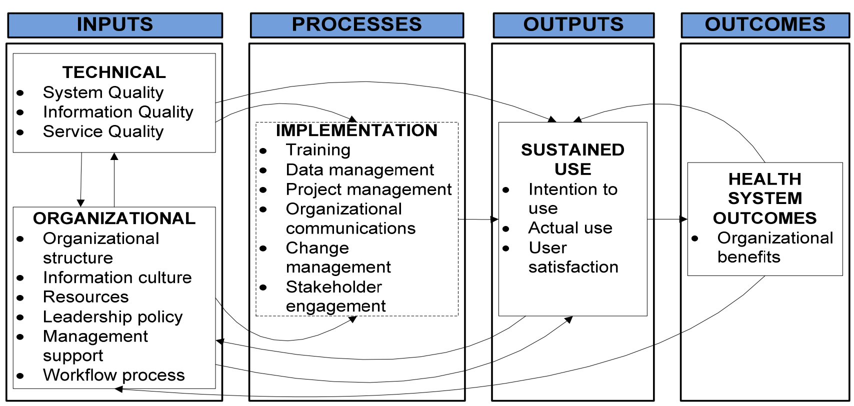


Figure 1. Conceptual framework for organizational dynamics of eHealth acceptance *(Fanta, Pretorius and Erasmus, 2017)*.

Figure 1 depicts the impact of the technological, organizational and eHealth implementation process on acceptance of technology. The immediate output of implementing the sustainable eHealth system was to improve healthcare services delivery through the use of information product (Aqil, Lippeveld and Hozumi, 2009). The main benefits of using an eHealth system are enhancing the internal organizational efficiencies such as improving the decision-making process and internal communications in the organization (Gorla, Somers and Wong, 2010).

4 The dynamic hypotheses of techno-organizational factors

The dynamic hypotheses of techno-organizational factors focus on the influence of organizational factors on the acceptance of eHealth systems. The dynamic hypotheses are developed from the conceptual framework for organizational dynamics of eHealth by applying a systems thinking approach on the findings of the literature studies, the evidence from focus group discussions and the researchers experience in the field of eHealth implementation.

The positive influence of resources readiness, management support and change management on technology acceptance and the impact of inhibitors on ICT culture within an organization to negatively influence technology acceptance are discussed below.

The influence of management support on technology acceptance

Management support refers to the level of general support offered by top management which includes encouraging the use of a system, allocating resources, understanding the benefits of the system, intent to see the users are happy in using the system (Al-Mamary, Shamsuddin and Aziati, 2014). Al-Mamary, Shamsuddin and Aziati, (2014) hypothesized that top management support influences perceived usefulness and users satisfaction.

The influence of resources readiness on acceptance rate

The resources readiness includes the availability of human resources, internet connectivity, network infrastructure, electric power and digital equipment such as computers, printers, scanners, etc. (Aqil, Lippeveld and Hozumi, 2009; WHO, 2011; Bilbao-Osorio, Dutta and Bruno Lanvin, 2014). When the organizational benefit from technology and information use is evident, the management support increases and the end-users' intention to use the technology will be high (Aqil, Lippeveld and Hozumi, 2009).

The influence of change management on technology acceptance

The alignment of technology with the organizational workflow processes maximises the meaningful use of technology. Organizational policy and leadership played a key role in building an organizational structure that promoted the use of technology. Tsiknakis and Kouroubali (2009) indicated that the lack of skilled technical support team resulted in a low fit in the task-technology dimension.

The inhibitors' influence on ICT culture

Inhibitors negatively influence the acceptance of technology through the spread of bad news about technology. The rejected users could damage the ICT culture and the use of technology in the health sector (Aqil, Lippeveld and Hozumi, 2009). Organizations that promote a culture of information perform better in the implementation and use of eHealth technology (Aqil, Lippeveld and Hozumi, 2009). The information culture of a healthcare organization influences the workflow process and affects the output of technology performance (Aqil, Lippeveld and Hozumi, 2009).

The concepts discussed as part of this section in the dynamic hypotheses are expanded to develop a system dynamics techno-organizational model of technology acceptance as shown in the next section.

5 A system dynamics model

The techno-organizational system dynamics model structure of technology acceptance shows the influence of organizational factors on 'potential users' to become 'actual users', i.e., acceptance rate (Figure 2). The 'actual users' either turn to 'satisfied users' or 'dissatisfied users' based on their experience of the system use. The model further depicts the possibility of dissatisfied users to become 'terminated users' if their dissatisfactions are not addressed on time with some type of intervention to convert them to satisfied users.

As depicted in Figure 2, 'potential users', 'actual users', 'satisfied users', 'dissatisfied users', 'individual perception to use', 'current workforce' and 'current infrastructure' are defined as stocks. Stocks can accumulate or deplete; on the other hand, flows make stock increase or decrease (Sterman, 2000). Flows are variables that can change stocks. Time can be an important element in differentiating stocks and flows. Stocks continue to exist when time is stopped; however, flows will disappear with time as they are actions.

Technological and social factors are embedded within an organizational environment of technology (Musango and Brent, 2010). The system dynamic model of techno-organizational factors incorporates key parameters to the sustainability of eHealth systems that are in the social, technical and organizational domain. The acceptance of technology by end-users is the combined effect of an 'Individuals' intention to use', 'Influence from social promoters' (positive word of mouth) and 'Influence from social inhibitors' (negative word of mouth) as shown in Figure 2 and Equation 1.

$$\begin{aligned} Acceptance\ Rate\ (AR) = {} & Individuals\ Intention\ to\ Use\ (I) \\ & + Influence\ from\ Social\ Promoters\ (SP) \\ & - Influence\ from\ Social\ Inhibitors\ (SI) \end{aligned} \quad (1)$$

The key variables selected to study the behaviour of techno-organizational factors of eHealth acceptance are infrastructure, workforces, supportive organizational structure, supportive policy and organizational ICT culture (Figure 2).

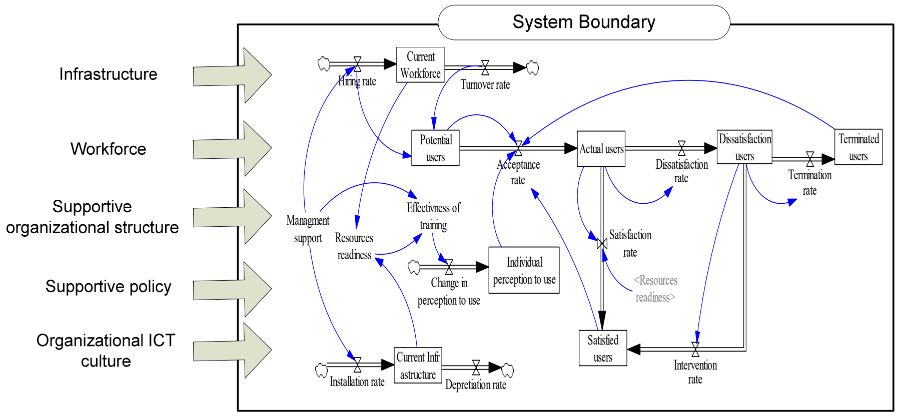


Figure 2. Techno-organizational model structure of technology acceptance.

Infrastructure refers to the internal capability of a healthcare organization to support the implementation of sustainable eHealth systems (Bilbao-Osorio, Dutta and Bruno Lanvin, 2014). These capabilities include electric power, computers, local area networks (LANs), internet connection, printer, and scanner that support the implementation of the eHealth (Rippen et al., 2013). Labour force addresses the readiness of skilled human resources that can use technology and provide technical support (Rippen et al., 2013; Bilbao-Osorio, Dutta and Bruno Lanvin, 2014).

The endogenous, exogenous and excluded variables that define the model boundary chart of the techno-organizational factors of eHealth acceptance are presented in Appendix 1. The complete system dynamics simulation model of techno-organizational factors of technology acceptance is shown in Appendix 2. The simulation time horizon of fifteen years with TIME STEP of 1 year is selected for this system dynamics modelling because eHealth is a relatively new field in the developing countries (Coleman, 2016).

Vensim DSS Version 6.3D software is used to develop, simulate and test the system dynamics model of techno-organizational factors. The model validation and verification with direct and indirect structural tests are conducted using the case study, interview and focus group discussion data to ensure the system model robustness. The variables, values and equations of the model are shown in Appendix 4 and 5.

The focus group data and the simulation results are discussed in an integrated way to explain the system dynamics model of a techno-organizational model of technology acceptance in the next section. The impact of resources readiness, organizational ICT culture, and management support and workflow alignment on acceptance of eHealth is discussed by integrating the simulation results and empirical evidence of techno-organizational.

6 Discussions of techno-organizational factors

The techno-organizational factors shown in Figure 3 are developed in ATLAS.ti by analysing the qualitative data gathered through focus group discussions and document analysis. The codes and code groups generated in the qualitative data analysis of techno-organizational factors are presented in Appendix 3. Some details are discussed under management support, organizational ICT culture, organizational structure, resources readiness and workflow processes.

Figure 3. Organizational factors that influence eHealth acceptance.

Management support

'Management support' addresses the willingness of top management to deploy and use eHealth, and allocates necessary resources for the successful implementation. It also evaluates the commitment of top management in accepting SmartCare and eHMIS as an important tool, set goal and plan for the implementation and use within the hospital. The level of organizational policy to support the implementation of eHealth systems, known as 'Supportive policy' and 'Organizational ICT culture' influence the level of management support as indicated in Equation 2.

Management support = (Supportive policy + Organizational ICT culture)/2

(2)

'Supportive policy' refers to the availability of organizational roadmap and guideline to accommodate electronic health systems within a healthcare organization to facilitate the healthcare services provision. The government policy encouraged the use of electronic systems in the health sectors. The "Information revolution" document showed the government supportive roadmap towards using ICT in the health sector to improve the quality of data, use of information, and informed decision making (FMOH, 2016). 'Supportive policy' and 'culture of ICT' lead to better management support towards the implementation of eHealth, whereas the lack of supportive policy and ICT culture limits support from the top management.

Organizational ICT culture

'Organizational ICT culture' refers to the culture of using ICT systems within an organization to support day-to-day activities. In this research study, the culture of information and technology use was measured by the number of available electronic systems in the health facilities. The focus group team believed that the more electronic systems available, the higher was the level of information culture within the healthcare organization. Besides 'Effectiveness of training' influences the 'Organizational ICT culture' as shown in Equation 3.

$$\text{Organizational ICT culture} = (\text{Effectiveness of training} + \text{Familiarity with electronic systems}) / 2 \quad (3)$$

The 'Familiarity with electronic systems' represents the percentage of electronic health systems available in the health facilities. The national health information system (HIS) in Ethiopia includes ten electronic health systems (FMOH, 2016). The focus group team indicated that the number of available electronic systems in the hospital could measure the culture of information and technology use. 'Familiarity with electronic systems' was measured by calculating the ratio of the number of available electronic system by the total number of HIT systems (i.e., ten) indicated in the Ethiopia National Health Information Enterprise Architecture (FMOH, 2016).

The 'Effectiveness of training' is determined from the FMOH assessment reports (FMOH, 2011, 2013, 2014b; EPHI, FMOH and WHO, 2016). In summary, as more users became familiar with electronic systems, the culture of technology use grew and the quality and use of information improved. Yet the improvement in the culture of technology use for the work yields was weaker than that of personal benefits. Moreover, the culture of information dissemination was lagging in the healthcare sector of Ethiopia.

Resources readiness

'Resources readiness' assesses the adequacy of human resources and ICT infrastructure to implement a successful eHealth system (Equation 4). The focus group discussion with the FMOH partner organizations indicated that the readiness of ICT infrastructure (computers, LAN, internet, printer, scanners, etc.) and electric power within the organization were key to the successful implementation of eHealth technology.

$$\text{Resources readiness} = (\text{Current Infrastructure} + \text{Current Workforce}/\text{Desired Workforce})/2 \quad (4)$$

Access to reliable electric power and the internet were infrastructure challenges highlighted by the focus group members. The ICT infrastructure of health facilities in Ethiopia was described as unprepared to the successful implementation of eHMIS and SmartCare systems. According to EPHI, FMOH and WHO (2017) survey data, only two percent (2%) of health facilities in Ethiopia have a computer with internet. The commercial electric power interruption frequently is high; however, some facilities have a backup generator, solar or UPS. Approximately one-fourth of the facilities (23%) have access to a power source (e.g. electricity grid, generator, solar, or other) (EPHI, FMOH and WHO, 2017).

A single point of failure, lack of backup servers, and shortage of servers' capacity to accommodate an increasing amount of data were some of ICT infrastructure problems in the implementation of eHMIS and SmartCare systems. Another major problem to implement successful eHealth systems in the health facilities was the shortage of skilled manpower and high turnover of staffs as indicated by the FMOH focus group team. A high turnover of both ICT and clinical staffs after acquiring skills on the electronic systems resulted in skill gaps in the successful operation of eHMIS and SmartCare.

Workflow processes

The workflow processes alignment focuses on understanding the current workflow processes in the service units of the healthcare facility, identifying service units where eHealth will be implemented and determining the possible changes of workflow processes to align the technology with existing workflow processes (Lluch, 2011). Equation 5 expresses the 'Workflow alignment' in terms of 'Management support', 'Resources readiness' and 'Supportive organizational structure'.

$$\text{Workflow alignment} = (\text{Management support} + \text{Resources readiness} + \text{Supportive organizational structure})/3 \quad (5)$$

The focus group discussion with the FMOH partners highlighted that the end-users resistance to using electronic systems significantly reduced by aligning the electronic systems with an existing workflow process. In general, the implementation of the electronic health system in Ethiopia followed the manual workflow processes that made it easy to use.

Organizational structure

'Organizational structure' represents the availability of organizational units such as the IT department and project management unit to support the successful implementation and operation of SmartCare and eHMIS. The IT structural units were not available in most of the health facilities in Ethiopia. The focus group discussion indicated that the IT structure was only available at the Federal and Regional Health Bureau levels. Therefore, most of the technical support to health facility level was offered by a technical team available in the Federal and Regional Health Bureau.

The fragmented technical support structure in health facilities also caused end-users to call different teams to get technical assistance. As a result, the end-users described the technical support service as weak and slow. The focus group discussion with the FMOH partner further highlighted that the lack of proper IT structure also affected the speed of technical support and the use of eHealth technology.

The assessment of hospital readiness to implement SmartCare in Addis Ababa conducted by the FMOH technical working group showed that only four of ten (40%) hospitals in Addis Ababa had IT structure in-place in their organizational structure. The interview data of eHMIS using health facilities showed that only five of twenty-four (20%) facilities had incorporated the ICT department in their organizational structure.

The next section discusses some simulation results of the techno-organizational model of eHMIS and SmartCare acceptance.

7 Simulation of techno-organization model of eHealth acceptance

The eHMIS and SmartCare cases in Ethiopia are simulated separately to study the behaviour of techno-organizatioanl factors of technology acceptance. The techno-organizational model of eHealth acceptance and equations were developed by the authors originally in Vensim. Vensim which is a flexible, fast and powerful software package for model building, simulation and sensitivity analysis (Ventana Systems, 2015).

The simulation results depict the influence of management support, organizational culture, availability of resources (infrastructure and human resources) and workflow processes on eHMIS and SmartCare acceptance. An 'individuals' intention to use', ‘promoters’ and 'inhibitors’ are the key factors that influence ‘acceptance rate’ as shown in Equation 1. The influence of organizational variables on the ‘acceptance rate’ through ‘individuals’ intention to use’ is discussed below.

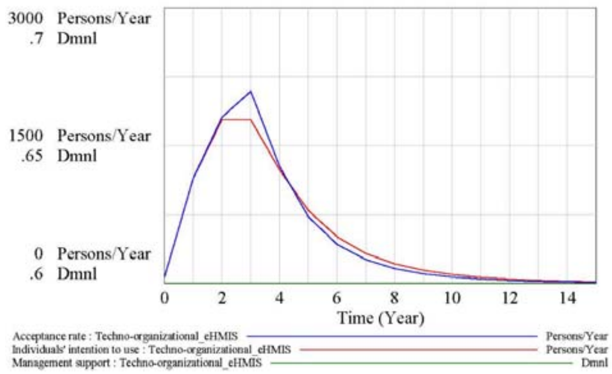
Management support on individuals’ intention to use

The ‘individuals’ intention to use’ developed from the effectiveness of training and communication about the technology to the ‘potential users’. The ‘management support’ influences the ‘individuals’ intention to use’ through the ‘effectiveness of training’. The causes tree (Figure 4) depicts the influence of organizational factors on ‘effectiveness of training’. It is uniquely developed in systems thinking as part of a Vensim model to show the dynamic influence management support on ‘effectiveness of training’. The qualitative analysis of focus groups’ discussion was a key input in the systems thinking processes.

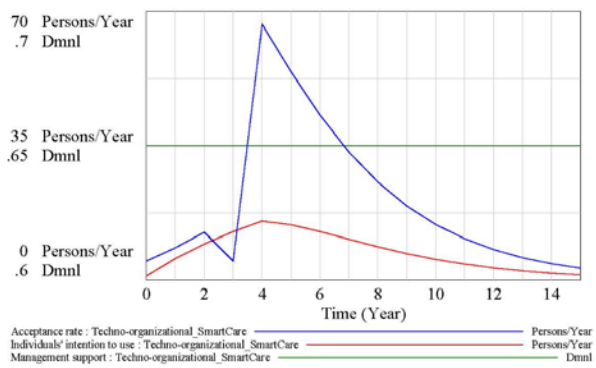
Figure 4. The influence of management support on ‘effectiveness of training’.

The techno-organizational model of technology acceptance depicts the dynamic influence of ‘management support’ on ‘effectiveness of training’. ‘Management support’ was an important organizational factor to improve ‘individuals’ intention to use’ through effective training and communication. The FMOH management supported the training effort during eHMIS implementation together with the two partner organizations.

High ‘management support’ helped to improve the ‘effectiveness of training’ which led to better ‘individuals’ intention to use’ as simulated. ‘Individuals’ intention to use’ (red colour) was a dominant factor to influence ‘acceptance rate’ (blue colour) in the early years of technology acceptance of eHMIS (Figure 5 (a)). The dominance of ‘individuals’ intention to use’ on ‘acceptance rate’ was affected by an increasing number of ‘inhibitors’ starting from year three and two in eHMIS and SmartCare respectively (Figure 5 (a) and (b)).



(a)



(b)

Figure 5. Comparison of 'management support', 'individuals' intention to use' and 'acceptance rate' (a) eHMIS. (b) SmartCare.

8 The verification and validation of techno-organizational model

The model testing process consists of model verification and validation processes (Pruyt 2013). Model verification ensures the correctness of codes and simulation that includes the verity of equations, consistency of units and the accuracy of numerical parameters (Pruyt 2013). The model validation process is not the effort of proving the correctness of the model but it is the process of falsification of the model to build confidence in the model and its usefulness for the intended purpose (Pruyt, 2013; Barlas, 2016).

The model testing confirms the structural and behavioural validity of a model. The two categories of tests that are designed to evaluate the validity of the model structure are direct structure tests and structure-oriented behaviour tests (Barlas 1994). In this simulation study, the model verification is addressed by direct inspection of equations, numbers, and units in addition to the verification of equations and units with simulation software (Vensim DSS Version 6.3D). The 'unit checks' were performed to ensure that the model is error-free using Vensim software package to verify the model correctness.

8.1 Direct structure tests

The model equations, the logical relationship of the model variables, dimensional consistency and the validity of parameters are assessed in the direct structure tests (Barlas 2016).

Structure confirmation test

A structurally valid model should not contradict the knowledge about the structure of the real system (Forrester and Senge, 1980; Barlas, 2016). The model variables were presented in two focus group discussion sessions to evaluate the structural validity of the model against the eHMIS and SmartCare projects in Ethiopia. The focus group members from the FMOH and the FMOH partners confirmed that the model variables capture the reality in the two eHealth projects, SmartCare and eHMIS. The details of system dynamics model structure and the equations used in the model are supported by the literature study and the focus group members involved in the design, implementation and operation of the eHMIS and SmartCare systems in Ethiopia.

Dimensional consistency test

The dimensional consistency checks the left and right sides of the equations for dimensional consistency and the real-life meaning of the parameters. All techno-organizational model equations are made to pass the dimensional consistency test. The 'unit check' functionality of Vensim DSS 6.3D is used to ensure the consistency of all variable units across the model.

Parameter confirmation test

The parameter values can be judged and estimated from interviews, expert opinion, focus groups, archival materials, direct experience, historical data etc. (Sterman, 2000). The parameters of the model are linked to the elements in the real system to ensure conceptual confirmation (Barlas, 1996). The exogenous parameter values of the two cases (eHMIS and SmatrtCare) in this research study are judged from the focus group discussions, the interview data, the FMOH documents, eHMIS database and experts opinion. The parameter values adequately reflect the real-life condition of both eHMIS and SmartCare projects in Ethiopia. Indirect structure tests are discussed in the next section.

8.2 Indirect structure tests

Indirect structure tests include extreme-condition test, boundary adequacy test, and behaviour sensitivity test (Barlas 2016).

Boundary adequacy tests

Key techno-organizational factors necessary for the implementation of eHealth systems in Ethiopia are addressed in the techno-organizational model of eHealth acceptance. The model boundary chart showing the endogenous, exogenous and excluded model variables are indicated in Appendix 1. The techno-organizational model of eHealth acceptance is limited to the healthcare organization's settings. Hence the boundaries are adequately and appropriately set within the context of healthcare institutions.

Extreme conditions test

The extreme conditions test examines the feasibility of each decision rule (rate equation) by direct inspection when each input to the equation takes on its maximum and minimum values (Sterman, 2000). The test can make "reality checks" possible and quickly uncover flaws that direct inspection may miss (Sterman, 2000; Barlas, 2016).

Extreme conditions of 'supportive policy' on 'acceptance rate'

Figure 6 depicts the behaviour of simulated 'acceptance rate' to extreme values of 'supportive policy'. Low 'supportive policy' resulted in a low value of the simulated 'acceptance rate' (blue colour) and vice versa (Figure 6).

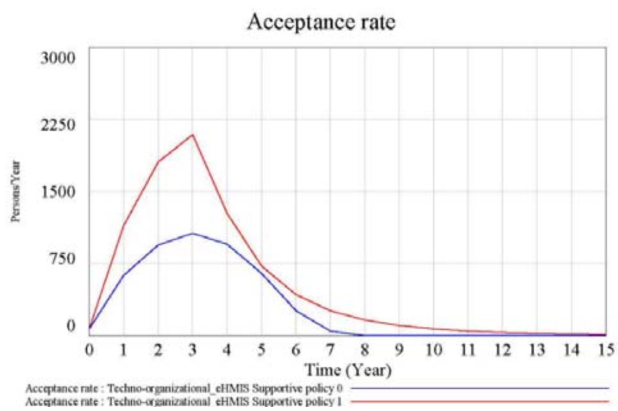


Figure 6. Extreme conditions of 'supportive policy' on 'services quality'.

In general, 'supportive policy' influenced 'acceptance rate' through 'management support', 'resources readiness', 'services quality 'and 'promoters'. The extreme conditions tests of 'supportive policy' confirmed that the model response of the simulated 'acceptance rate' was in line with the anticipated model behaviour in real life.

Extreme conditions of 'current workforce' on 'acceptance rate'

The influence of workforce readiness on the simulated 'acceptance rate' showed in Figure 7 happened through 'services quality'. Technology acceptance was influenced by 'services quality' (DeLone & McLean, 1992, 2003). In the first extreme case (Case 1), the hiring was set to zero but the turnover rate was set to maximum. The simulated 'acceptance rate' exhibited a quick drop to zero as anticipated because all the 'potential users' resigned from the organization (See Figure 7 in blue colour).

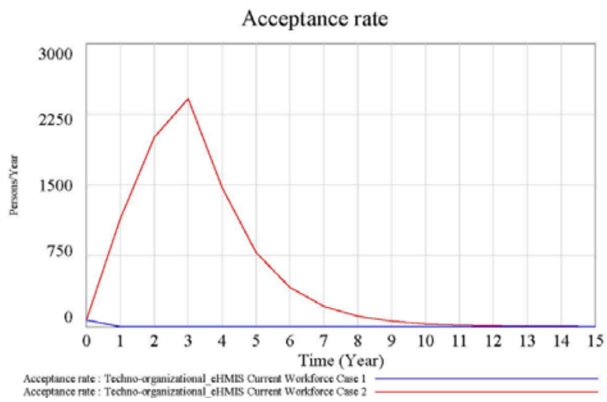


Figure7. Extreme conditions of ‘current workforce’ on ‘acceptance rate’.

The behavioural responses of the simulated ‘acceptance rate’ to the extreme conditions of ‘current workforce’ was in agreement with the expected behaviour of the model variables in the real world.

Extreme conditions of 'current infrastructure' on 'acceptance rate'

Figure 8 showed that the simulated ‘acceptance rate’ slightly dropped with low readiness level of the ‘current infrastructure’ (Case 1 in red colour) as anticipated in the real world.

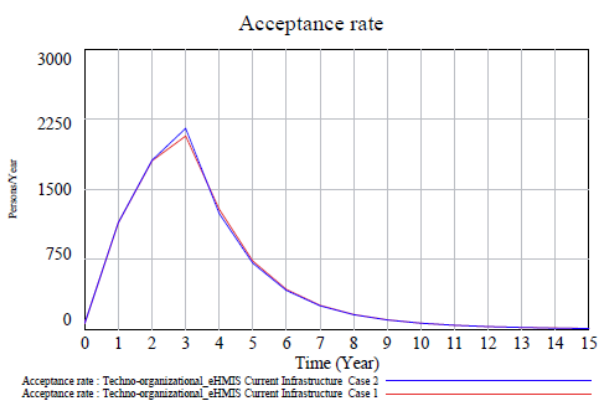


Figure 8. Extreme conditions of ‘current infrastructure’ on ‘services quality’.

In summary, the response of techno-organizational model of eHealth acceptance to the extreme conditions of ‘current infrastructure’, ‘current workforce’ and ‘supportive policy’ agrees with the anticipated behaviour of ‘acceptance rate’. Sensitivity analysis is performed by changing the input parameters of the model to study the output behaviours in the following section.

9 Sensitivity analysis of techno-organizational model

Sensitivity analysis studies the effect of changes in input parameters on the outputs (Sterman, 2000; Pruyt, 2013; Hekimo and Barlas, 2017). There are different methods of sensitivity analysis in the Vensim sensitivity simulation module (Hekimo and Barlas, 2017). The first step of sensitivity analysis is univariate, i.e., each parameter in the list is changed independently, while others are held constant at their original model values each (Hekimoglu and Barlas, 2014). Univariate sensitivity analysis may not be sufficient to comprehensively study a nonlinear and complex model (Sterman, 2000). Hence a univariate should typically be followed by a multivariate method of sensitivity analysis (Hekimoglu and Barlas, 2014).

A univariate and multivariate sensitivity analysis using the random uniform distribution with 200 number of simulations is used to run the simulation model. As suggested by Sterman (2000), the minimum and maximum parameter values are chosen in the distribution range of 20% of the actual model value. Table 1 shows the proposed minimum and maximum parameter values of selected exogenous variables for sensitivity analysis of techno-organizational model of eHealth acceptance.

Table 1. Exogenous variables used in the sensitivity analysis of techno-organization model of eHealth acceptance.

Exogenous variables	eHealth Applications	Estimated Value in basic model	Proposed minimum value of variable	Proposed Maximum value of variable
Supportive policy	eHMIS	1.0 (dimensionless)	0.8	1
	SmartCare	1.0 (dimensionless)	0.8	1
Familiarity with electronic systems	eHMIS	0.2 (dimensionless)	0	0.4
	SmartCare	0.3 (dimensionless)	0.1	0.5
Supportive organizational structure	eHMIS	0.2 (dimensionless)	0	0.4
	SmartCare	0.4 (dimensionless)	0.2	0.6
Average workforce turnover	eHMIS	0.092 (dimensionless)	0	0.292
	SmartCare	0.092 (dimensionless)	0	0.292
Digital equipment installation rate	eHMIS	0.005 (dimensionless)	0	0.205
	SmartCare	0.03 (dimensionless)	0	0.23

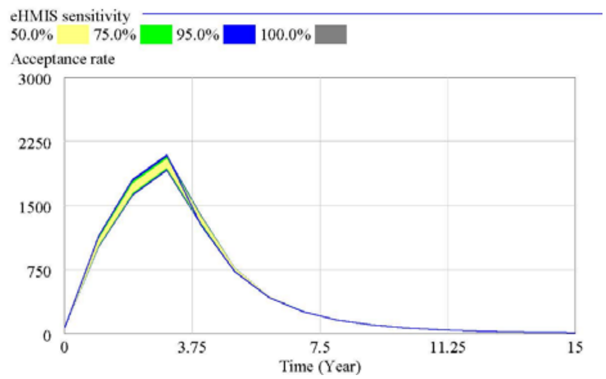
9.1 A univariate sensitivity analysis of eHMIS and SmartCare 'acceptance rate'

The simulated behaviour pattern of 'acceptance rate' of eHMIS and SmartCare due to the changes in the 'supportive policy', 'familiarity with electronic systems', 'supportive organizational structure', 'average workforce turnover', and 'digital equipment installation rate' is discussed below.

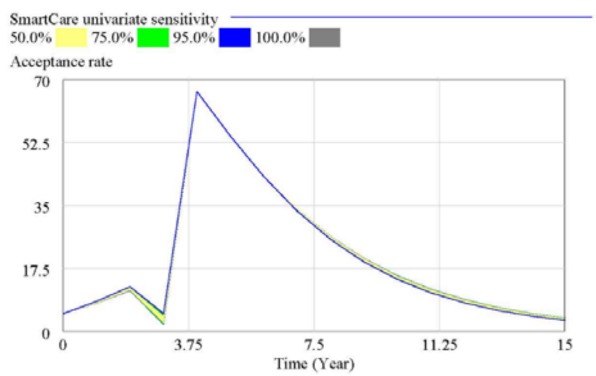
'Digital equipment installation rate' represents the rate at which electronic devices such as computers, scanners, printers, etc. are made available to health facilities. According to the Ethiopian Public Health Institute (EPHI) survey data, the 'Digital equipment installation rate' in Addis Ababa is 3% per annum and in the Southern Nations, Nationalities, and People's Region (SNNPR) is 0.5% per annum (EPHI, FMOH and WHO, 2017; EPHI and FMOH, 2018).

The ‘acceptance rate’ of eHMIS and SmartCare under uncertainty in ‘supportive policy’

Uncertainty in ‘supportive policy’ did not bring a substantial change to the essential original behaviour pattern of simulated ‘acceptance rate’ of eHMIS. The random changes in ‘supportive policy’ (0.8,1) resulted in minimal simulated numerical variations in the ‘acceptance rate’ of both eHMIS and SmartCare (See Figure 9 (a) and (b)).



(a)

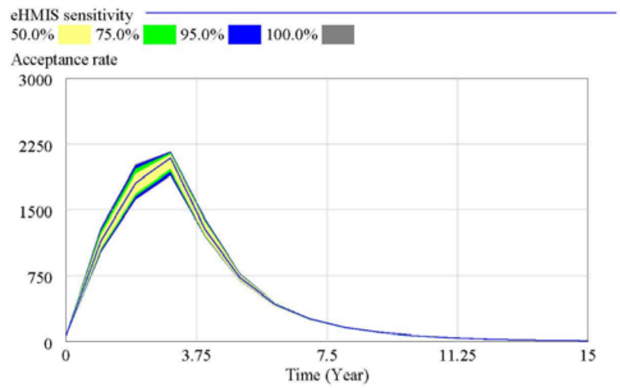


(b)

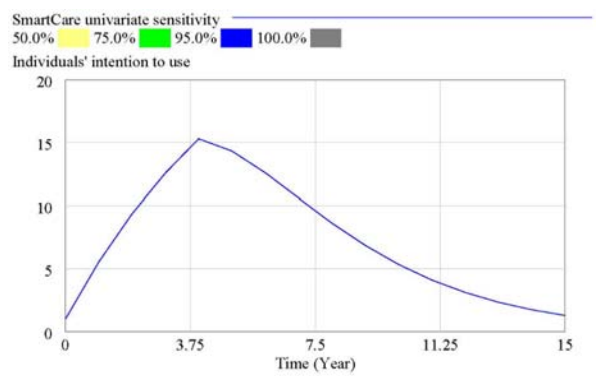
Figure 9 (a) eHMIS ‘acceptance rate’ under uncertainty in ‘supportive policy’ for interval (0.8,1). (b) SmartCare ‘acceptance rate’ under uncertainty in ‘supportive policy’ for interval (0.8,1).

The ‘acceptance rate’ of eHMIS and SmartCare under uncertainty in ‘familiarity with electronic systems’

Figure 10 (a) showed randomly changing ‘familiarity with electronic systems’ (0,0.4) resulted in a small simulated numerical variation of eHMIS ‘acceptance rate’. Figure 10 (b) showed that uncertainty in ‘familiarity with electronic systems’ (0.1,0.5) did not produce a significant change to the main essential behaviour pattern and hardly showed a numerical variation on the simulated SmartCare 'acceptance rate'. The essential original behaviour response of the model remained unchanged in both cases.



(a)

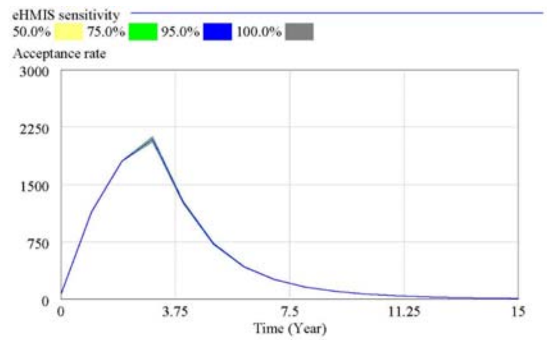


(b)

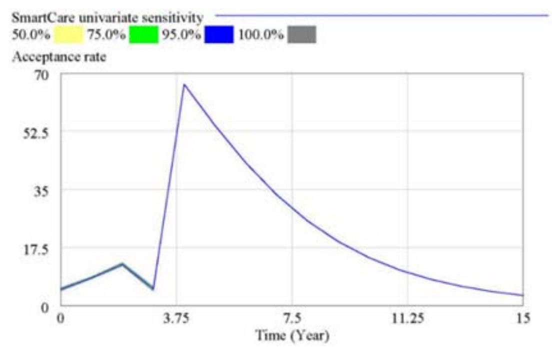
Figure 10 (a) eHMIS 'acceptance rate' under uncertainty in 'familiarity with electronic systems' for interval (0,0.4). (b) SmartCare 'acceptance rate' under uncertainty in 'familiarity with electronic systems' for interval (0.1,0.5).

The 'acceptance rate' of eHMIS and SmartCare with uncertainty in 'supportive organizational structure systems'

Figure 11 (a) and (b) showed that the main essential simulated behaviour of the model remained unchanged in both cases. Besides, uncertainty in 'supportive organizational structure systems' resulted in almost no fundamental change in the numerical values of the simulated 'acceptance rate' of both eHMIS and SmartCare systems.



(a)

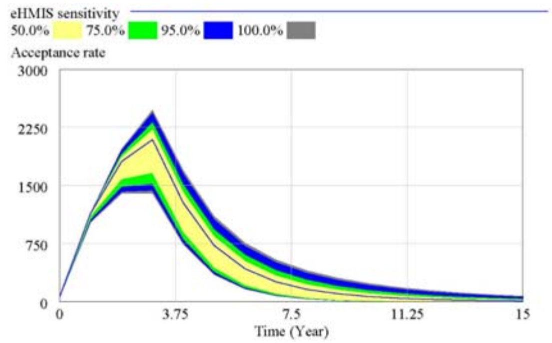


(b)

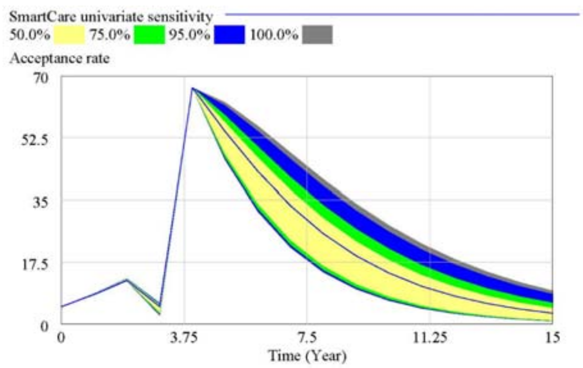
Figure 11(a) eHMIS 'acceptance rate' under uncertainty in 'supportive organizational structure' systems for interval (0,0.4). (b) SmartCare 'acceptance rate' under uncertainty in 'supportive organizational structure' for interval (0.2,0.6).

The 'acceptance rate' of eHMIS and SmartCare with uncertainty in 'average workforce turnover'

The simulated behaviour pattern of 'acceptance rate' of eHMIS and SmartCare remained unchanged under uncertainty in the 'average workforce turnover' (See Figure 12 (a) and (b)). However, significant numerical variations were observed in both eHMIS and SmartCare. Since a healthcare organization can have control over 'average workforce turnover', the 'acceptance rate' of both eHMIS and SmartCare systems can be maximised by ensuring low workforce turnover. The average turnover rate of the health workforce in Ethiopia is 9.2% per annum (Gesesew et al., 2016). Hence, 'average workforce turnover' can be a good candidate for policy analysis.



(a)

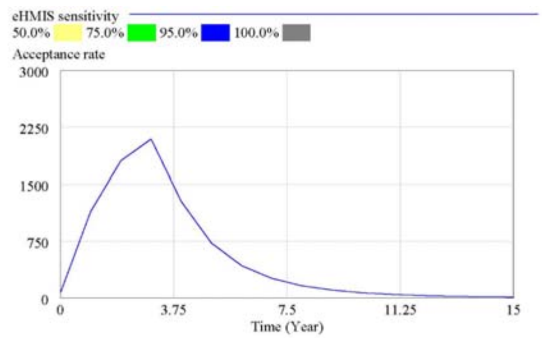


(b)

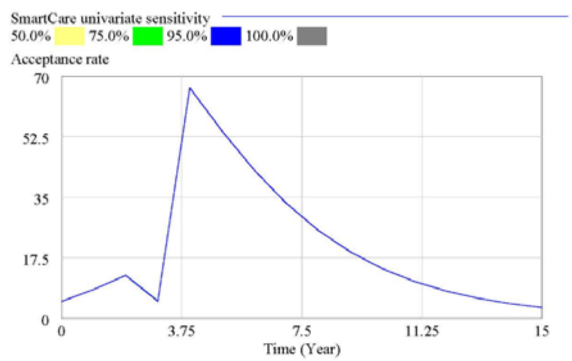
Figure 12 (a) eHMIS 'acceptance rate' under uncertainty in 'average workforce turnover' for interval (0,0.292). (b) SmartCare 'acceptance rate' under uncertainty in 'average workforce turnover' for interval (0,0.292).

The 'acceptance rate' of eHMIS and SmartCare with uncertainty in 'digital equipment installation rate'

Figure 13 (a) and (b) showed that the main essential simulated behaviour of the model remained unchanged in both eHMIS and SmartCare cases. Besides, uncertainty in 'digital equipment installation rate' resulted in almost no substantial changes in the simulated 'acceptance rate' in both eHMIS and SmartCare systems.



(a)



(b)

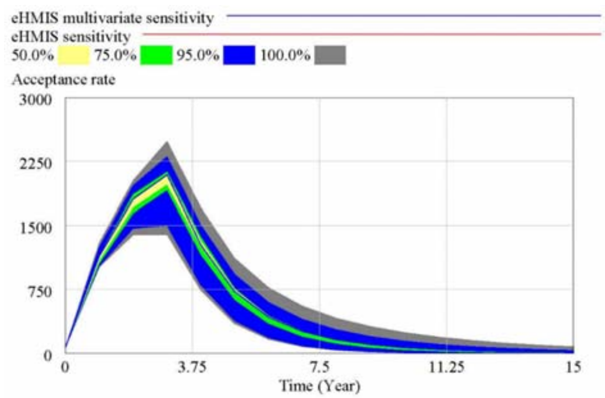
Figure 13 (a) eHMIS 'acceptance rate' under uncertainty in 'digital equipment installation rate' for interval (0,0.205). (b) SmartCare 'acceptance rate' under uncertainty in 'digital equipment installation rate' for interval (0,0.23).

In summary, the sensitivity analysis with random variation in the 'supportive policy', 'familiarity with electronic systems', 'supportive organizational structure', 'average workforce turnover', and 'digital equipment installation rate' produced no fundamental change in the simulated behaviour pattern of 'acceptance rate' of both eHMIS and SmartCare. However, uncertainty in these exogenous variables produced from very minimal to significant numerical variations in the simulated 'acceptance rate' of both systems.

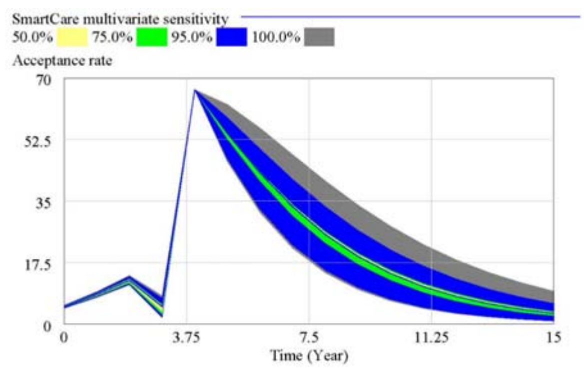
The change in 'average workforce turnover' produced significant numerical variations in the simulated 'acceptance rate' of eHMIS and SmartCare. Since healthcare organizations can have control over workforce turnover, the variable can be a good candidate for policy analysis to maximize the 'acceptance rate' of both eHMIS and SmartCare. The pattern of the model behaviour of simulated 'acceptance rate' fundamentally remained unchanged for both eHMIS and SmartCare.

9.2 Multivariate sensitivity analysis of eHMIS and SmartCare

All five exogenous parameters namely 'supportive policy', 'familiarity with electronic systems', 'supportive organizational structure', 'average workforce turnover' and 'digital equipment installation rate' (See Table 1) were changed together to perform a multivariate sensitivity analysis. The number of simulations was set at 200 and a random uniform distribution was selected in Vensim to examine the simulation results. The simulation results of multivariate sensitivity analysis are presented below.



(a)



(b)

Figure 14 (a) A multivariate analysis of eHMIS 'acceptance rate'. (b) A multivariate analysis of SmartCare 'acceptance rate'.

'Acceptance rate' of eHMIS and SmartCare (multivariate sensitivity analysis)

The multivariate sensitivity analysis of the simulated 'acceptance rate' of eHMIS and SmartCare showed that the essential behaviour pattern remained unchanged throughout the entire simulation under a random uniform distribution (Figure 14 (a) and (b)). However, significant numerical variations observed in simulated 'acceptance rate' of both eHMIS and SmartCare showed the possibility of policy interventions to improve ‘acceptance rate’.

10 Policy analysis of techno-organizational model

A policy is a decision rule, a general way of making decisions (Barlas, 2002). System dynamics deals with dynamic policy problems and has the potential to developing strategic models for policy analysis (Design, Rashedi and Hegazy, 2016). Policy analysis is about the sensitivity of model behaviour to the policy parameters and/or policy structures (Barlas, 2002; Design, Rashedi and Hegazy, 2016). The system dynamic approach is perhaps the most promising simulation method for long-term policy analysis through quantitative simulations and qualitative conceptual models (Lyons and Duggan, 2015; Design, Rashedi and Hegazy, 2016).

The policy analysis in this paper focused on improving the performance of ‘acceptance rate’ by varying selected exogenous parameters. As seen in the univariate and multivariate sensitivity analysis, ‘average workforce turnover’ was a candidate for policy analysis due to a significant numerical influence on the simulated ‘acceptance rate’. Therefore, the ‘average workforce turnover’ variable was varied in the what-if simulation analysis to test alternative policies.

10.1 What-if scenario analysis

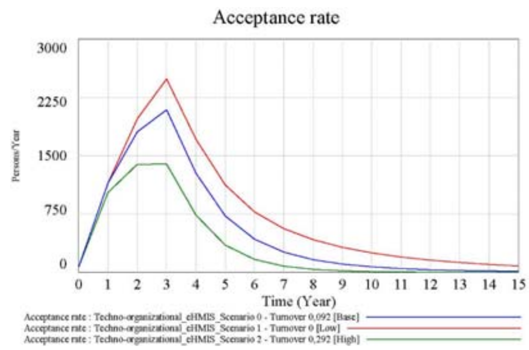
The purpose of the “what-if” simulation experiment is to examine the impact of candidate exogenous variables ‘average workforce turnover’ on the simulated ‘acceptance rate’. The values of ‘average workforce turnover’ were varied and tested under different scenarios for alternative policies. The what-if experiment analysis of base scenario for the ‘average workforce turnover’ was represented in scenario 0. Scenario 1 denoted 20% lower values of ‘average workforce turnover’ for eHMIS and SmartCare from scenario 0 (base) values. Whereas Scenario 2 described a 20% higher values of ‘average workforce turnover’ for eHMIS and SmartCare from scenario 0 (See Table 2).

Table 2. What-if experiments for ‘average workforce turnover’.

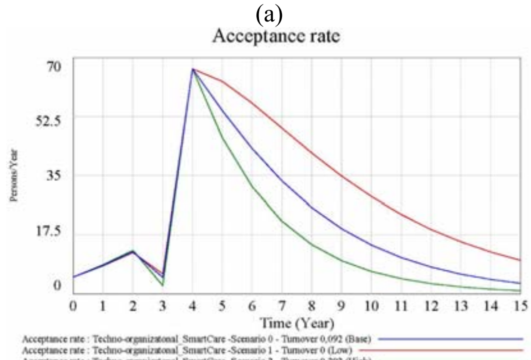
Scenario	eHealth application	Average workforce turnover’
0 (Base)	eHMIS	0.092 (Base)
	SmartCare	0.092 (Base)
1	eHMIS	0 (low)
	SmartCare	0 (low)
2	eHMIS	0.292 (high)
	SmartCare	0.292 (high)

Improving ‘acceptance rate’ through ‘average workforce turnover’

The influence of ‘average workforce turnover’ was significant in terms of changing the peak values of the simulated ‘acceptance rate’ of eHMIS (See Figure 15 (a)). On the third year, the biggest gaps and the peak values of the different scenarios of simulated ‘acceptance rate’ of eHMIS were observed (See Figure 15 (a)). A 0.2 (20%) increase in the ‘average workforce turnover’ reduced the simulated ‘acceptance rate’ of eHMIS by 33.46% from 2089 to 1390 Persons/Year on the third year (See Figure 15 (a) in blue and green respectively). Conversely, a 0.2 (20%) reduction in the ‘average workforce turnover’ improved the simulated ‘acceptance rate’ of eHMIS by 19.1%, from 2089 to 2488 Persons/Year on the third year (See Figure 15 (a) in blue and red).



(a)



(b)

Figure 15 (a) A what-if analysis of ‘acceptance rate’ of eHMIS with respect to changes in ‘average workforce turnover’. (b) A what-if analysis of ‘acceptance rate’ of SmartCare with respect to changes in ‘average workforce turnover’.

The impact of different scenarios of ‘average workforce turnover’ on the simulated ‘acceptance rate’ of SmartCare was significant after year four (Figure 15 (b)). As shown in Figure 15 (b), a 0.2 (20%) increase in the ‘average workforce turnover’ reduced the ‘acceptance rate’ of SmartCare by 36.36% from 33 Persons/Year (in blue colour) to 21 Persons/Year (in green colour). On year seven, a 0.2 (20%) decrease in the ‘average workforce turnover’ produced an increase in the ‘acceptance rate’ by 48.48%, from 33 Persons/Year (in blue colour) to 49 Persons/Year (in green colour). The impact of ‘average workforce turnover’ on the ‘acceptance rate’ of SmartCare was more significant in the later years of implementation (See Figure 15(b)).

The ‘average workforce turnover’ showed a significant influence on the simulated ‘acceptance rate’ of both systems. A 20% increase in the ‘average workforce turnover’ has produced much more reduction in the simulated ‘acceptance rate’ of eHMIS (33.46%) and SmartCare (48.48%). The significant drop in the simulated ‘acceptance rate’ of SmartCare compared to eHMIS due to an increase in the workforce turnover can relate to the frustration of SmartCare users due to existing high-level workload.

Hence retaining trained workforces in the healthcare organization could increase the ‘acceptance rate’ of eHMIS and SmartCare in Ethiopia. The top management should implement a policy to minimize the workforce turnover rate by addressing staffs' concerns captured during the employees’ exit interviews.

11. Conclusions

The interplay between the techno-organizational factors of eHealth success factors were captured by three reinforcing loops and one balancing loop through the systems thinking approach. The influence of resources readiness, management support, and change management on users’ satisfaction and technology acceptance were addressed in the reinforcing loops while the balancing loop highlighted the impact of inhibitors on ICT culture within a healthcare organization. The focus group data and the simulation results are discussed in an integrated way to explain the techno-organizational model of technology acceptance and system dynamics model validation tests.

‘Resources readiness’ addressed the adequacy of human resources and ICT infrastructure to implement successful eHealth system. The overall resources readiness was weak to the implementation of successful eHMIS and SmartCare systems in Ethiopia. However, management support was strong and executives showed a willingness to allocate human and ICT resources to the successful implementation of electronic health technologies. The electronic system success was influenced by the level of top management support (Al-Mamary, Shamsuddin and Aziati, 2014). The support from management increased the quality of data, use of information, informed decision making as indicated by the focus group team.

The culture of ICT within healthcare organizations improved as the end-users became familiar with technology and understood the value of its information product. Aqil et al (2009) confirmed that the information culture of a healthcare organization influenced the workflow process and affects the output of technology performance, i.e. the quality of data and continuous use of information. The growing culture of ICT within health facilities in Ethiopia improved the quality of data and the use of information for decision making; however, information dissemination culture was weak.

The alignment of the technology workflow with existing workflow process reduced the end-users resistance. Rippen et al. (2013) also showed the fit between technology and clinician's workflow was one of the key reasons for the success of eHealth applications in the healthcare sectors. The implementation of both eHMIS and SmartCare systems followed the existing manual workflow processes.

The validity and robustness of techno-organizational model of eHealth acceptance were confirmed through direct and indirect structure tests. The focus group discussions, the interview data, the FMOH documents, eHMIS database and experts opinion were used to judge system dynamics model parameter values. The boundary adequacy test, extreme condition tests and univariate and multivariate sensitivity analysis satisfied the validity of the model in maintaining the essential behaviour pattern described in the eHealth case study data.

The policy analysis indicated that the ‘average workforce turnover’ significantly influenced the simulated ‘acceptance rate’ of eHMIS and SmartCare systems. The impact of ‘average workforce turnover’ on the simulated ‘acceptance rate’ of SmartCare was more significant than that of eHMIS. Therefore, retaining skilled workforces in the healthcare organization should be the main focus in the techno-organizational dimension of sustainable eHealth implementation to increase the ‘acceptance rate’ of eHMIS and SmartCare in Ethiopia. The satisfaction of users increased with low workforce turnover due to reduced work burden on the end-users.

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