MODELING TECHNOLOGICAL CHANGE ON TELECENTER EFFECTIVENESS

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Abstrak

Perubahan teknologi (TC) adalah proses keseluruhan penciptaan berterusan, inovasi dan penyebaran teknologi yang bertujuan untuk meningkatkan prestasi teknikal. Tanpa TC, tidak akan ada pertumbuhan perniagaan dan pembangunan terutamanya di telecenter. *Telecenter* adalah persekitaran awam yang dibangunkan sebagai suatu pusat kemahiran digital untuk mengakses maklumat dan teknologi komunikasi bagi mengujudkankan pembelajaran dan mencapai keperluan khusus mereka. Matlamat utama *telecenter* adalah untuk merapatkan jurang digital antara kawasan bandar dan kawasan luar bandar, dan menyediakan perkhidmatan sokongan digital kepada masyarakat jiran. Penggunaan telecenter secara berkesan adalah isu utama kelestarian *telecenter* kerana ia telah di dapati mengalami kekurangan penggunaan. Oleh itu, kajian ini memberi tumpuan kepada mengenal pasti faktor TC yang menyumbang secara ketara kepada keberkesanan *telecenter*. Objektif pertama kajian ini adalah untuk mengenal pasti faktor penyumbang kepada TC. Objektif kedua adalah untuk membina satu model *computational* berdasarkan faktor terpilih yang diperolehi daripada objektif 1. Objektif ketiga adalah untuk menilai keberkesanan model. Kajian ini dijalankan dengan menggunakan pendekatan model *computational* melalui tiga fasa: abstraksi, perasmian, dan penilaian. Hasil kajian menunjukkan bahawa model *computational* dapat menunjukkan kesan TC yang dipilih terhadap keberkesanan *telecenter* dalam pelbagai senario. Penggunaan *telecenter* boleh menjadi lebih berkesan dengan mempertimbangkan faktor TC yang bersesuaian.

Kata Kunci: perubahan teknologi, faktor, telecenter, model pengiraan, penggunaan yang berkesan

Abstract

Technological change (TC) is the overall process of continuous invention, innovation and diffusion of technology that aims at improving the quality of technical performance. Without TC, there would be no business growth and development particularly in a telecenter. A telecenter is public environments that people develop essential digital skills to access information and communications technologies to create, learn and achieve their specific needs. The major goal of a telecenter is to bridge the digital gap between the urban and the rural areas, and provide digital support services to the neighbouring community. Telecenter effective usage is a major issue of telecenter sustainability because it has been found that there a lack of usage. Hence, this study focused on identifying TC factors that contribute significantly to telecenter effectiveness. The first objective of the study was to identify the contributing factors of TC. The second objective was to construct a computational model based on selected factors obtained from objective 1. The third objective was to evaluate the effectiveness of the model. The research was conducted using the computational model approach through three phases: abstraction, formlization, and evaluation. The results showed that the computational model was able to show the effect of the selected TC on telecenter effectiveness in different types of scenarios. The usage of telecenter can be more effective by considering the TC factors that are appropriate.

Keyword: technological change, factors, telecenter, computational model, effective usage

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CHAPTER ONE

INTRODUCTION

1.1 Background

Telecenter is commonly associated with Information and Communication Technology (ICT) (Di Stefano, Gambardella, & Verona) for development projects (Mishra, 2013). Telecenters are considered as one of the most successful projects of ICT diffusion in developing countries, particularly the poor and people living in remote rural areas (Rajalekshmi, 2007). It branded by many names likes community technology centers, multimedia community centers or cyber centers. According to Gomez, Pather, and Dosono (2012) and Razak, Hassan, and Din (2010), a telecenter is a place where ICT facilities such as computers, and Internet services, training, and Internet access are provided to the rural community. Previous findings have shown that communities have opportunity to improve their access to information, job creation, skill development, study opportunities, and increased income, due to effective utilization of telecenter (Bailey & Ngwenyama, 2013; Buhigiro, 2013; Zamani-Miandashti, Pezeshki-Rad, & Pariab, 2013). In addition, a study carried out by Ibrahim, Yasin, and Dahalin (2010) to ascertain financial sustainability among 132 Malaysian telecenters, has discovered that telecenteres were a resourceful point with the provision of Internet service for economics, academic and social development, and others utilities of the community. It also enhances information circulation, e-government services, e-health as well as e-banking in order to enhance the focused community's socioeconomic condition (Ibrahim et al., 2010).

Hence, telecenter effectiveness has been measured by the ability of achieving the community's demands in terms of different factors such as social, economic and political growth and able to sustain for long term (AbdulWahab, 2012; Garrido, Sey, Hart, & Santana, 2012). In addition, Garrido et al. (2012) explored different techniques for measuring performance of telecenter such principal agent, feasibility failure, and business techniques appraisal. A study carried out by Bonadia, Ávila, Ogushi, and de Holanda (2008), run simulation to show the relationship between an assured factors to express some aspects of certain problems related to adoption and utilization of telecenter.

However, the findings of a study conducted by Cheang and Lee (2010) showed that the average effectiveness of telecenters has not yet reached its potential, and also observed that technological change impacts have not been study well. According to Heeks (2008), one of the important factors that affecting telecenter performance is technological innovation (Cheang & Lee, 2010). Technological innovation has been examined impacts on telecenter effectiveness in terms of relevant factors such technology infrastructure, costs, quality of services, and information accessibility (Garrido et al., 2012; Gomez, 2012; Jimoyiannis, 2010; Meng, Samah, & Omar, 2013). Hence, telecenter is required to determine the impacts of technological change (TC) on its effectiveness, and how technology services provided by telecenter could attain the potential usages of the communities (Madon, Reinhard, Roode, & Walsham, 2009; Sey & Fellows, 2009). In addition, the affordable access to ICT resources has been attributed to improvement or changes in technology which have assisted individual and corporate organization in acquiring useful information. This convenience utilization has been an important factor for telecenter acceptance (Qureshi & Trumbly-Lamsam, 2008).

TC has been mentioned as a combination of invention, innovation, and diffusion of technology (innovation) and services that required by users needs. The positive impact of TC on utilizing products and services includes affordability and quality that increased performance of firms, while negative effect of TC includes prices and complexity (Heeks, 2008). Therefore, TC is referred to as an instrument that can indicate the effect of firm performance during the implementation of new technology in a specific area and highlights the findings of the utilization (Jorgenson, 2001). Rapid improvement of technology contributed to knowledge through engaging people and making new resources accessible and affordable for them. Easy access to IT has created a substantial effect to telecenter environments through the usage of the new technology devices. The innovation in technology has helped towards the accomplishment of societal development through citizenry involvement, functional health care as well as improved education as well as community discourse (Harris, 2001; Qureshi, 2013; Qureshi & Trumbly-Lamsam, 2008).

Hence, according to Gomez et al. (2012), some researcher studies have observed that the performance of telecenter can be evaluated on the technology applied. Therefore, considering the effort and resources that many organizations, both private and governmental, have put into starting telecenters, it is important to understand which factors underlie this lack of demand (AbdulWahab, 2012). Thus, this study aims to explore TC factors in terms of invention, innovation, diffusion, and external factors such as government policies and individuals commitment, how they can affect telecenter usage. Simulation model was developed to show relationship of TC factors that have significant impacts on telecenter. The simulation goal is to achieve an effective training environment for evaluating these factors. The simulated data should help to analyze, and show when the factors have most significant impact, with finding strategic plans that can be designed to enhance telecenter effectiveness.

1.1 Problem Statement

The purpose of telecentre deployments is to provide access to ICT in order to enhance community development (Bailey & Ngwenyama, 2009; Meng et al., 2013). Therefore, the successful implementation of telecentre depends widely on the communities usage of ICT (Wang & Shih, 2009). Previous studies on telecenters for development declared that one of the significant challenging of telecenter is sustainability (Bailur, 2006; Stoll, 2008). According to Tschang, Chuladul, and Le (2002), in just about two years of their establishment, at least 70% of the first wave of telecenters in Australia went into extinction. Likewise, only 22% of telecenters established by the Ministry of Environment in rural Mexico remained functional after two years. Hence, recent researcher studies reported that telecenters were not living up to their potential and were seen to close down because of being labeled as not important from rural residents and produced little developmental impact (Doshi & Gollakota, 2009; Sey & Fellows, 2009).

A major problem reported was lack of societal interest in rural telecenters, resulting in low demand for such services. Telecenter sustainability, according to Stoll (2008) was based on effectiveness of usage. Telecenter effectiveness has also been measured by the ability of achieving community's demands in terms of different factors such social, economic and political growth and able to sustain for long term (AbdulWahab, 2012; Garrido et al., 2012). The study carried out by Bonadia et al. (2008) that used a simulation model showed that there are relationship between assured factors to express some aspects of certain problems related to adoption and utilization of telecenter effectiveness.

In addition, many studies addressed different factors related to telecenters effectiveness. One of the major factors of telecenter ineffectiveness is lack of usage (AbdulWahab, 2012; Doshi & Gollakota, 2009; Sey & Fellows, 2009). Several frameworks have been developed to established effectiveness of telecenters in terms of different factors such technology infrastructure, services, technology knowledge, and information accessibility (Bailey & Ngwenyama, 2009; Meng et al., 2013; Naik, Joshi, & Basavaraj, 2012). Heeks (2008) observed that rapid changes in ICT and technologies affect telecenter usage. Recent studies found that the deployment of new technologies and quality of services have vital impact on individuals utilization and satisfaction of telecenter effectiveness (Abdulwahab & Dahalin, 2010; Doshi & Gollakota, 2009).

Unfortunately, most researchers of telecenter effectiveness have not focused on technological change factors; hence, this study is aimed at addressing the issue, that is modeling TC factors in terms of invention, innovation, and diffusion with respect to external factors such as government policies and individuals commitment with telecenter effective usage.

1.2 Research Questions

Q1- What are TC factors that have impact on telecenter effectiveness?

Q2- Can a computational model be used to identify TC factors that contribute to telecenters effective?

Q3- How to evaluate the proposed model to represent telecenter effectiveness?

1.3 Research Objectives

The main objective is to develop a computational model that can be used to illustrate factors contributed to TC that can influence telecenters' effectiveness. The sub-objectives are:

1- To identify factors that contributes to the telecenter effectiveness.

2- To construct a computational model based on the selected factors obtained from Objective one.

3- To evaluate the proposed computational model.

1.4 Significance of the Study

This research aims to help the telecenters' decision makers, stakeholders, and to identify TC factors that influence the telecenters' effective usage. The results can be used to develop an effective plan and to design policies specifically for sustaining telecenters' operations.

1.5 Scope of the Study

The focus of this study is on the TC factors with respect to telecenters' effectiveness usage. The factors were obtained from past literatures. For this study, the approach was based on the standard computational model development process and simulated using Matlab. The model evaluated using stability analysis.

CHAPTER TWO

LITERATURE REVIEW

The rapid change in technologies has enabled different groups and levels of people to easily access and use computers and other information gadgets through telecenter based on the premise of its economic transformation ability. However, the revolution of new technologies has impacted both positively and negatively on ICT usage such as the relative advantage and cost (Gould & Gomez, 2010). This chapter conducts a literature review with the intent of establishing the impact of TC on telecenter ability to fulfill their universal access to ICT and developmental objectives. In achieving this, an extensive literature review on the concepts and issues of telecenter effectiveness was conducted. This was followed by TC concepts, factors of TC and determination of their impact on telecenter effectiveness. This shall be followed by a survey of similar models and approaches that explored related concept to this study. A computational model approach has been explored which is used in this study.

2.1 Telecenter Concepts

The concept of telecenter was first introduced in the early eighties in the Nordic countries particularly in Denmark where it is known as telecottage. Telecenter later spread to other countries such as Europe, North America and Australia (Proenza, 2001).

One of the hype of telecenter is that of its many definitions. According to Best and Kumar (2008), a telecenter as a physical location that provides access to Information and Communication Technology (ICT). On the other hand, telecenter also known as multi-purpose community telecenter, public Internet access points, or information kiosks is an avenue for providing ICT services to rural communities (Gomez, 2012). While according to Zulkefli and Sulaiman (2009) “A telecenter provides ICT services needed by the disadvantaged and rural communities and foster the usage of ICT ". However, in this research telecenter was defined as a place where public access to ICT for economic, social and cultural development is provided through internet (Bailey & Ngwenyama, 2009).

In general, a telecenter can be described as a mechanism which uses ICT to support a community’s economic, social and educational development, bridging the digital divide, and empower women. Telecenter was a government project to experiment the use of new ICTs by persons who would ordinarily have no access to them, such as farmers. These telecenters focused more on computer and on-line services. In a telecenter, Internet and computer services (ICTs) are provided to the rural community enabling the rural people who are mostly farmers to increase their income through improved productivity and marketing (Doshi & Gollakota, 2009). Global growth in ICTs industry has created an awareness of the ability of ICTs to transform lives and alleviate poverty most especially to the downtrodden masses. ICTs have been recognized as a vital tool for both social and economic development (Doshi & Gollakota, 2009). Based on this premise, several telecenters have been set up by governments, NGOs, private-public partnership (PPP) and development agencies such as UNDP (Doshi & Gollakota, 2009) . In Asian countries like the rest part of the globe, ICTs are rapidly assuming an inescapable and essential element of rural development projects (Zamani-Miandashti et al., 2013).

According to Meng et al. (2013) there are estimated 524 telecenters spread across Malaysia. In Malaysia telecenters are funded by several sources, including both the federal and state governments, NGOs, donor agencies and the private sector (Meng et al., 2013). Likewise telecenters in Malaysia are being implemented under several names such as “Medan Info Desa” (MID), “Community Broadband Center” and “Rural Internet Center”. Among the numerous of ICT projects that have been established, these are the most “attached” telecenters projects to the rural community.

From the foregoing, two important roles can be observed: (1) Telecenters are avenue for providing access to ICTs facilities to the disadvantaged; (2) Telecenters are introduced based on the premise of its ability to alleviate poverty and improves social conditions of the disadvantaged. Based on (1), it can be argued that telecenter is highly dependent on ICTs. While ICTs involves provision of access to information and communication via technologies such as radio, TV, video, computers, copiers, scanner, telephone, and internet (Rao, 2008). Hence ICTs are highly dependent on technologies.

On the second important issue bothering is on the ability of telecenter to bring about development, though a number of literatures has reported the success of these telecenters (Meng et al., 2013). However there still a sizeable numbers of researchers who reported that majority of telecenters have not lived up to their budding. Many telecenters either closed down because of financial or technical difficulties or failed to scale up and have any substantial effect on the livelihood of communities with only a few number of telecenters attaining sustainability (Doshi & Gollakota, 2009; Sey & Fellows, 2009). Despite government sponsorships and NGO's supports for telecenters, their effectiveness remains at minimal levels (Abdulwahab & Zulkhairi, 2011).

2.2 Telecenter Effectiveness

In evaluating the telecenters effectiveness, researcher studies mostly use empirical measurement such as the number of people use it, number of users satisfy from quality of services implemented and facilities available that give them benefit such as jobs created, and training with low cost (Gurstein, 2007; Ibrahim et al., 2010). Research studies such as Garside (2009); Rothenberg-Aalami and Pal (2005) have included the human development and well-being of the users in measuring telecenter effectiveness. Generally, research work on telecenters in development has tended to cluster around three key issues: sustainability, impact, and best practice. Tschang et al. (2002) stated that at least 70% of the first wave of telecenters in Australia disappeared only after two years. Sustainability also emerged as an issue in investigation of telecenters funded by the more recent wave of ICT4D investment (Avgerou, 2010; Proenza, 2001). From the perspective of Roman (2003) sustainability can group into: Financial sustainability which is seen to arise when a project "an inflow of revenue is equal to or greater than the expenditure and economic return of a project" (Roman, 2003).

Attaining financial sustainability over time after initial funding agency ends its financial support remains a challenge to telecenter effectiveness. Bailur (2006) observes that the cost US$5,000 is required to set up a telecenter, however it may cost US$3,000 to maintain it annually. Social sustainability is an ongoing support due to the positive impact of telecenters on the social and economic development of the local community in terms of relative advantages. Again, this can be difficult to achieve effectiveness usage of telecenter when the local community may identify other priorities to information and services if that provided with non-value (Avgerou, 2010).

In contrast, Bailur (2006) observed that information on community impact is necessary for a firm understanding of social sustainability. Based on Whyte (2000), impacts of telecenter projects on community can be broadly divided into two (a) Ability of telecenter to meets ICT needs of the community, (b) Ability to bring about local equity and economic development. Lastly, political sustainability relates to continuing support for telecenters from the policy-making and regulatory environment. This, too, may not always be found possible due to change in governments or transfer of staff. While Lahlou (2008) argued that telecenters effectiveness for long term is a critical issue that bothers on several spheres: financial, political, technical, social, and cultural. Lahlou (2008) remarked that aside financial and political sustainability, ensuring that technology works in low resource environments will promote technological sustainability. Benjamin (2001) investigates the role of telecenters as engines of growth with a particular focus on South Africa. He argued that for telecenter initiatives to achieve the goal of promoting economic growth there is a need for an effective telecenter which is well-structured and defined. Other study focus on the significance of monitoring and evaluation in telecenter initiatives for short term (Hudson, 2001).

However, time factor can play a vital role to evaluate the effectiveness of telecenter related to utilization of services over time (Shakeel, Best, Miller, & Weber, 2001). In addition, effectiveness of telecentres can be evaluated over time depending on satisfaction of technologies and working with providing new services to community (Latchem et al., 2001). Moreover, community satisfaction is a significant factor identifying developmental impacts of telecentre effectiveness's usage over time. Hence, effectiveness in terms of utilization and satisfaction of new technologies and services can be evaluated over period of time. Therefore, telecenter sustainability can be measured depending on long term effectiveness which is refer to the period of time (months / years) that shows user satisfaction and utilization of new technologies and services (Best & Kumar, 2008; Hudson, 2001). Hence, long term effectiveness related to user's satisfaction and utilization can be evaluated telecenter effectiveness over period of a certain time (months/years).

On the other hand, the above challenges and issues of telecenters effectiveness, several other issues related to technological change, which has been identified by researchers as enumerated below:

2.2.1 Technological Infrastructure Sustainability

The equipment and facilities to be employed at telecenters are referred to as technological infrastructures which according to Bashir et al. (2011), are very vital in building a knowledge society. According to Meng et al. (2013), stability, endurance, connectivity, observes security as well as insurance, users' oriented facilities and the supply and upkeep of IT facilities are the essential factors for infrastructure sustainability. Moreover, ICT facilities like computers, scanners, and printing machine need to be supplied in contingent with the financial backings of the telecenters. Poor infrastructure in terms of insufficient resources and poor maintenance culture has been identified as one of the telecenters problems (Cheuk, Atang, & Lo, 2012; Meng et al., 2013), and many centers were found without a contingent sustainability plans which were difficult for such telecenters to get the resources needed to sustain the centers. The low rate of broadband connections in most of the urban centers has also been identified as a serious challenge. Therefore, current state of technology, capability, high rate of technology counted as major factors derived innovation and impacts on users' oriented facilities, and the supply and upkeep of ICT facilities such as network network infrastructure. are the essential factors for infrastructure sustainability (Jacobsson & Bergek, 2011).

2.2.2 Collaboration

In order to sustain telecenter, it should not be run in isolation and according to Razak et al. (2010), this requires collaborate with other telecenters within an environment to get more experiences and capabilities. This is to make sure that uninterrupted backing is received from the end users as well as the local supporters which can be getting in touch with for collaboration in terms of offering coaching to others, sharing of ICT facilities (Antonelli, Crespi, & Scellato, 2013). Collaboration assist employees in various telecenters to collaborate together towards ensuring the significance, sustainability and the ability of telecenters in inspiring representative of the community needs of exciting technology and to improve it. Therefore, collaboration acts as a medium of adequate opportunity exploration for skills acquisition which can aid innovation practices thereby promoting effective sustainability of the telecenter usages. Effective collaborations with other stake holders in the same field aid innovative knowledge and enhance effective management as well as the quality of services being offered (Doloreux & Shearmur, 2012). Hence, collaboration considers an important factor which contributes to innovation.

2.2.3 Technology Adoption (Knowledge)

According to Lashgarara, Karimi, and Mirdamadi (2012), it was revealed that a significant relationship existed between adoption of new technologies as well as usage of ICT in villagers; education level, language familiarity, and occupation coupled with their behaviors towards technological infrastructure provision in the centers, mode of delivering services as well as enthusiasm towards IT usage, provision of computer knowledge to the villagers as well as government investment to the centers. Other study has also shown that the rural communities mindfulness of services provided will rise if their educational level increase necessary knowledge, ICTs as well as information services is enhanced (Lashgarara et al., 2012). Also found that technological knowledge provides independence services that influence implementation of new services that can attach to the user needs (Bailey & Ngwenyama, 2009). Therefore, technological knowledge and benefits of using ICTs lead to determine the user needs and to produce new services that enhance the performance of telecenter and effectiveness.

2.2.4 Technological Costs (Pricing Challenges)

The interview conducted with locals according Sumbwanyambe, Nel, and Clarke (2011), reveals that one of the obstacles to Internet usage is the billing arrangement**.** Also, the Internet usage price prevents the users from promising technologies and considers substantially issue affecting the use of telecenters. Telecenters if not for the pricing technique promote technology circulation which aids economic development in rural area. However, its feasibility in a rural community is delayed. Various interest groups are expected to be involved in the competing price arrangement that will bring about economic development of the community. In the survey carried out by Prahalad and Mashelkar (2010), it was realized that pricing arrangement in telecenter is directly associated with the client or users' willingness to pay, which is determined by their income. Therefore, it is claimed by Sumbwanyambe et al. (2011), that reasonable price technique like urban-rural cross subvention can be adopted by telecenters to support rural communities. On the other hand, the government through price appropriation can enhance rural community market towards telecommunication. A major obstacles confronting telecenter include low level of business novelty, wrong price services which has an adverse effect on telecenter in achieving their goals (Sumbwanyambe et al., 2011). Therefore, it is claimed by Sumbwanyambe et al. (2011), that reasonable price technique like urban-rural cross subvention can be adopted by telecenters to support rural communities.

Consequently, the significance of infrastructural sustainability, technological knowledge, collaboration and technological costs has been extensively justified within the sections above through related theories and expert discussions. Therefore, these factors are considered in this study to have high impact on the dynamism of changes in technology that can determine the state of effectiveness of telecenter. Roman and Cole (2002) claimed that:

> "Telecenters are systemic entities composed of interrelated elements, including: research (feasibility studies, needs analysis, evaluation), organisational planning (for example, clarification of telecenter goals and objectives), the challenges of sustainability, community social structure and demographics, capacity-building (regarding both the community and the telecenter), partnerships, participation and staffing, and various other elements. Each element is linked in some important way with each other element (p.24)."(Rega & Poglia, 2010).

2.3 Issues Related to User Satisfaction of Using Telecenter Services

2.3.1 Quality of Services (QoS)

The QoS are substantial issue affecting the telecenter performance (Bashir et al., 2011). Individuals were attracted to using telecenter if they are satisfied from the quality and type of services provided. In order to sustain telecenters, high quality and user-friendliness services are necessary (Meng et al., 2013). According to him, there is a demand for telecenters to put service availability and quality on their uppermost priority. For that it has been recommended that telecenter should hold the vision that communities have to be encouraged and empowered toward developing skills by providing them with fitting courses, resources, and services (Bashir et al., 2011). Despite the fact that individuals owned computer at home, they keep on realizing the services by telecenters very vital that the usefulness of using telecenters is the accessibility to essential facilities. Contrary to this, the result of survey conducted by Cheuk et al. (2012), on the community perception and attitude towards the use of telecenter in Sarawak, Malaysia, reveals that the presence of alternative sources of internet made a significant numbers of respondent not to use the telecenter. This was further compounded by erratic nature of Internet connection. Also telecenters have been very useful for young artist from a poor community to make use of the telecenters for collecting comic books (Bailey & Ngwenyama, 2013). However, according to Gomez (2012), it was observed that if the services and sources to operate telecenters are not put in place, many people would fail access to, and use technological services. Therefore, it is important identifying these necessities and providing services that will draw a lot of youth to telecenters. Hence, QoS should be taken as vital factor that empowers communities to use telecenter facilities depending on utilizing modern services related to TC.

2.3.2 Information Technology Services

An important issue for emerging countries in terms of Information technology (IT) is the revolution of the Internet usages. Internet has contributed immensely in different ways to community’s life. Thus, the role Internet usage plays in the development of urban cities makes it a necessity in rural areas. One of the objectives of introducing TCs in rural areas is to bridge the digital gap between them and the urban areas, by developing the usage information facilities and providing easy access to information (Proenza, 2001). The usage of the Internet creates more chances for networking and easy access to available information and other services which are not available for the low income earners before, due to distance (Rogers & Shukla, 2001).

On the other hand, TC has introduced new applications that is considered cheaper solutions using IT services such as " Voice over Internet Protocol (VoIP)", which helped individuals to use ICT facilities for communication purposes to contacts others. However, VoIP and other services still have comforting limitation on the use related to access and communication (Gomez, 2012). A challenge here is to provide Internet connectivity, to be affordably available at telecenter. Internet may also work in conjunction with the early means of communication such as radio to disseminate information at wide range at lower cost. However, the main feature in recent telecenters is to provide IT services that meet individuals' demands.

2.3.3 Information Accessibility

According to Naik, Joshi, and Basavaraj (2010), accessibility as well as a valued information rely on the certain element which include affordability in terms of information available at a lower cost; connectivity; capacity in terms of lack of expertise towards information accessibility especially in a community where there is a low level of education; the reliability of the information; locally essential information for local context in terms of employment and agriculture. According to Naik et al. (2010), if people have access to information, it will improve their opportunities for livelihood, enhance their living standard as well have lessened their risk towards external risk as well as vulnerabilities. Hence, the expertise can play a vital role to provide technological capability that meet communities need of information accessibility.

In conclusion, telecenter has been found to provide ICT applications, goods or services that are used towards information creation, processing, dissemination and transformation. Examples include radio and television transmission, soft and hardware, electronic media as well as computer services (Meng, Samah, & Omar, 2013). According to Bashir et al. (2011), the widely revealed demands concern in ICT project development in Malaysia include ability to capture community needs, availability, quality as well as maintenance of infrastructural facilities, required expertise employee to do the job as well as the technological capabilities in the center. Hence, infrastructural technologies are vital means towards knowledge society building. Therefore, there is a need to lay more emphasis on the accessibility and quality of services required towards telecenters development. Lastly it was argued by Cheuk, et al., (2012) that to ensure the success of telecenter, the support of the community members must be sought and obtained. And futher stated that community support implies continuous usage and derivation of benefit. For the purpose of this study, telecenter effectiveness was examined based on TC factors that have affected the usages and ability of telecenter to meets ICT needs of the community.

2.3.4 Individual Commitment

Individuals play an exemplary role in determining the usage of telecenters. They serve as a key player in determining the quality of the services being provided, thus, the measure of effectiveness of this service depends on the satisfaction individuals attached to its usage. Meanwhile, the establishment of telecenters is primarily for human engagement, and as a result of this, the evaluation of its success or failure depends on individual commitment driven by satisfaction derived from the usage of the services being provided. Alaswo, Udomsade and Niyamangkoon (2010) claim that understanding people's attitude towards telecenter utilization is an important factors towards determining the level of development of telecenters as well as the dynamics of user behaviors towards its usage. Individual commitment determines the rate of utilization of telecenters which in turn depends on the state of its effectiveness.

2.4 Models of Adopting and Measuring Telecenter Effectiveness

At the heart of telecenter lies technology (Jensen & Walker, 2001). And a well-known fact about TC is that not only it is costly but also characterized by high uncertainty (Fischer & Newell, 2008; Ma & Nakamori, 2008). The last decade has seen telecenters becoming most widespread application of ICT for Development Project (ICT4D). Being a developmental project financed by government or donor agencies, and operating in the nonprofit manner, telecenters provide the opportunity to access ICT services such as computer, Internet, and email to the most disadvantaged people such as the urban poor and rural community (Cheang & Lee, 2010). Accessing the impact of developmental projects coupled with the facts that most of the telecenters seized to be functional few years after their commissioning calls for models to measure the their performance and also identified factors responsible for the dismal performance (Naik &

Joshi, 2010). In view of this several methods have been used for measuring different factors that affect the performance of the telecenter and this section try to give a view of models that have been used in previous studies for measuring telecenter effectiveness.

Business model is seen as one of the widely used technique. It is for appraising the benefit of any telecenter project (Kumar & Best, 2007). It is useful in comparing, assessing as well as exploring the feasibility of any telecenters scheme. Furthermore, it serves as a strategy adopted by an organization towards the accomplishment of its goals, profit maximization as well as its overall success. In the process of adopting this model, the central goal of the telecenter include the examination of services provided towards profit maximization and creating an equilibrium amid the revenue generated and the cost and this has being one of the widely employed techniques towards the assessment of ICT projects (Garrido et al., 2012).

The negotiation among stakeholders are offered by the Principal-Agent Model which examines how the establishment are commissioning a task, and which establishment or individual agents are appointed in accomplishing a task (Garrido et al., 2012). However, the intended motives and results of both the agent as well as the principal are always in pressure. For instance, while the stakeholder wants to maximize it production at a lower cost, the users of ICT are at the same time struggling to make their own profit which has a direct effect on the stakeholder in terms of increased cost. Therefore, the stakeholders may adopt series of techniques in order to maintain the agent towards its target in terms of profit sharing (Garrido et al., 2012). Performance appraisal and wages while the agents confronted with the fear of being sacked from his work.

Therefore the Principal-Agent techniques or model concentrate on the relationship between the principal and the agent as well as understanding what is functioning.

Another model is the Sustainability Failure Model which according to Kumar and Best (2006) was grounded from the work of Heeks and Bhatnagar (1999) which examined the critical factors towards success and failure in ICT (Garrido et al., 2012). Furthermore, such factors include the information, techniques, and procedures, of the establishment. Therefore, the success of a project largely depends on how far such factors are taken into consideration. However, according to Bailur (2006), measuring the sustainability of telecenter should be based on the impacts of telecenter on the community. Accordingly, telecenter impacts on community can be measured based on Telecenters' ability to meets ICT needs of the community such as relevance, appropriateness, innovation & creativity, technological best practices, (Tushman & O'Reilly, 1996). Economic development in the community brought about by telecenter such as IT awareness, access to government services (e-government), and timely information marketing. Ethnographic Decision Tree Modeling (EDTM) is one of the most widely used methods to evaluate the information received through interview in order to establish the individuals reasoning prototype of people who set up telecenter as an entrepreneurial ventures (Bailey & Ngwenyama, 2013). According to Dey, Newman, and Pendergast (2010), it enhances the decisions discovered by the researchers towards the influence telecenters' management. Therefore, these techniques aids simulation as well as conceptual model development gotten result generated from the research on the influence of TCs on telecenters' accomplishment.

The focus of some technology acceptance models' theories like the theory of planned behavior and reason actions is on the intellectual facet of technology adoption (Garrido et al., 2012). These theories investigate the attitudinal elements considered relevant in directing the behaviors of the customers. This correlated simplicity in the usage of technology with its usefulness and users' plan of continue usage. The extent of technology adoption by users are influenced by social influence (Garrido et al., 2012). Thus, to fill the gap of user attitude toward new technologies we need to understand technological change (TC) and the influenced factors that impact telecenter effectiveness.

2.5 ICT Approach of Telecenter

In general, telecenter can be described as a mechanism which uses ICT to support a community's economic, social and educational development, bridging the digital divide, and empower less privileges ones. Previous studies have revealed that technological changes have great impacts on ICT usage. Technological change is referred to as an instrument that can indicate the effect of performance during the implementation of new technology in specific area and also highlights the findings of these technological changes (Jorgenson, 2001). These impacts can be on different aspects of life such as education, social, political and economic growth (Antràs, Garicano, & Rossi-Hansberg, 2006). Community life has been greatly affected by ICT via easy access and utilization of technological resources in various disciplines. It has bridged the gap of access to information and technological instrument among the citizens (Qureshi & Trumbly-Lamsam, 2008). It has been mostly discussed that the upsurge access to information, knowledge sharing and enhancing the building of social capital for citizens in developing perspectives is due to effective information and communication technologies (ICTs).

Recently Amoroso and Ogawa (2013) research on mobile and Internet adoption factors of loyalty and users' satisfaction with online shopping observed that advances in ICT aid economical development. They concluded that new information technologies and telecenters help more people displaying their products to sell and to communicate cheaply and efficiently. It also helps to educate people, promote community participation economically, politically and culturally, and generate new employment.

Similarly Irving and English (2011), pointed out that new communication technologies like the Internet allow access specific information suited to individual needs, and give the chance to "talk back" to many contacts with similar interests, greatly facilitating and intensifying the transfer of information. This in turn encourages the development and diffusion of new service techniques within the telecenter. This service aims at assisting community members in developing and/or diffusing new techniques and social practices that will promote the community's sustainable development.

2.6 Concept of Technological Change (TC)

The rapid and radical changes and development in the world technology, including information technology (IT) or information and communication technology (ICT) are described as technological change (TC). The concept of TC is also known as technological progress according to Hritonenko and Yatsenko (2013) that connoted "the presence of a self-sustaining mechanism of cumulative productivity growth". The field of TC has gained attention in recent years due to the more apparent results of what happens when a large organization does not innovate effectively and becomes overtaken by newer organizations with new technologies and practices. New firms replacing old ones is not new, but has been accelerated in recent years and thus made much more apparent, especially in rapidly developing fields such as ICT (Benson & Magee, 2012). Many contemporary firms evolve in a complex business environment, characterized by globalization, internationalization of markets and the requirement for greater efficiency, effectiveness and competitiveness based on innovation and knowledge (Lin, 2007).

In a major study by Adam, Newell, and Stavins (2002), TC is inter-used with technology development (TD) or technology advancement (TA) which is used to describe the overall process of invention, innovation and diffusion of processes or technology. The term is also synonymous with technological achievement, and technological progress. They explained technological change as the invention of a technology (or a process), the continuous process of improving a technology (in which it often becomes cheaper) and its diffusion throughout the industry or society. In general, TC is based on continuous improvement of technology in a more cheaper and affordable medium to achieve social and economic development (Crabtree, 2006). Also, in the same study, technology has been defined in terms of space matrix and element; the specific type of good, service or process is referred to as technology element. Whereas technology at a given point in time can be represented by these elements present, the extent of the diffusion of those technology elements in the economy and society, and the value contributed by each technology element unit, either individually or in conjunction with other elements. This is defined by a three-dimensional technology space matrix which was graphically illustrated by Crabtree (2006) and the sparse matrix was used to illustrate the meaning of technological change that context; which is a change in the dimensions of the technology space matrix. Also the same principle to Adam et al. (2002) was used to define technological progress as a net increase in the matrix. This definition is based on the principle of goods, service and process, which is similar.

2.6.1 Conceptual Models on Technological Change (TC)

One of the earlier models used to explain TC process is the linear model of innovation which is suggested that change happens in a linear fashion from invention to innovation to diffusion as shown in the figure below (Rogers, 2003).

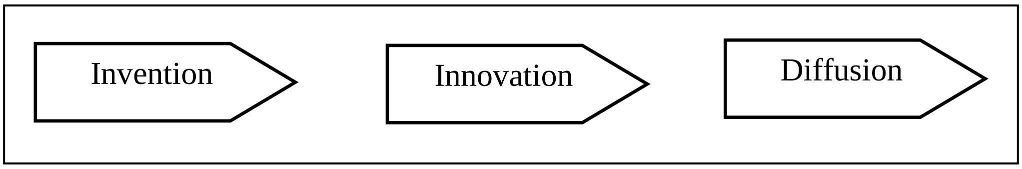

Figure 2.1. The Three Phases Linear Model of TC (Rogers, 2003)

Earlier studies were also referred to the process of TC as the traditional phase gate model because the concept of gates and gatekeeper was used to illustrate it (Rothwell, 1994). It involves the process of series of sequential phases arranged in such a manner that the preceding phase must be cleared before moving to the next phase. The project is assumed to pass through a gate (phase change) with the permission of the gatekeeper (task completion check) before moving to the next succeeding phase. Hence, TC has been represented by the process stages of invention, innovation, and diffusion (Rogers, 2003).

The model of linear innovation has supported into different factors, depending on the economic and social factors, firm operations, and complexity systems of innovation process (Galanakis, 2006). Thus, different theories have been developed to support the process of TC such as Technology Push Model (TPM) and Market Pull Model. According to Rothwell (1994) the process of TC as explained by the technology push model can be better perceived as a linear progression from scientific discovery, through technological development in organizations; which is the main concept of the linear model of innovation. It gives the concept that basic sciences is of the source of marketing ideas, and the ideas should undergo the innovation processes as suggested by the model before it emerges in the hand of users.

The model generally perceived processing from basic knowledge, through research and development in firms, to the marketplace. The technology push concept of innovation assumed that “more research & development (R&D)” resulted in “more successful new innovation out (Rothwell, 1994). Moreover, the Market Pull Model of innovation introduced the concept that the market knowledge and science is the source of invention which is directed to R&D, manufacturing and later emerges as products to be handled by users.

The linear model of innovation is one of the historically developed theoretical frameworks to understand science and technology with its relation to the economy. On the other hand, Godin (2006) discovered that TC depend on either research or basic research. Also the absence of feedback and loops in the models suggested that there is a need for research and development into TC process. (Krell, 2000) noted that end-users play vital role in effective communication of TC, and influence firms effectiveness.

Moreover, the realization by the governments that the social benefits can be higher than the private ones, and the needs to mitigate uncertainty related to investments in technological development, have been playing a significant role to provide enabling environment for TC through formulation of polices such as taxes, incentives, patents laws, funding, to stimulate TC (Dolfsma & Seo, 2013; Shi & Pray, 2012). In a study by Shi & Pray (2012), liberation, investment in public research and education, strengthening intellectual property rights (IPRs), investor restriction were government policies found to have an influence on firms' business. Therefore, in this study the process of TC in terms of invention, innovation, and diffusion were considered the major concept in the conceptual model with respect to research and development (R&D).

2.6.2 Impact of Technological Change (TC) on Telecenter Effectiveness

In a major study, Hlungulu (2010) maintained that TC present special opportunities to communities previously marginalized socially and/or geographically. They observed that technologies like wireless communications permit easier integration of marginal areas that could not be connected physically (hard wired). The interactive capacities of these new technologies offer the added advantage of permitting previously marginalized communities to transmit information symmetrically, as opposed to earlier technologies, which only allowed communities to “receive” information from dominant institutions, experts, and other information gatekeepers. The interactive characteristics of new information technologies points to important debates about the developmental roles of experts, gatekeepers, and technology itself.

Technological Change (TC) is considered today as the central of the theory of economic and business growth. It is recognized as an important driver of effective growth and the emergence of new technologies from which user derive the perceived benefits (Dillon & Morris, 1996). It depends not only on the work of scientists and engineers, but also on a wider range of technological markets (Sun, Fang, Lim, & Straub, 2012), the operation of markets, and a range of governmental policies (incentives policy, innovation policy, funding policy, competition policy, etc). Thus, the advancement and proliferation of technological products as in many ways affect telecenter effectiveness (Ibrahim et al., 2010). This effectiveness can either be seen between the telecenter management and end-users, in whichever case; there is always an applicable technological device to smoothen the relationship. This suggests that TC can have a direct effects on telecenter Utilization (Pick & Nishida, 2014). In the same scenario, Yen and Lu (2008) studied the effects of e-service quality on perceived benefits and discovered that there is link between user satisfaction and utilization. They considered user satisfaction as a key success in today’s highly competitive environment (Kuo, Chen, & Hsu, 2012).

On the other hand, in another major study, Tidd and Bessant (2011) investigation of TC suggested that it had been found to be most influential and vital source for economic development. This suggestion is supported by Ruttan (1997), observation that the aggregate mass of technology cannot define the course of history but it can be defined by individual innovations. In addition, Nusair and Kandampully (2008) studied the creation of an enjoyable devices to attract the attention of users. They argued that the principle of fun and enjoyment can be used to attract, satisfy and retain users. Many other scholars like Cyr, Head, and Ivanov (2006) equally argued that TC has a great influence on user satisfaction and utilization. Likewise, Baily, Manyika, and Gupta (2013) observed that TC can bring about significant influences. Some people might use these new technologies to assist generate new employment, market goods and services, educate themselves on a variety of topics including healthcare, government programs and agriculture, communicate with others, and participate politically, whereas others may use these services for other negative reasons like gambling, pornography, or just spending too much time online. Similarly, these technologies can disrupt traditional family life and authority; they can give the younger population more power than parents. Users use these services for a variety of reasons, like social capital, community, content, wired news, politics online, economics, culture and socialization, as well as personal and global context. Research has shown that users tend to develop their own online agendas that are not necessarily consistent with the intention of the telecenters (Chen & Wellman, 2005).

Generally, TC has both positive and negative influence on telecenter effectiveness (Cyr et al., 2006; Nusair & Kandampully, 2008). It can be argued that effective organization is built around social interaction which is achieved on the platform of technology. These studies have shown that TC and telecenters can facilitate community access to information socially, economically and developmentally. It equally revealed that access is gain on alternative forms of political organization, and to information on national governments' performance and resources available to the community, all of which could increase the community's political participation and strengthen the democratic process (Brodnig & Mayer-Schonberger, 2000). Though, the vast change in technology has enabled different group and level of people to easily access and use computers and other information gadgets, the insurgence of new technology has also some negative impact (Gould & Gomez, 2010).

Similarly, for end-users satisfaction to be achieved then telecenter management has to keep up with the latest technological advances or suffer the consequences. However, change in business is never easy which can be positive or negative depending on the direction of the TC according to Tushman and O'Reilly (1996), when they explored the direction of TC relating to discontinuities or technology cycles. If the direction is positive, it leads to user satisfaction and improve the utilization and effectiveness of the company from the users' perception. However, when the direction is negative it leads to complication and dissatisfaction from users. This dissatisfaction is generated from the responsiveness of user to increase the problem solving attitude of a technology. Instead, of making the task easier to achieve, the technology is creating more problem to the user.

Hence, factors of TC that can enhance telecenter satisfaction and utilization which may lead to long term effectiveness of telecenter usage.

2.6.3 Challenges of Technological Change

The development of new technologies has enabled mankind to grow into the civilization that exists today. One of the basic changes that have enabled growth in civilization is TC. The advent of new technologies (inventions) has led to the creation of new capabilities not feasible without innovation (Benson & Magee, 2012). According to Ahuja and Lampat (2001), it is a belief that at the center of wealth creation lies radical or breakthrough invention. Survival of firms or systems to a large extent is dependent on its ability to develop and innovate, due to the facts that technologies are more than ever enabling rapid change and development. This has made the issue of technological development and innovation potent in present day reality (Benson & Magee, 2012). The advent of new technological understanding and inventions has enabled industries of all kinds to create unprecedented new capabilities that would not have been possible (Ahuja & Lampert, 2001). As observed by Antonelli, Crespi, and Scellato, (2013), inventions and scientific breakthroughs have the capability of making some portions of the stock of knowledge or technologies obsolete. Ability to predict the future impact of TC on firms is one of the potent survival means.

However, TC is double-edged swords which can either impacted positively or negatively on exiting industries, technologies, or services, thus TC has been remained as a significant challenge, hence these challenges can be shown from the obstacles that confront the process of TC (Benson & Magee, 2012). Dawid (2006) in his research, examined that one of these challenges during the representation of the process of TC is a large black box between the inflowing funds and the productivity, this result by the lack of venture capital. However, there are many factors that have been affected TC process, and composed significant challenges, also can be classified into exogenous and endogenous TC. Exogenous technological change is introduced as a model that has effected into an economic system from outside the firm, such as governmental policies which occurs as a reaction to economic incentives and opportunities to develop new technologies. In contrast, endogenous technological change (ETC) is considered as a consequence factor of different focused activities, such as research and development (R&D) efforts of profit-maximizing firms. Models of ETC have been developed to explain the sources and forces of TC (Hritonenko & Yatsenko, 2013). However, there are many factors can be affected TC process in terms of Invention, innovation, and diffusion. In contrast, a study held by Yates (2004) stated that researchers and developers examined TC theories are no comprehensive which considered that advanced technology is better and more effective from lower technology for the user. Hence, TC approach has been studied as a process in terms of invention, innovation, and diffusion that research and development considered as important factor that affect the initial process of TC.

2.7 Technological Change Process in Effective Usage of Telecenter

Studying technological changes in effective usage of telecenter, the concept depends on the interplay of several processes that can aid satisfaction as well as utilization of telecenter thereby leading to effectiveness. Among the conditions considered in this study are some input factors (such as infrastructural sustainability, technological knowledge, collaboration, cost, individual commitment as well as government policy) that can aid the TC processes of invention, innovation and diffusion. The factors are chosen based on their contributions identified in different literatures and support models backing expert opinions on technological factors contribute to telecenter effectiveness. However, TC in terms of the process of invention, innovation, and diffusion has been regarded in different literature as a basic element needed to enhance satisfaction and utilization of certain products and services. These however depend on the quality of service resulting from these processes over time that can affect usage of services.

2.7.1 Invention

Invention denotes development of new idea which can transform product, process or services. As observed by Antonelli et al. (2013), inventions and scientific breakthroughs have the capability of making some portions of the stock of knowledge or technologies obsolete. It involves studying the relationship between complementary technologies, knowledge relatedness, and invention outcomes in high technology mergers. Appropriate government intervention through granting of patent on invention serves as protection and guarantees the property rights of the inventor (Makri, Hitt, & Lane, 2010). Using a repeatable method to identify, describe and analyze the important inventions in an industry, it was discovered that patents and knowledge spillover effect of development contribute to invention (Benson & Magee, 2012). Likewise funding and patents were identified as critical factors that promote new innovation by government policies (Latham & Le Bas, 2006).

On the other hand, Shaista (2006) argued that R&D efforts resulted into invention and creation of new ideas. Development of ideas generated by invention through R&D resulted into innovation. Hence R&D efforts lead to invention and invention leads to innovation. Makri et al. (2010), were of the opinion that since invention involves creation of new idea, granting of property rights on that idea will promote invention. It was further argued that technological knowledge, R&D efforts and learning rate are essential ingredients of invention (Makri et al., 2010). Investments into R&D can improve the competitiveness of a new technology to a point where it can be tested in markets. Existing knowledge and, R&D aids technological invention (Baldwin & Von Hippel, 2010). According to Ma and Nakamori (2008), invention process is characterized by R&D efforts, technological learning rate. Dawid (2006) proposed an agent-based models of innovation and TC and posited that the knowledge base, and R&D have significant effects on invention and subsequently on innovation.

According to the perspective of invention stressed by Suarez-Villa (2000), that inventive capabilities can be learned, knowledge and organizational support are normally required for invention to be generated endogenously. In general, invention requires capabilities as well as parallel interactions among technological, market knowledge, and organizational technological knowledge (Khilji, Mroczkowski, & Bernstein, 2006). During the translating process from inventions to innovations, firms process knowledge to commercialize the market needs depending on dynamics and build new capabilities to speed up the process of innovation. A large economy can be a factor promoting TC (Crabtree, 2006). Therefore, the available knowledge of market need for product-services can simulate invention, motivate innovation, and promotes diffusion.

Hence, invention when fully successful enhances quality of service as well as rate of innovation. According to Garcia and Calantone (2002), an invention only becomes innovation until it subsequent diffusion into market place. Based on Crabtree (2006), the general assumption is that of the likelihood of invention taking place is highly dependent on the capability of employees' accumulated TC. This implies that there is correlation between accumulated knowledge and invention and consequently innovation (Solow, 2000). Makri, Hitt, and Lane (2010), argued that technological knowledge, patents right, R&D efforts and are essential ingredients of TC. Infrastructural sustainability in term of adequate provision of technological amenities that support services delivery enhance the rate of effectiveness, also updating technical knowledge on efficient services contribute immensely to the level of invention as well as innovation.

2.7.2 Innovation

Innovation is an economic undertaking aimed at development or enhancing the quality of product, process or services that produce novelty, thus it considered a very important determinant of TC (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007). According to Grübler, Nakicenovic, and Victor (1999) the process of innovation, which is the improvement in cost and performance effected by capability gained by technological knowledge. Likewise, successful innovation requires organizational changes and collaboration at process level as well as conversion of idea into commercially product adopted in the market (Verloop, 2004). Breakthrough, innovation is highly dependents upon accumulated knowledge in a particular field of technological infrastructural. Knowledge represents a decisive input for innovation (Feldman, 2002). The success of any innovation is measured by its success at market place based on the quality of service and societal impact in terms of economic wellbeing, growth and success. Also, it affected by efficient capability of firm to generate new knowledge and its subsequent infrastructural to the wide range of activities that firms engage in (Antonelli et al., 2013). Antonelli et al., (2013) in their study of persistence of innovation identified innovation capability, knowledge, competitive innovative.

Technological knowledge in terms of prior innovation experience, and skills are the important factor based on innovation (Peters, 2009). On the other part, both Raymond, Mohnen, Palm, and van der Loeff (2010) and Clausen, Pohjola, Sapprasert, and Verspagen (2012) were of the opinion that factors of innovation that impacted on TC includes: knowledge, and invention output. Based on Crespi and Pianta (2008) innovation factors are ICT facilities and the current state of technology, and market demand of services. Hekkert et al. (2007) argued that understanding the effect of innovation on TC requires framework and hence proposed functions of innovation systems. The proposed framework was applied on the sustainable technology which related to factors such as educational system qualities, entrepreneurs, and collaboration, and knowledge as innovation factors that driving TC. Dawid (2006) developed an agent-based model of innovation and technological. Using this model, current investment, collaboration, knowledge base, and current state of technology were identified as important factors of innovation. In addition, innovation process also takes into account the rapid growth of knowledge base and the related market demand and user perceived in the developing innovation activity.

However, the interplay of invention and innovation processes is important in aiding the quality of services and acceptability of such service to enhance utilization and satisfaction. Moreover, market demand enables the diffusion of innovation to market needs in order to support its adoption (Di Stefano et al., 2012). On the other hand, the concerns for real or feared adverse penalties if an innovation is not pursued have factually been vital sources of motivation for TC. It is also widely believed that competition plays a vital role in enhancing innovation as it boils out of the satisfaction derived from the use of such services (Windrum & Birchenhall, 2005). Innovation making firms and public projects need to determine new products and services of technologies, continuously these days to sustain in the markets due to such increased global competition (Lee, Kang, & Chang, 2011).

2.7.3 Diffusion

Diffusion represents the last and crucial stage in the linear model of TC. It represent the number of usage or rate of adoption of an innovation and also serves a means of measuring the level of utilization of a particular product or services (Crabtree, 2006). While proposing a model for understanding TC, Crabtree (2006) introduced the concept of “value technology” implying the probability of a new technology to displace existing one. Diffusion of innovation theory according to Rogers (2003) is the process by which innovation spread across society through communication channels. Roger’s theory of diffusion was also applied by Kumar and Best (2007), to measure the social impact of telecenter diffusion in rural communities. Factors of telecenter diffusion according to the report of their study include relative advantage, and communication channels. Moreover, relative advantage or benefits have been measured with regards to users whose have many economic and social benefits. However, cost (price) and satisfaction can also play important factors for diffusion process (Robinson, 2009).

Moreover, factors of diffusion identified by Crabtree includes: cost, benefits, uncertainty, and social environment. In a review of Roger's theory of diffusion, Sahin (2000) enumerated innovation, uncertainty, communication channels, time, reinvention, rate of adoption as determinant of innovation diffusion. In addition, based on consumer equilibrium theory, the rate of diffusion or the number of services used or items bought is directly proportional to the cost and perceived benefits and available information (Hung & Tu, 2011). Relative advantage of an innovation is the level at which an innovation is seen to be better off prior product or services fulfilling the same need. Relative advantage is highly correlated with diffusion, the higher the relative advantage, the higher the diffusion rate and vice versa.

While using demand theory, Crabtree (2006) argues that the cost of services or product gradually decreases due to competition resulting into an increase in diffusion rate. In contrast, fear of losing out to competitors motivates firms to undertake innovation initiatives (Lee et al., 2011). Competition drives innovation with possible reduction in cost. Reduction in cost will make the firm or product-services to be competitive and also leads to high diffusion rate. A large economy can be a factor promoting TC (Crabtree, 2006). Moreover, interaction between different technological elements creates complementary or synergetic effect that can be positive or negative.

2.8 Government Policies and Technological Change

It is well known fact that TC can be enormous benefit for private business, economy and the larger society with similar effects on businesses and society (Dolfsma & Seo, 2013). TC is not only characterized by high cost but also by high level of uncertainty (Ma & Nakamori, 2008). The manner in which Japan and some Asian countries attained rapid growth in the 1960s–1980s prove that government policies and economic incentives can impact the TC in a country (Hritonenko & Yatsenko, 2013). The realization by the governments that the social benefits can be higher than the private ones, and the need to mitigate uncertainty related to investments in technological development, has been playing a significant role to provide enabling environment for TC through formulation of polices such as taxes, incentives, patents laws, funding, to stimulate technological innovations (Dolfsma & Seo, 2013; Shi & Pray, 2012).

In a study by Shi and Pray (2012) liberation, investment in public research & education, strengthening intellectual property rights (IPRs), foreign investor restriction were government policies found to have and influence firms' trade in China. Dolfsma and Seo (2013) argued that government policies on TC has achieved mixed outcomes and that policies should be implemented based on the nature of industry and desired outcome. Some of the government policies aimed at stimulating innovation tax, incentives, simulating public research facilities, activating antitrust law to prevent lock-in, deregulate industries, and liberalize markets, and flexible IPR regime. Government innovation policies alone does not guaranteed require result but "an understanding of the ways in which individual instruments are combined into effective policy mixes within national innovation systems" (Flanagan, Uyarra, & Laranja, 2011) and well further to consider policies such as procurement, regulation, and tax measures for promoting innovation.

Hence, government policies play a significant moderating roles in TC process through policies such as tax, incentives grants etc. High tax rate by government will increase cost of production and would slow down the rate of diffusion and vice versa. Likewise provision of incentives and grants by government will stimulate R&D efforts, motivate innovation that will engender diffusion. Funding has always remains a scarce resources not only needed for equipping telecenter but also for staffing and maintenance (Jensen & Walker, 2001). Funding R&D effort by government is likely to reduce cost of R&D, promotes innovation, lower the price of technology and thereby aiding diffusion. R&D investment decisions are guided by the cost of R&D based on the expected returns, involved risks and likely sanction (Jaffe, Newell, & Stavins, 2003). In addition to meet the markets demands and relative advantage, it can be achieved by the capability to innovate. Moreover, such a demand from firms requires R&D efforts, and that require funding, incentives from governments policies.

In conclusion, invention denotes development of new ideas that can transform product, process or services. Invention when successful becomes fully materialized as innovation. According to Garcia and Calantone (2002), an invention only becomes innovation until it subsequently diffusion into market place. Granting of patent on invention serves as protection and guarantees the property rights of the inventor (Makri et al., 2010). Shaista (2006) argued that R&D activities resulted into invention – creation of new ideas. Exploitation of ideas generated by invention through R&D resulted into innovation. Hence R&D efforts lead to invention and invention leads to innovation. Based on Crabtree (2006), the general assumption is that of the likelihood of invention taking place is highly dependent on the quality and quantity of employees' accumulated technological knowledge. This implies that there is correlation between accumulated knowledge and invention and consequently innovation (Solow, 2000). Makri, Hitt, and Lane (2010) argued that technological knowledge and R&D efforts are essential ingredients of invention.

Innovation is an economic undertaking aimed at development of product, process or services that produce novelty. It connotes the ability to blend and weave together several kinds of knowledge to yield completely new, unique and of economic value products or services. Breakthrough in innovation highly depends upon accumulated knowledge in a particular field. Knowledge represents a decisive input for innovation (Feldman, 2002). Likewise, successful innovation requires organizational changes at process level as well as conversion and collaboration of idea into commercially product adopted in the market (Verloop, 2004).

The success of any innovation is measured by its success at market place based on the returns to the innovator and societal impact in terms of economic wellbeing, growth and prosperity. Hence, innovation success is determined by rate of adoption or diffusion. TC does not develop in a vacuum, hence future TC to a large extent depends on the existing current state of technology. According to Dosi (1982), the probability of future technological advances depends on the position a firm or country currently occupies vis-à-vis the existing technological frontiers which is a factor of cumulative technological knowledge.

Rogers (1985) described diffusion as a process by which innovation spread across society through communication channels. Based on consumer equilibrium theory, the rate of diffusion or the number of services used or items bought is directly proportional to the cost and perceived benefits. Relative advantage/ perceived benefits of an innovation is the level at which an innovation is seen to be better off prior product or services fulfilling the same need. Relative advantage is highly correlated with diffusion, the higher the relative advantage, the higher the diffusion rate and vice versa.

While using demand theory, Crabtree (2006) argued that the cost of services or product gradually decreases due to competition resulting into an increase in diffusion rate (market demand). Interaction between different technological elements creates complementary or synergetic effect that can be positive or negative change in diffusion rate of product/services can affect the diffusion or one or many products services proportionally or inversely. A large economy can be a factor promoting TC (Crabtree, 2006).

Government policies plays a significant moderating roles in TC process through policies such as tax, incentives grants etc. Likewise, provision of incentives and grants by government will stimulate R&D efforts, and motivate innovation that will engender diffusion. Funding has always remains a scarce resources not only needed for equipping telecenter but also for staffing and maintenance infrastructural (Jensen & Walker, 2001). Funding R&D effort by government is likely to reduce cost of R&D, promotes innovation, lower the price of technology and thereby aiding diffusion. R&D investment decisions are guided by the cost of R&D based on the expected returns (Jaffe et al., 2003).

2.9 Description of Modeling and Simulation Approach

This study makes use of computational modeling technique to simulate the impact of TC on telecenter usage based on the concept discussed above. Law (2007) referred to modeling as the process of abstracting a model from a real or proposed system. Pidd (2003) pointed out that the most important aspect of modeling is rightly abstracting the appropriate simplification of reality from the proposed system. Modeling is an act of getting information about a phenomenon without the actual real life testing. Hence, this study will explore related modeling approaches that will guide the research in simulations TC factors that influence telecenter utilization.

Computational modeling is one of the recent methods that used to generate a symbol of the system-in-context that approximates the underlying process of the phenomenon and behavior of the observed system. Adner, Polos, Ryall, and Sorenson (2009), pointed out that formal models are more advantageous over verbal (non-formal) theories because they are more precise, transparent, and internally consistent approach for theorizing. For formal models, the internal consistency arises from the need to get a working simulation where the system of interest exhibits the phenomenon the theory is intended to explain (Johnson-Laird, 2012; Louis Lee, Goodwin, & Johnson-Laird, 2008). Formal model shows the description of the factors whether they are viable (though not necessarily valid; i.e., a true representation of the system). This can be accomplished via simulations because it shows what happens as factors interact with one another over time, perhaps revealing emergent phenomena over a period of time (Weinhardt & Vancouver, 2012).

Modeling enables understanding of the interaction among parts and the systems as a whole and therefore lets designers to dynamically vary design decisions and instantly observe the outcomes. Alternatives and options can be evaluated without creating risks or expensive prototypes, making simulation technologies not only financially attractive, but also very environment friendly, especially when resulting system is as good as desired (Tolk, 2010). Moreover, interest in simulation applications is growing due to: cheaper and safer than conducting experiments with a prototype; which is more realistic than traditional experiments, as they allow the free configuration of environment parameters found in the real situation. It also allows them to be conducted faster than real time; and allow setting up a coherent synthetic environment that allows for integration of simulated systems in the early analysis phase.

Four types of modeling approaches were enumerated by Tolk (2010) that includes continuous; Monte-Carlo; discrete event; and agent-based simulation.

Continuous Simulation deals with systems that rely on differential equations, in cases like physical system with mechanical components, electrical circuits, thermal effects, hydraulic elements, etc. In continuous simulation, the state variables describing the characteristics of the system change continuously with time.

Monte-Carlo, is a deterministic simulation model which is a mapping from input variables to output variables that is done without explicitly modeling time. The simulation is used to iteratively evaluate the model by feeding random variables and evaluate the resulting outputs applying statistical analysis. Applying Monte-Carlo requires a deep knowledge in statistics.

Discrete Event Simulation: is one of the most widely used. It models a system as Modeling techniques it evolves over time as a series of system states that are triggered by events at discrete times and that change the state instantly. Events and resulting state changes are simulated in chronological order. In order to be able to do so, the events must be stored and delivered in the right order, which is normally accomplished by the use of event lists. Furthermore, a simulation clock representing the time within the simulation, as well as an appropriate time advance algorithm are needed.

Agent-directed Simulation: are interacting in a situated environment. Agents perceive the environment and other agents and act within the environment. They should be autonomous (acting with human input), flexible (learning to react appropriately), and exhibit social capabilities (act with or against other agents or agent populations). Of recent agent-based simulation has found wider adoption due to its ability to function at individual level and capture complex emergent situation (Kiesling, Günther, Stummer, & Wakolbinger, 2012). An agent-based simulation approach that use analysis of the past event to predict short term future adoption of technology in energy sector was developed by Ma, Chi, Chen, and Shi (2009). In developing the adoption model, assumptions and variables used includes:

Assumptions:

i. The economy is technological based with homogeneous goods – electricity.

ii. Consist of existing, incremental, and revolutionary technologies

- Variables: cost, efficiency, learning rate, demands, past knowledge, growth rate for 3 years.
- Model: The model was formulated mathematically as follows:

  - The sum of resources used by each technology at time t is given as

$$\mathrm{R}^t = \sum_{i=3}^{3} \frac{1}{\eta} x_i^t$$

  - Cumulative installed capacity technology i is denoted by

$$\sum_{j=-\infty} C_i^j = \sum_{j=1}^{t} C_i^j + \bar{C}_i^0$$

  - The overall model for predicting the future demand of the energy is given as $d^{t+1}\,(1+\alpha\,)\mathrm{d}^{t}\,\frac{(1-e^{p})p^{i+1}+(1+e^{p})p^{t}}{(1+e^{p})p^{i+1}+(1-e^{p})p^{t}}$ where

t is time period (year),

α is the exogenous annual growth rate of demand,

d^t and d^{t+1} is the demand at times t and t+1, respectively;

e^p represent price elasticity of demand;

p^t and p^{t+1} denotes the prices of the goods at time t and t+1.

Based on the model, the demand is expected to increase over time with an exogenous annual growth rate depending on the availability of price for satisfying the demand. Though the result of the simulation of the models predicts slower adoption of revolutionary technology, the author however admits the need to subject the result to sensitivity analysis to validate the result simulation.

Gillingham, Newell, and Pizer (2008) providing an overview of the different approaches to model technological change in a climate policy model. It identified three major approaches that include: direct-price, R&D, and learning induced. according to them, it is a critical determinant of its results "No single approach appears to dominate on all these dimensions, and different approaches may be preferred depending on the purpose of the analysis, be it positive or normative". Nonetheless, each of this approach can be combined together based on the purpose to obtain hybrid model as exemplified in Fischer and Newell (2008). In the model, the knowledge stock (represents input into the cost function of a specific industry) as a constant elasticity of substitution function cumulative R&D, Ht, and cumulative output, Qt, as shown below. Where k_1 and k_2 represent parameters.

$$K_t(Q_t, H_t) = \left(\frac{Q_t}{Q_1}\right)^{k_1} \left(\frac{H_t}{H_1}\right)^{k_2}$$

In contrast to the above models, a model of communities' attitude towards telecenter and its impact on rural tourism was developed by Cheuk et al. (2012) using partial least squares method of structured equation modeling technique (SmartPLS). On the other hand, a study conducted by Galanakis (2006) developed a model that contained TC factors and their relationship that affected on produce new products as shown in Figure 2.2.

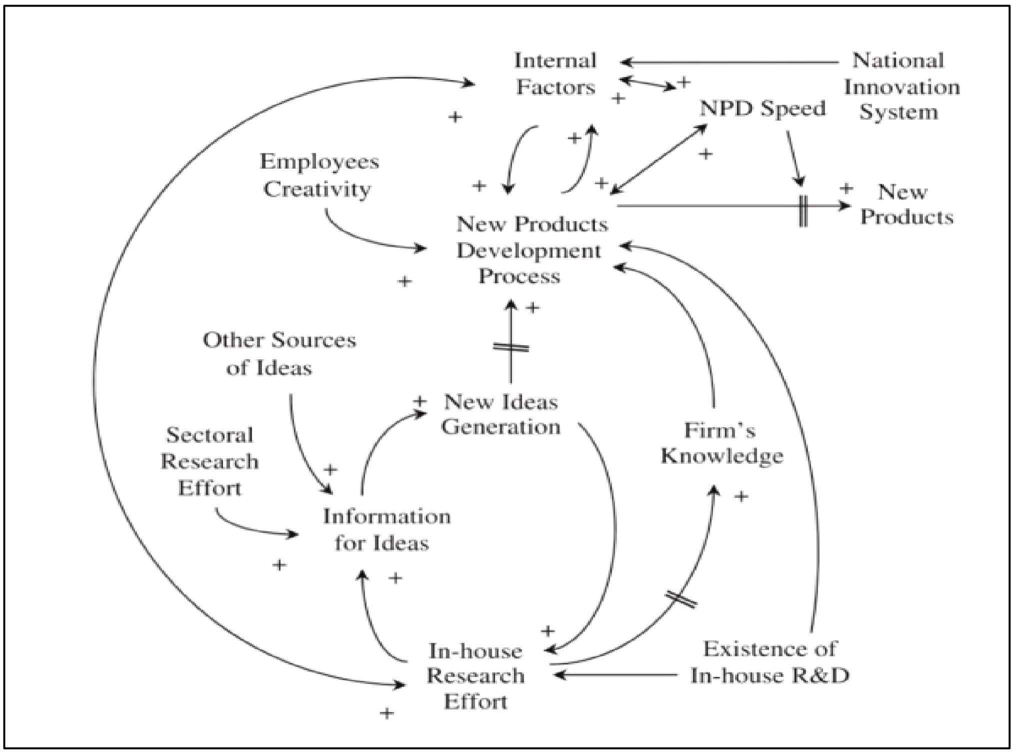

Figure 2.2. Influences Diagram of TC Factors to Produce New Products(Galanakis, 2006)

This diagram has examined TC factors that were gained from different models and literature studies. These factors are represented by the correlation and the influence on produce new product (Galanakis, 2006). The direction of these model influenced in producing new products by the existing ideas that need research and development by the firm's internal factors, such as technological capabilities and other factors. The number of factors that are considered during this process depends on; the changes in the firm's environment from internal factors that take place during the development period and the markets demands for producing new products. For example, changing in firm structure; organizational knowledge; technological capabilities and corporate policy can be significant factors for fitting development of a new product (Galanakis, 2006). This approach was concern to be a guideline in this study for modeling the relationship of TC factors which have significant effects on telecenter usage.

In contrast, fuzzy set theory is one of successful approach that can determine the weights of the factors by using different methods (Lee et al., 2011). In addition, the concept of fuzzy set has been used recently in solving different complex problems and represented in variety models, and has been applied in a variety of fields since its introduction. One of the important routes of fuzzy set theory in the theoretical development is linguistic approach. The logic of linguistic approach is that the truth values are fuzzy sets and the rules of inference are estimated rather than exact (Lee et al., 2011). Fuzzy set theory has been applied plentifully in decision making research studies by giving the probability for each factor in different scenarios. However, there are different approaches of modeling TC factors and in this study were depending on the correlations of TC factors and the scenarios that examined for different cases of TC factors.

In contrast, several modeling techniques and tools have been developed and employed to model the effects of innovation and TC such as dynamic equilibrium analysis, static and dynamic games, theory of complex systems or evolutionary theorizing, and standard equilibrium models (Dawid, 2006). But, Hritonenko and Yatsenko (2013) argued that the shortcomings of these models are their inability to offer sufficient explanations for several of the empirically established a certain pattern which nonetheless appear obviously in agent-based models. However, in modeling TC, computational modeling technique is being employed to establish for relationship among factors needed to determine the actual state of effectiveness in the usage of telecenter.

2.10 Description of Computational Modeling Approach

Computational modeling technique refers to an approach that gives detail description of a set of process abstracted from the real world situation to describe certain phenomenon through systematic computation algorithm (Sun & Ron, 2008). It employs several modeling techniques which are non- significant in order techniques to express relationships among variables declared inform of mathematical representation; usually in formal logic order. Its overall concept is back by the theory, assumption and expert opinions describing the intended phenomenon under investigation (Sun & Ron, 2008).

The approach is a remarkable one as it offers much expressive power and flexibility to modeling that might be insignificant in other approaches. It empowers the researchers to study and established correlations that might perhaps be difficult to establish through virtuous experimental procedures as well as approximation that might be difficult to assume through extrapolation of the existing data as indicated in the agent simulation modeling technique. Also, this approach is being widely used in various fields (as highlighted in the table below) as it is more valuable in term of intensity of the process details and the granularity of both input and output interactions that are fundamental to the phenomenon being illustrated.

2.10.1 Related Works on Computational Modeling Approach as Applied in Other Fields.

Below Table 2.1 shows the related works on computational techniques as applied in varies other fields. These techniques have various area of use depending on the concept if is being employed to explain. As discussed above, if is capable and representing real world abstractions relating to the description of certain phenomenon under investigation.

Table 2.1 Examples of Computational Modeling Approach

AUTHOR	YEAR	TITLE	APPROACH
Simon Farrell and Stephan Lewandowsky	2010	Computational Models as Aids to Better Reasoning in Psychology.	Computational modeling was used to explore human reasoning.

Tibor Bosse, Matthijs Pontier and Jan Treur	2010	A computational model based on Gross' emotion regulation theory.	The authors employed computational modeling technique for emotional regulation.
Bosse e.t al.	2013	An Ambient Agent System Assisting Humans in Complex Tasks by Analysis of a Human's State and Performance	The authors employed computational modeling to explore human knowledge for intelligent assistive system.
Takashi Omori, Ayami Yokoyama, Kasumi Abe, and Takayuki Nagai.	2013	Cognitive modeling of Human-Robot interaction estimating other's internal state.	Computational modeling was used to explore human-robot interaction through intention estimation.
Dilhan,J. Thilakarathne, Jan Treur.	2013	A computational cognitive model for intentional inhibition of actions.	The authors employed computational modeling to explain the concept of selection and intention inhibition

2.11 Model Evaluation Approach

The simulation model is the penultimate stage of a development process that began with the decision to formulate a modeling and simulation project to resolve an identified issue (Bitra & Arbez, 2007). Because modeling and simulation is a representation of real life situation, there is therefore the need to proof that the model and the result correctly represent the systems, interactions, and phenomena of interest. Based on this, validation and verification are done to proof the credibility of modeling and simulation (Carley, 1996; Tolk, 2010).

There are two major approaches to model verification: mathematical and automatic verification analysis (Ab Aziz, 2011). The aspect of validation involves real world experimentation. Mathematical methods involve the use of mathematical assumption especially, distributive law, that is to analyze the likely equilibrium justification for the assumptions made in the model while the automatic verification is done following certain principle specified with temporal trace languages. Thus, in this study mathematical approach were considered to justify the balance between the factors leading to effective telecenter effectiveness.

2.12 Summary

This chapter reviewed previous studies related to telecenter usage and TC. The purposes and benefits of telecenter together with challenges and success factors were studied. TCs' role and relationship with telecenter was also examined and factors of TC that potentially impact telecenter effectiveness were discussed. A concept of the TC impact on telecenter effectiveness was presented. The chapter closes with a description of computational and evaluation methods for the proposed model.

CHAPTER THREE

RESEARCH METHODOLOGY

This chapter describes the research methodology adopted in the study. The methodology consists of 3 phases of Abstraction, Formalization, Simulation and Evaluation. Figure 3.1 shows the phases and related objectives.

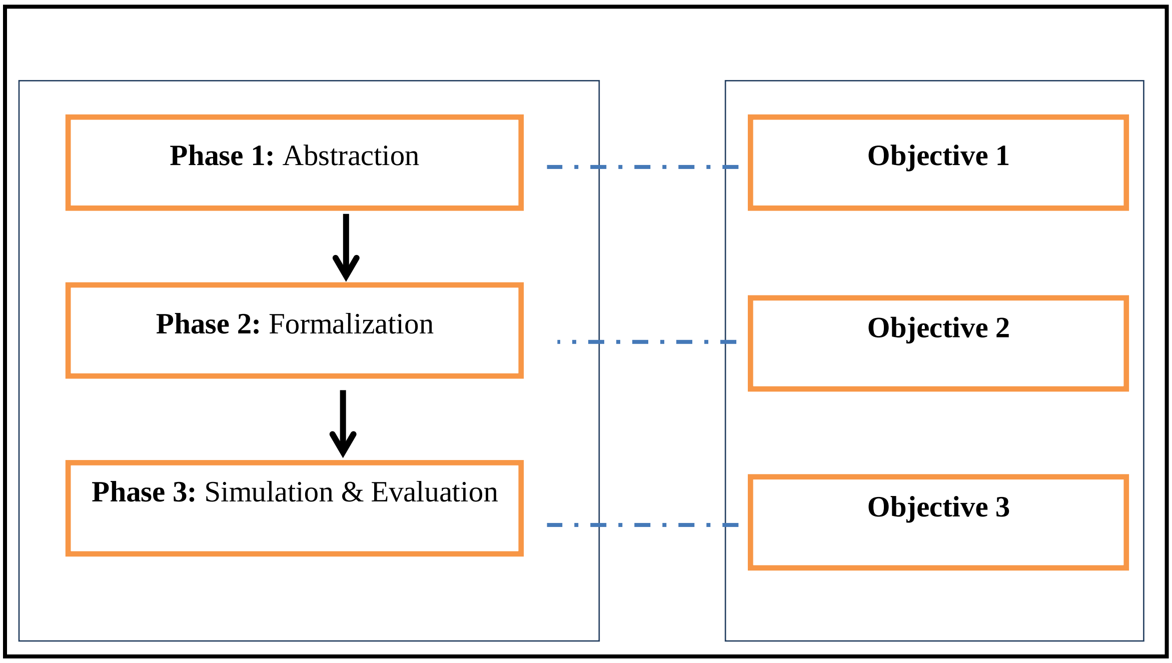

Figure 3.1. Methodology for the Study (Aziz, 2010)

3.1 Abstraction

In this stage, factors of telecenter effectiveness and related to TC were identified from previous literatures. These factors include Technological Knowledge, Research and Development, Collaboration, Infrastructural Sustainability, Quality of service and

Individual commitment, Cost, Government policy, Invention, Innovation, Diffusion, Utilization, Satisfaction, and Effectiveness as shown in (Table 3.1). From the identified TC factors, those relvant to telecenter effectiveness were selected. Though, the significant role of every factor varies with respect to major reflections on TC. In the case of computational modeling, major factors are considered to represent the actual relationships/contributions of the input/external factors to the internal conditions that will determine the nature of the output (Sokolowski & Banks, 2011).

Recently, computational modeling techniques has been used to explore wide range of situations and conditions whose abstractions/ theoretical description may not give actual justifications through any other alternative measures (Sutcliffe & Wang, 2012). Hence, in this study, a computational model was developed and simulated to measures TC with respect to telecenter effectiveness usage. The developed model include various related factors as well as the role of government and individuals in effecting technological changes that can influence invention, innovation, and also, diffusion with likelihood impact on telecenter effective usage. The selected factors were based on their possibilities to affect satisfaction and utilization that determine telecenter effectiveness over time.

Table 3.1 The Abstracted Factors for the Model

S/N	FACTORS	Description
1	Technological knowledge (Khilji et al., 2006)	Adoption of new knowledge as well as usage of technological sustainability that support

		invention and motivate innovation
2	Technological Infrastructural sustainability (Jacobsson & Bergek, 2011)	The current state of technology, capability, high rate of technological items that support innovation
3	Collaboration (Doloreux & Shearmur, 2012)	Acts as a medium of adequate opportunity exploration for skills and knowledge acquisition which can aid innovation practices
4	Research and Development (Shaista, 2006)	The means by which business can experience future growth through development of new ideas, products and services that support invention
5	Individual Commitment (Udomsade and Niyamangkoon, 2010)	The evaluation of services success or failure depends on individual commitment driven by satisfaction derived from the usage of the services being provided
6	Government Policy (Makri et al., 2010).	Plays a significant role in through policies implementation such as incentives granting of patent to investors, taxes regulation to encourage operational of new idea that can enhance productivity
7	Cost (Crabtree, 2006)	is an essential tool to control individual commitment towards utilization of a particular product
8	Invention (Antonelli et al., 2013)	Process of introducing something new or making a significant change to an existing system within major factors implementation
9	Innovation	Process of the improvement in cost and

	(Hekkert et al., 2007)	performance effected by capability, adequate invention and technological development
10	Diffusion (Hung & Tu, 2011).	It represent the level of usage or rate of adoption of an a particular service
11	Quality of Service (Bashir et al., 2011)	It an essential determinants of the level of effectiveness of a particular product or service
12	Satisfaction (Meng et al., 2013)	It is a measure of how services provided meet user expectation
13	Utilization ((Cheuk et al., 2012)	Determine the level of usage with respect to satisfaction Derived from a particular product or service
14	Effectiveness (Hudson, 2001)	It measures the level of utilization and satisfaction relative to a provided service

Having identified various factors contributing to technological change and impact on telecenter effectiveness in Table 3.1 above, only the major factors related to TC process that contribute to telecenter effectiveness were selected. However, according to literature studies for reach potential effectiveness of telecenter should be evaluated for long period of time. Thus, to illustrate the period of time we used long term as a changing in time to measure the effectiveness of telecenter. Hence, utilization, satisfaction, and effectiveness represented as long term over period of time which considered long term as temporal factors. Therefore, (17) factors derived from Table 3.1 in order to construct the conceptual model.

Table 3.2 Shows the factors used to construct the conceptual model, and depicts the formalization of factors for the model that were derived from Table 3.1. The parameters/factors have been examined into three categories which are external, instantaneous, and temporal. External factors are the operating factors that directly contribute or can determine or serve as basic or functional measures of the concept under investigation. Instantaneous factors are affected or impacted by the external factors, the result and behavior can be estimated or measured with a particular period/ short predict of time. Temporal parameters are factors test that depends on the various of a certain contribution whose behaviour/result could be estimated or measured over a period of time (Worboys, 2001). Thus, long term is a temporal parameter over period of time usually months/years, used in order to evaluate telecenter effectiveness, contributed by utilization and satisfaction.

Table 3.2 Factors Formalization of Conceptual Model

S/N	**FACTORS**	**Formal Representation**	**Relationship**
1	Technological Knowledge	*Tk*	*External*
2	Infrastructural Sustainability	*Is*	*External*
3	Collaboration (Razak et al., 2010)	*Cb*	*External*
4	Research and Development	*Rd*	*External*
5	Individual Commitment	*Ic*	*External*

6	Government Policy	*Gp*	*External*
7	Cost	*Cs*	*External*
8	Invention	*Iv*	*Instantaneous*
9	Innovation	*In*	*Instantaneous*
10	Diffusion	*Df*	*Instantaneous*
11	Quality of Service	*Qs*	*Instantaneous*
12	Utilization	*Uz*	*Instantaneous*
13	Effectiveness	*Ev*	*Instantaneous*
14	Satisfaction	*Ss*	*Instantaneous*
15	Long term Utilization	*Lu*	*Temporal*
16	Long term Satisfaction	*Ls*	*Temporal*
17	Long term Effectiveness	*Lv*	*Temporal*

3.2 Formalization

The structure of the relationships between the technological change factors on telecenter effectiveness that derived from the literature analysis of chapter two is represented in Figure 3.2 below:

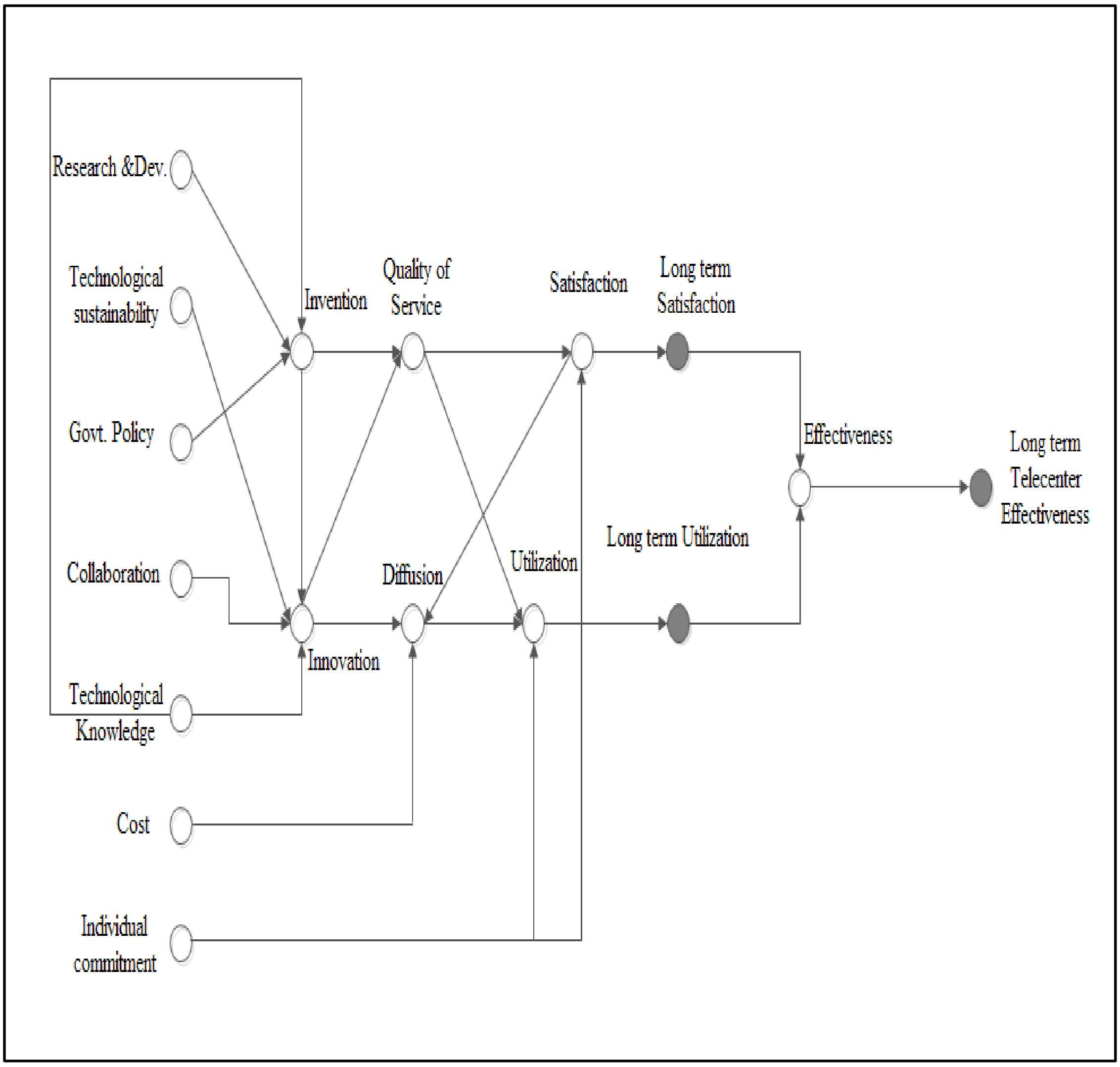

Figure 3.2. Relationship between TC Factors and Telecenter Effectiveness

Based on the factors identified in phase 1, and the model above, the correlations of the parameters and their mathematical equations is established below:

3.2.1 Invention:

Invention as an act or process of introducing something new or making a significant change to an existing system is a major factor that influences TC. Based on the model shown above, Invention *(Iv)* is being affected by three sub factors which are *Rd*, *Gp* and *Tk*. Figure 3.3 below depicts the relationship between the factors.

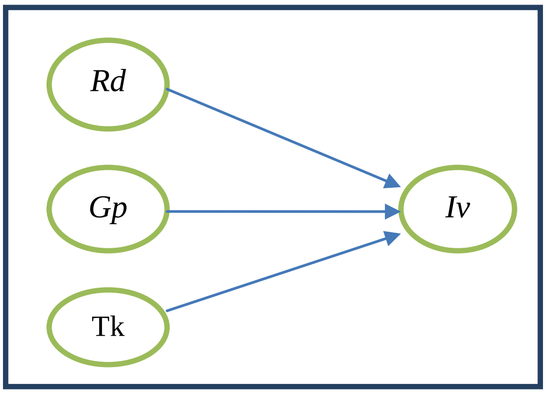

Figure 3.3. Relationship of Invention

Eq1 below formalize Figure 3.3 mathematically.

$Iv\ (t) = w_{iv1} * Tk\ (t) + w_{iv2} * Gp\ (t) + Rd\ (t) * w_{iv3}$..Eq1.

Iv(t) is changing in invention with respect to time,

$W_{1\text{-}3}$ is the constant weights to regulate the contributions of each factor,

(t) represent periodic/time variances of each factor's contribution.

The Eq1 above indicates that *Iv* can exist if there is an improvement in ***Rd***, or the Government policies ***Gp*** favors the investors. Also, contributed to invention is adequate adoption of technological knowledge ***Tk*** which assists the investors to invent several practices that can aid innovation.

3.2.2 Innovation

Factors such as collaboration *Cb*, technological knowledge *Tk*, and technological sustainability Ts affected possible changes in innovation. Also, Invention *Iv* enhances innovation practices. Figure 3.4 below depicts the relationship between the factors.

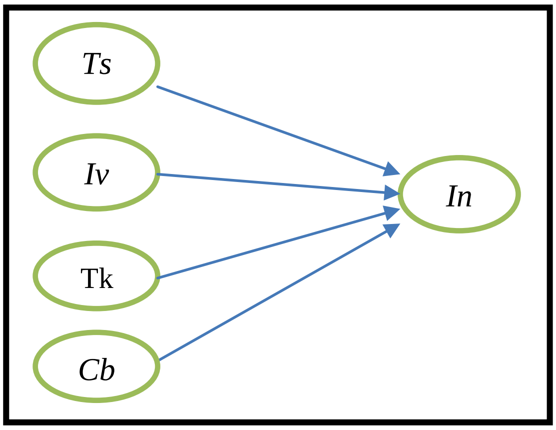

Figure 3.4. Relationship of Innovation

Eq2 below formalize Figure 3.4 mathematically.

$$In\ (t) = Iv\ (t) * (wiv\_1 * Cb\ (t) + wiv\_2 * Tk\ (t) + Ts\ (t) * wiv\_3) \ldots\ldots\ldots\ldots \text{Eq2}$$

In(t) is changing in innovation with respect to time,

Wiv_1-3 is the constant weights to regulate the contributions of each factor,

(t) represent periodic/time variance of each factor's contribution.

The figure and the equation above represent how Technological sustainability, collaboration, Invention and technological knowledge enhance diffusion as well as the quality of service.

3.2.3 Diffusion

The rate of diffusion of service, which is the dynamism of individual attention to the service being provided by the telecenter, is influence by the affordability (cost, *Cs*), level of innovation, *In* and the satisfaction, *Ss* derived from such services. Cost of services or product decreases resulting into an increase in diffusion rate and vice versa. Thus, if the level of innovation is high, cost is affordable and the service is satisfactory. This may enhance commitment to utilization and if this continues over time, individual commitment grows and thus triggers Long term utilization which aid effectiveness. Figure 3.5 below shows the relationship.

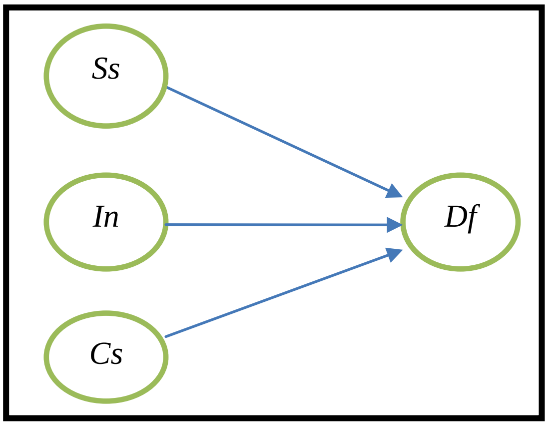

Figure 3.5. Relationship of Diffusion

Eq. 3 below gave a formal representation of the relationship:

$$Df\,(t) = (\beta * In\,(t) + (1-\beta) * Ss\,(t)) * (1- Cs(t)) \quad \text{..Eq.3}$$

Df(t) is changing in diffusion with respect to time,

B (Beta) a constant to regulate the contribution of the factors,

(t) represent periodic/time variance of each factor's contribution.

In the equation shown above, the contribution of diffusion as an element of technological change depends on the impact of innovation, cost and the satisfaction people derived from the service being provided.

3.2.4 Quality of Service

If the quality of service being offered by the telecenter is high due to the level of technological changes experienced over time, this may trigger satisfaction and utilization arising from individual commitment which when continued over time may generate Long term satisfaction as well as utilization, thereby enhancing effectiveness. Figure 3.6 below shows the relationship:

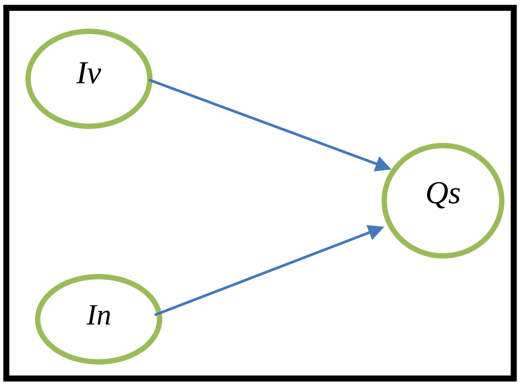

Figure 3.6. Quality of Service

Eq. 4 below formalized the relationships of Figure 3.6 mathematically:

$Qs\,(t) = \alpha * In\,(t) + (1-\alpha) * Iv\,(t)$..Eq. 4

Qs(t) is changing in quality of service with respect to time,

α (Alpha) a constant to regulate the contribution of the factors,

(t) represent periodic/time variance of each factor's contribution.

The equation above shows that either a substantial increase in the level of innovation or invention will directly influence the Quality of service and vice versa. Thus, an effective usage of telecenter can only be achieved if the quality of service being offered is better enough to influence satisfaction as well as utilization rate.

3.2.5 Satisfaction

Satisfaction determines the initial value attached to a particular service which influences its usage of individual commitment. However, if this continues over a period of time, it enhances long term usage of such service due to the confidence it has built in the users over time. Below shows how satisfaction can be enhanced through quality of service and individual commitment.

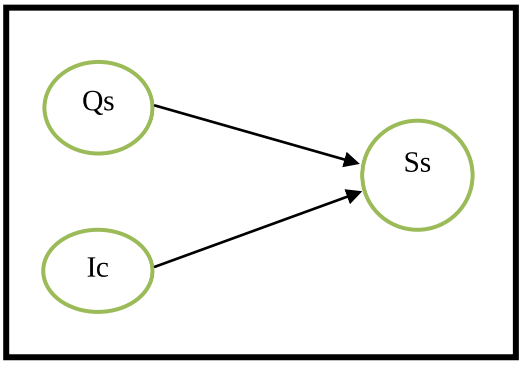

Figure 3.7. Relationship of Satisfaction

Eq5 below formalize Figure 3.7 mathematically.

$Ss(t) = Qs(t) * Ic(t)$..Eq5

Ss(t) is changing in satisfaction with respect to time,

(t) represent periodic/time variance of each factor's contribution.

The relationship as identified by the equation denotes that, *Qs* and *Ic* play a dependent role on the realization of *Ss*. Thus, satisfaction cannot be realized if the quality of service is bad or individuals are not committed.

3.2.6 Long term Satisfaction

Satisfaction which builds up over a period of time generates long term satisfaction. Figure 3.8 shows the relationship.

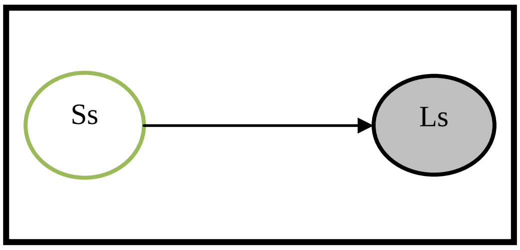

Figure 3.8. Long term Satisfaction

Eq6 describe the accumulated effect of long term satisfaction (*Ss*) over a period of time (Δt).

$Ls(t) = Ls(t-1) + \tau * (Ss(t) - Ls(t-1)) * Ls(t-1) * \Delta t$ Eq6

Ls (t) are changing in long term satisfaction with respect to time.

(t) Represent periodic/time variance of each factor's contribution.

Δt (Delta_t) a temporal time change.

The above relationship signifies an accumulated effect of *Ss* on *Ls* and Tau (τ) was used to regulate the condition over time.

3.2.7 Utilization

Utilization determines the initial value attached to a particular service which influences its usage of individual commitment and the diffusion of innovation. However, if this continues over a period of time, it enhances long term usage of such service due to the confidence it has built in the users over time. Figure 3.9 below shows how utilization quality of service, individual commitment and diffusion of particular service affect utilization.

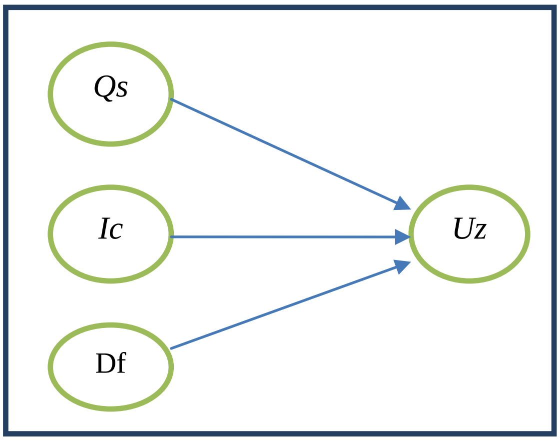

Figure 3.9. Relationship of Utilization

Eq7 below formalize Figure 3.9 mathematically.

$Uz(t) = Ic(t)*(\Omega * Qs(t)+(1- \Omega)* Df(t))$**................................*Eq7***

Uz (t) is changing in utilization with respect to time,

Ω (Omega) a constant to regulate the contribution of the factors,

(t) Represent periodic/time variance of each factor's contribution.

The relationship as identified by the equation, denote that, *Qs* and *Ic* play a dependent role with Df on the realization of Uz. Thus, utilization cannot be realized if the quality of service is bad and individuals are not committed or diffusion of particular service was not high.

3.2.8 Long term Utilization

Utilization which builds up over a period of time generates long term utilization. Figure 3.10 shows the relationship between utilization and long term utilization.

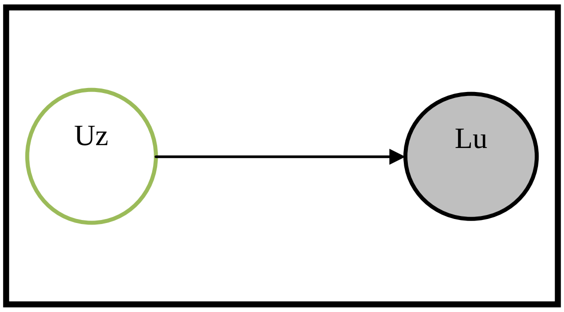

Figure 3.10. Relationship of Utilization

Eq8 describes the accumulated effect of long term utilization (*Lu*) over a period of time *(Δt)*.

Lu (t) = Lu (t-1) + Ω *(Uz (t) - Lu (t-1))* Lu (t-1)* Δt.................... Eq8

Lu (t) is changing in long term utilization with respect to time,

Ω (Omega) a constant to regulate the contribution of the factors,

(t) Represent periodic/time variance of each factor's contribution.

Δt (Delta_t) a temporal time change.

The above relationship signifies an accumulated effect of *S*u on *L*u and Omega (Ω) was used to regulate the condition over time.

3.2.9 Effectiveness

Effectiveness of telecenter is realized by considering the contribution of the Long term satisfaction derived from the usage of services provided. Thus, *Ls* and *Lu* play active role and this is shown in the figure below and Eq9:

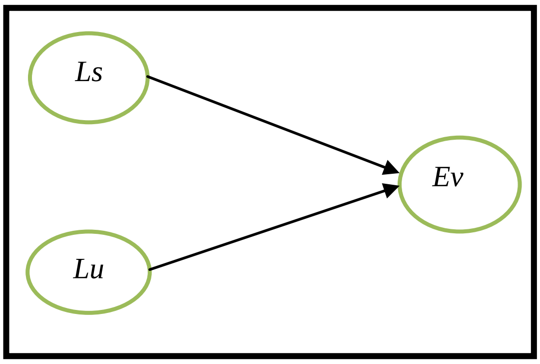

Figure 3. 11. Relationship of Effectiveness

Eq9 below formalize Figure 3.11 mathematically.

$$Ev\ (t) = \gamma * Ls\ (t) + (1-\gamma) * Lu\ (t) \qquad \text{Eq9}$$

Ev(t) is changing in effectiveness with respect to time,

γ (Gamma) a constant to regulate the contribution of the factors,

(t) Represent periodic/time variance of each factor's contribution.

The relationship as identified by the equation denotes that, *Ls* and *Lu* play an independent role in the realization of *Sv*. Thus, effectiveness can be realized if any of those factors play role and gamma (γ) is a constant used to regulate the condition.

3.2.10 Long term Effectiveness

Long term effectiveness is a predictable factor to the ultimate expectation of the use of telecenter over time. It can only be achieved if there is a progress in the technological change factors coupled with input factors that contribute to effective usage of telecenter. Long term effectiveness emerges from effectiveness that is progressive over time.

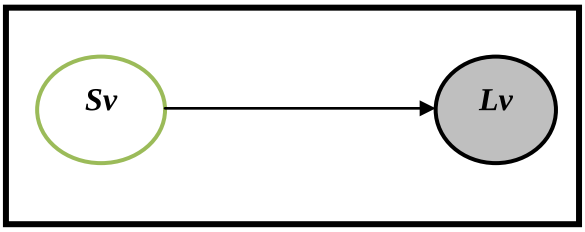

Figure 3.12. Long term Effectiveness

Eq. 10 below formalizes Figure 3.12 mathematically.

$Lv\ (t) = Lv\ (t\text{-}1) + \sigma * (Ev\ (t) - Lv\ (t\text{-}1)) * Lv\ (t\text{-}1) * \Delta t$.....................Eq10

Lv(t) is changing in long time effectiveness with respect to time,

σ (Sigma) a constant to regulate the contribution of the factors,

(t) represent periodic/time variance of each factor's contribution,

Δt (Delta_t) a temporal time change.

The relationship as identified by the equation denotes that *Lv* is derived from the accumulated effect of *Ev*. Thus, Long term effectiveness can be realized if there is a progressive change in effectiveness and Sigma (σ) is a constant used to regulate the condition.

3.3 Simulation

In this phase, Matlab was used to simulate the computational model in terms of equations. In, order to regulate the various conditions depict by these factors, constants are introduced to justify the trend of contributions among factors. In computational modeling, values assigned are always between 0 and 1. Zero, denotes no contribution, while values between 0 and 0.4 denoted low contributions, 0.5 is a moderate value while any values above 0.5 denote high contributions and 1 is the highest as shown in Table 3.3. Non value is always set above 1 as this is the boundary to modeling. Thus, the choice of values depends on the interpretation of the corresponding situations and relations among factors. The simulation traces were generated by applying it to three different scenarios to test the effectiveness of the model which is shown in Chapter Four.

Table 3.3 The scale level of assigned values

Level	Values
High	0.6 – 1
Moderate	0.5
Low	0 - 0.4

The script coded using Matlab is shown in Figure 3.13.

```
% initializing all parameters to regulate the equations

    maxLimY = 1.2;                Beta    = 0.5;

    minLimX = 0  ;                Sigma =0.1;

    Delta_t = 0.9;                Alpha = 0.5;

    Lambda  = 0.5;                Omega = 0.5;

    Meu   = 0.5;                  Gamma= 0.5;

    Tau= 0.5;                     numStep = 500;

    Wiv_1=0.25;

    Wiv_2=0.25;

    Wiv_3=0.50;

%DECLARE VECTORS FOR ALL NODES and Set initial values to external factors

% External Factors

     Rd= zeros (1, num Step); % Research and Development

Is= zeros (1, num Step); % Infrastructural Sustainability

Gp=zeros (1, num Step); % Government Policy

Cb=zeros (1, num Step); % Collaboration
```

```
Tk=zeros (1, num Step); % Technology knowledge

Ic =zeros (1, num Step); % Individual Commitment

Cs =zeros (1, num Step); % Cost

 %Internal Factors

Iv =zeros (1, num Step); % Invention

In=zeros (1, num Step); % Innovation

Qs=zeros (1, num Step); % Quality of Service

Df =zeros (1, num Step); % Diffusion

Uz=zeros (1, num Step); % Utilization

Ss=zeros (1, num Step); % Satisfaction

Ls=zeros (1, num Step); % Long term satisfaction

Uz=zeros (1, num Step); % Long term Utilization

Ev=zeros (1, num Step); % Effectiveness

Lv=zeros (1, num Step); % Long term Effectiveness

 % initializing temporal Factors

Ls (1) = 0.3;

Lu (1) = 0.3;

Lv (1) = 0.3;

% initializing external factors

  % choose 1 to simulate high Effectiveness

  % choose 2 to simulate moderate Effectiveness

  % choose 3 to simulate low Effectiveness

     Effectiveness=1;
```

```
For t=1: num Step
Switch (Effectiveness)
  Case 1
          Rd (t) = 0.7;
           Gp (t) = 0.8;
           Is (t) = 0.7;
           Cb (t)=0.6;
           Tk (t) =0.6;
            Ic (t) = 0.8;
           Cs (t) = 0.2;
   Case 2
           Rd (t) = 0.5;
           Gp (t) = 0.5;
           Is (t) = 0.5;
           Cb (t) =0.5;
           Tk(t) = 0.5;
           Ic(t)=0.5;
           Cs (t) = 0.5;
    Case 3
           Rd (t) = 0.3;
           Gp (t) = 0.3;
           Is (t) =0.1;
           Cb (t) = 0.1;
```

```
            Ta (t) =0.1;
            Ic (t) = 0.1;
            Cs (t) = 0.9;
    End
    End
% initializing instantaneous Factors at time, t=1
Iv (1) = Wiv_1 * Ta (1) +Wiv_2* Gp (1) +Rd (1)*Wiv_3;       % Invention
In (1) = Iv (1)* (wi_1* Cb (1) +  wi_2* Ts (1) * Tk (1)*wi_3);  % Innovation
 Qs (1) = Alpha*In (1) + (1- Alpha)*Iv(1);                       % Quality of service
 Df(t) = (Beta* In(t)+ (1-Beta)*Ss(t))*(1-Cs(t));                % Diffusion
 Ss (1) = Qs (1)* Ic (1);                                         % Satisfaction
 Uz(1) = Ic(1)*( Omega* Qs(1)+(1-Omega)* Df(1) );                % Utilization
Ev (1) = Gamma*Ls (1) + (1- Gamma)* Lu(1);                      % Effectiveness
 % executing the Model at time t=2
  For t = 2: num Step
  Iv (t) = Wiv_1 * Ta (t) + Wiv_2* Gp (t) + Td (t) * Wiv_3;  %  Invention
 In (t) = Iv (t)* (wi_1* Cb(t) + wi_2* Ts(t)+wi_3*Tk (t));      % Innovation
 Qs (t) = Alpha*In(t) + (1- Alpha)*Iv(t);                       % Quality of service
Df (t) = ( Beta*In (t) +  (1-Beta)* Ss (t) ) * (1- Cs(t));      % Diffusion
 Ss (t) = Qs(t)* Ic(t);                                          % Satisfaction
 Uz(t) = Ic(t)*( Omega*Qs(t)+(1-Omega)* Df(t) );                 % Utilization
Ev(t)= Alpha*Ls(t-1) + (1- Alpha)*Lu(t-1);                       % Effectiveness
Ls(t) = Ls(t-1) + Tau*(Ss(t) - Ls(t-1))* Ls(t-1)* Delta_t;       %Long term Satisfaction
```

```
 Lu(t) = Lu(t-1) +Omega*(Uz(t) - Lu(t-1))* Lu(t-1)*Delta_t;     %Long term Utilization

Lv (t) = Lv(t-1) +Sigma* (Ev(t) - Lv(t-1))* Lv(t-1)* Delta_t;

% Telecenter Effectiveness

 End

% plotting graphs

hold on

t=1: num Step;

subplot (2,1,1);

y = plot(t, Lv,'r:',t, Ls, 'b--',t,Lu,'g-.');

xlabel('time steps');ylabel('levels');

xlim([0 numStep]);ylim([minLimX maxLimY]);

hold off;

legend(y,'Telecenter Effectiveness','Long term satisfaction','Long term Utilization')

 subplot(2,1,2);

y = plot(t, Iv,'r-.',t, In,'b--', t, Df,'k:');

xlabel('time steps');ylabel('levels');

xlim([0 numStep]);ylim([minLimX maxLimY]);

hold off;

legend (y,'Invention', 'Innovation', 'Diffusion');
```

Figure 3.13. The Script Code Using Matlab

3.3.1 Simulation Outlines

Figure 3.14 below shows the simulated outlines of the formal model written in Matlab code.

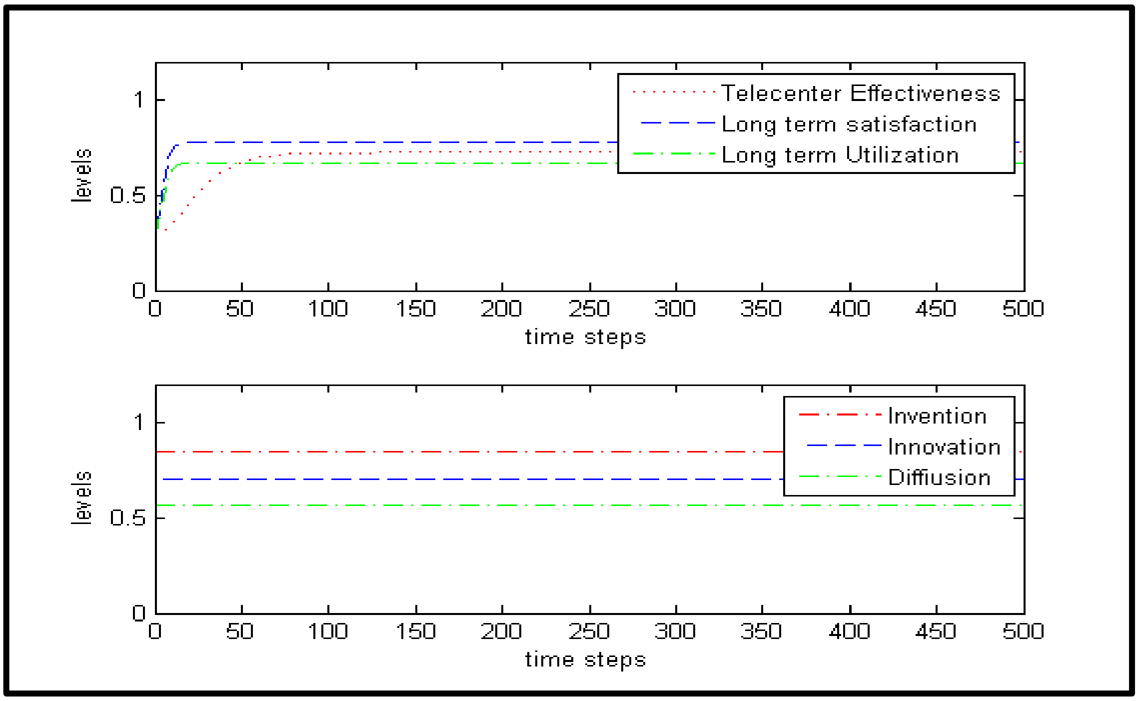

Figure 3.14. Simulation Outlines

3.4 Evaluation

The mathematical verification technique has been adopted to evaluate the results of simulated senario as showed in Chapter Four. The phase of verification provides certain explaination related to the concept applied for the model design within simple application of mathmetical rules to ascertain the balance between the input and the output parameters. This equilibria justification are abstracted from the equations derived for the model to describe the situations in which stable condition may be reached (Ab Aziz, 2011). Thus, this enhanced temporial equations justification for the validity and correctness of the model. However, the evaluation phase was implemented and discussed in Chapter Four.

3.5 Summary

The chapter presented the methodology adopted in the study. The methodology consists of three phases of Abstraction, Formalization, Simulation and Evaluation.

CHAPTER FOUR

SIMULATION RESULTS AND EVALUATION

In this chapter, the simulation results and evaluation of the computational model are presented and discussed.

4.1 Results of Simulation

As stated in Chapter Three, three major cases were simulated for telecenter effectiveness. This is related to the influence of various factors. The following sections present the results for each scenario.

Scenario #1: High Effectiveness

In this scenario, effectiveness is examined by a adapting various levels of impact of factors.

Note: Decrease in Cost of services or product resulting into an increase in diffusion rate, thus it must be assumed at low level to get high effectiveness.

Case 1: In order to realize high effective usage of telecenter, the impact of all the input variables (such: Technological knowledge, Collaboration, Government policies, Infrastructural sustainability, Researcher and development, and Individual commitment denoting technological changes) were be considerably high, and the input variable Cost considered low respect to literature review in Chapter Two. Table 4.1 presents the input values used in this case. The results is presented in Figure 4.1 below.

Table 4.1 Entry values for Case 1

S/N	Variable	Values
1	*Rd*	0.7
2	*Gp*	0.8
3	*Is*	0.5
4	*Cb*	0.6
5	*Tk*	0.8
6	*Ic*	0.8
7	*Cs*	0.2

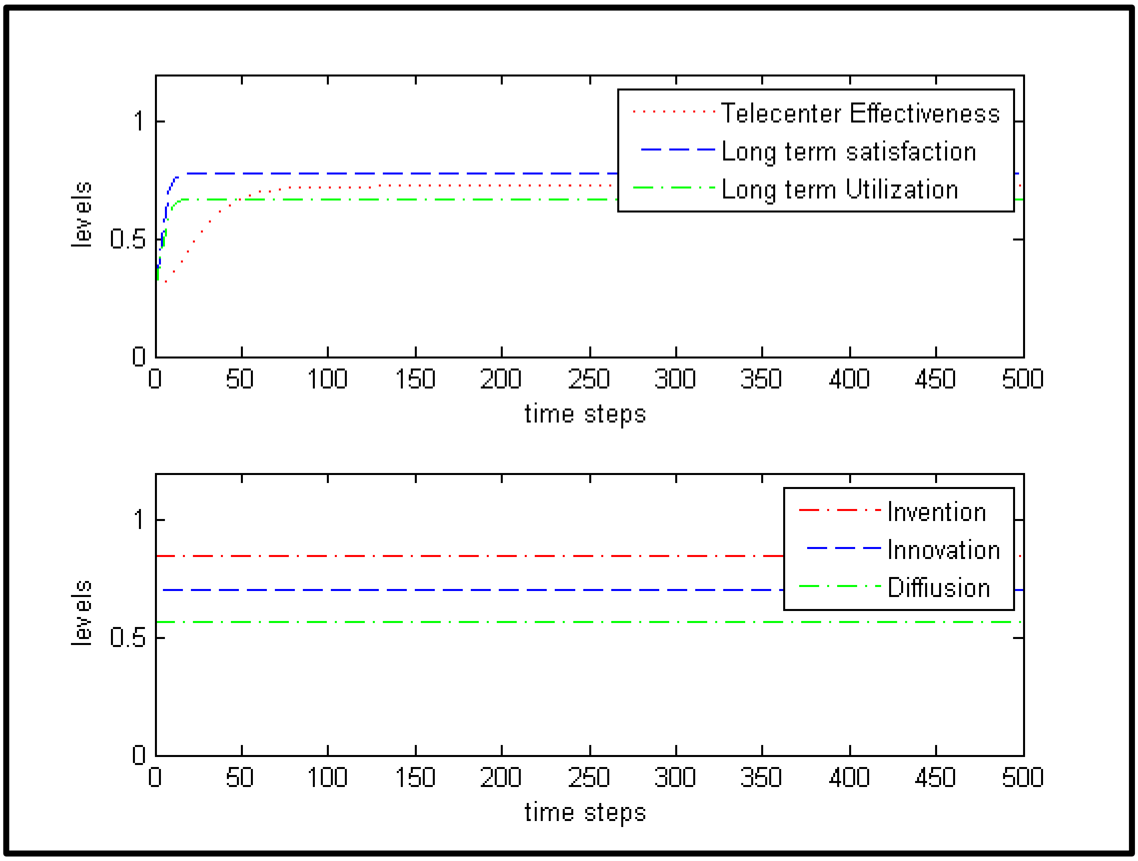

Figure 4.1. Results of Case 1

Based on the figure above, it can be seen that all the variables are equal or close to one. This shows that considerable increase in technological development, coupled with better government policies in terms of funding and reduction in tax rate as well as collaboration and individual commitment can play an active role in telecenters' effectiveness. Also, excellent technological knowledge and a moderate infrastructural facilities will contribute to high effectiveness.

Scenario #2: At this stage, variables are set to moderate levels in order to examine possible scenarios that yield moderate effectiveness.

Case 2: In order to have moderate effectiveness, the impact of the factors may vary according to the assigned values described below. Table 4.2 present the input values used in this case. The results obtained is presented in Figure 4.2.

Table 4.2 Entry values for Case 2

S/N	Variables	Values
1	*Rd*	0.5
2	*Gp*	0.5
3	*Is*	0.5
4	*Cb*	0.5
5	*Tk*	0.5
6	*Ic*	0.5
7	*Cs*	0.5

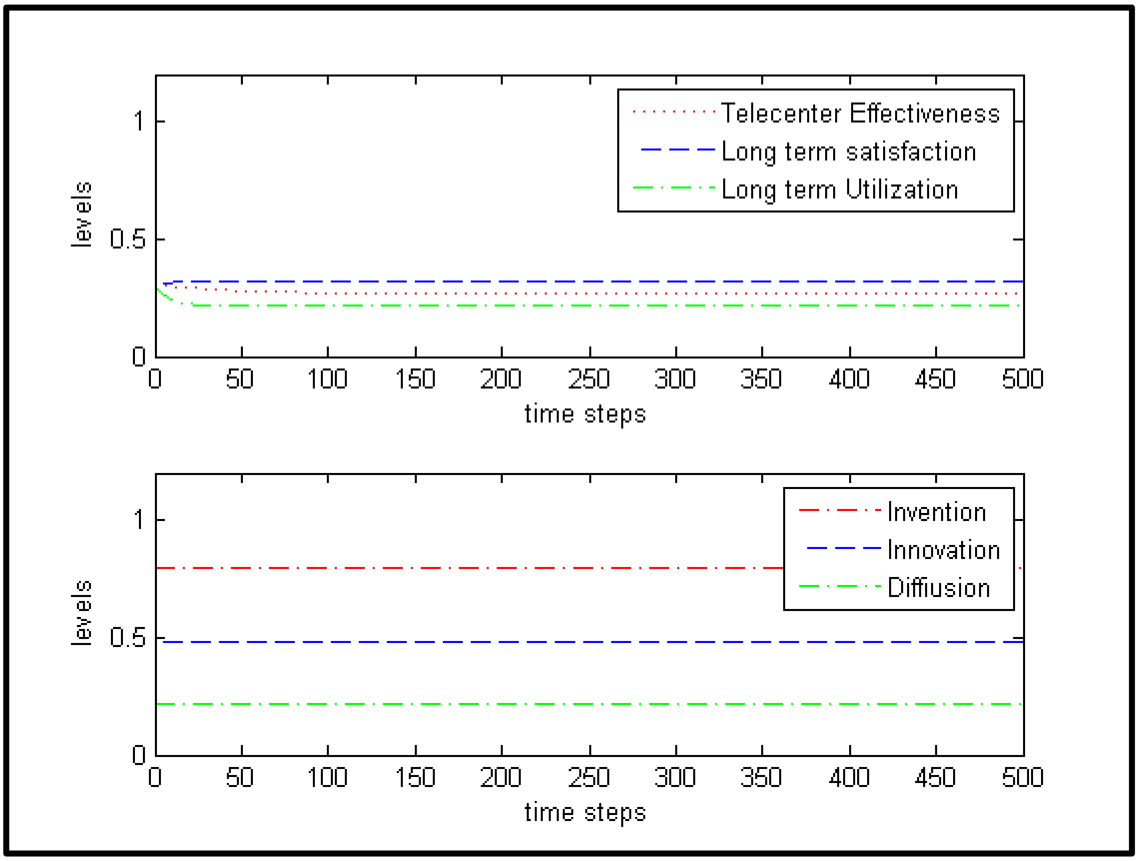

Figure 4. 2. Result for Case 2

The results presented in Figure 4.2 showed progressive changes in effective usages through moderate and progressive increases in the values assigned to the variables.

Scenario #3: Possible scenarios that can result to low effectiveness of telecenter is examined.

Note: Increase in Cost of services or product resulting into a decrease in diffusion, thus it must be assumed at high level to get low effectiveness.

Case 3: In order to realize low effective usage of telecenter, the impact of the input variables (such: technological knowledge, collaboration, government policies, infrastructural sustainability, researcher and development, and individual commitment denoting technological changes) must be considerably low, and the input variable cost must be consider high. Table 4.3 presents the input values used in this case. The result is presented in Figure 4.3.

Table 4.3 Entry values for Case 3

S/N	Variable	Values
1	*Rd*	0.3
2	*Gp*	0.3
3	*Is*	0.1
4	*Cb*	0.1
5	*Ta*	0.1
6	*Ic*	0.1
7	*Cs*	0.9

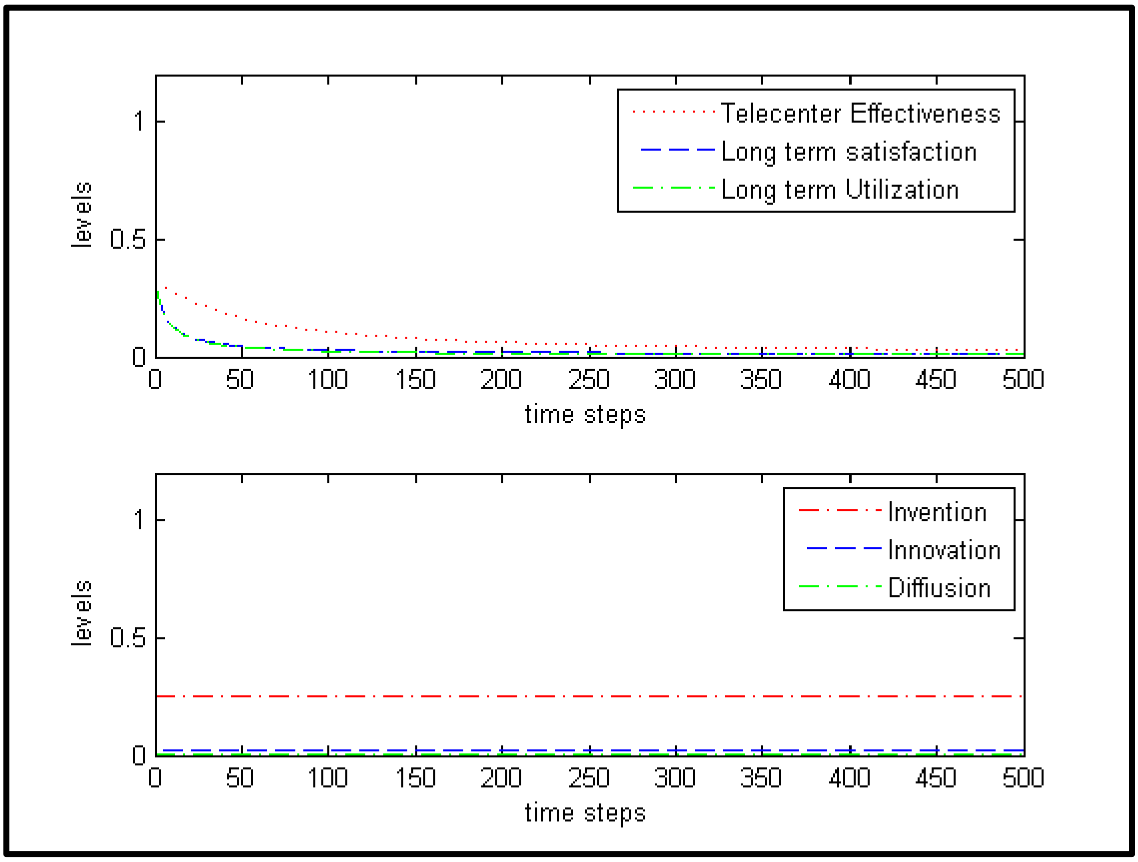

Figure 4.3. Result for Case 3

The data in Table 4.3 and plots in Figure 4.3 indicate that low changes in technology, coupled with poor invention, innovation, and diffusion will result to poor effectiveness of telecenter.

4.2 Evaluation Using Mathematical Verification

The mathematical verification technique has been adopted to evaluate the results of simulated senario. The aspect of mathmetical verification is concerned with some mathematical abstractions and proofing to examine the possible stable situation needed for the model in practice.

It provides certain explaination related to the concept applied for the model design within simple application of mathmetical rules to ascertain the balance between the input and the output parameters. However, this equilibria justification are abstracted from the equations derived for the model to describe the situations in which stable condition may be reached (Ab Aziz, 2011). Thus, this enhanced temporial equations justification for the validity and correctness of the model. The temporial equations considered of the model were, long term satisfaction, long term utilization, and long term effectiveness.

Thus, this can be done by assuming constant values for all variables. Meanwhile, in all the equations, reference to time variance may not be considered, and in addition, the temporality values in the differential equation for changes in temporal parameters may be simplified, for example: $Lv(t+ \Delta t)$ changed to $Lv(t)$. One important assumption being made here is that, all exogenous variables are having constant values. Assuming no parameter is equal to zero, this leads to the following equations where an equilibrium state is characterized by:

$$dLs(t) /dt = \tau ls * (Ss - Ls)* Ls*(1-Ls)$$

$$dLu(t)/dt = \omega lu*(Su- Lu)* Lu*(1-Lu$$

$$dLv(t)/dt = \sigma_{tv} * (Sv - Lv) * Lv* (1 - Lv)$$

Next, the equations are identified describing:

$dLs(t) /dt = 0$, $dLu(t)/dt = 0$, $dLv(t)/dt=0$

Assuming the parameters for all aforementioned equations are equal to 1.Tthe condition state was set to assume maximum value in order to evaluate the contribution of the specified parameters could justify effectiveness at their point, then these are equivalent to:

$$Ss = Ls \vee (Ls=0) \vee (Ls=1)$$

$$Su = Lu \vee (Lu=0) \vee (Ls=1)$$

$$Sv = Lv \vee (Lv=0) \vee (Lv=1)$$

In these analysis, the first conclusion can be derived where the equilibrium can be said to only occur when *Ls=1, Ss=Ls, or Ls=0* (as in 4). By combining these three conditions, it can be represented in a set of mathematical expression as:

$$(A \vee B \vee C) \wedge (D \vee E \vee F).$$

$$(Ss = Ls \vee Ls = 0 \vee Ls = 1) \wedge (Su = Lu \vee Lu = 0 \vee Lu = 1) \wedge (Sv = Lv \vee Lv = 0 \vee Lv = 1).$$

The expression can be further elaborated using Distributive law that is:

$$(A \wedge D) \vee (A \wedge E) \vee ,..., \vee (C \wedge F).$$

$$(Ss = Ls \wedge Su = Lu \wedge Lu=0 \wedge Sv = Lv) \vee ,........................, \vee (Ls = 1 \wedge Lu = 1 \wedge Lv = 1).$$

This therefore provide possible combinations of equilibria point that can be further analyzed. However, due enormous possibilities that can be infered frm the possible combinations, it may seem somehow difficult to come out with a complete analysis of the equilibria point. Thus, for some typical cases the analysis can be obtained as follows:

Case #1: $Ls = 1 \wedge Lu = 1 \wedge Lv = 1$

For this case, by Equation 9, it follows that

$Ev = \gamma * Ls + (1-\gamma) * Lu$

Therefore, $Sv = Lu$.

Case #2: $Lu = 0$

From equation 9, it means that

$Ev = Ls$

4.3 Summary

This chapter present the results of the simulated scenario provided clear understanding of how the varying levels of TC can enhance or discourage the effective usage of telecenter. Also, presented is the mathematical verification analysis to evaluate the correctness of the model. The corresponding relations established showed that long term effectiveness can be realized through the impact of either Long term utilization or Long term satisfaction which when accumulated over time yield Long term effectiveness.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The first chapter of this study proposed three objectives: (i) to identify TC factors related to telecenters' effectiveness, (ii) to construct a computational model based on factors obtained from the first objective and (iii) to simulate and evaluate the computational model.

This study achieved all objectives. For objective (i), the identified factors were identified from previous literatures and presented in chapter three. These factors include Technological Knowledge, Research and Development, Collaboration, Infrastructural Sustainability, Government Policy, Technological cost, Quality of service, Individual commitment, Invention, Innovation, and Diffusion with Satisfaction and Utilization factors that measure telcenter effectiveness.

For objective (ii), the computational model was developed. The model was presented in Chapter. three and formal equations were established using differential equations that represented the relationships of the factors selected in the previous phase (objective1).

For objective (iii), a simulation and evaluation were conducted on the model. Results were shown and discussed in Chapter four using three scenarios.

Three scenarios were simulated to represent the global possible changes in the factors and how these changes can bring about corresponding changes in telecenter effectiveness to experiment with different cases each varying inputs to each of the factors and different results were obtained. It is deduced that high changes in Invention, innovation and diffusion due to higher impact of the contributing variables brought about high utilization and satisfaction which in turn causes a corresponding increase in telecenter effectiveness (as shown in Figure 4.1). Also, it is deduced that if the corresponding contribution of these external factors are provided at a moderate level, satisfaction, utilization and effectiveness tend to progress moderately (as indicated in Figure 4.2).

In contrast, if there is little or no contribution of any of these variables, then, there tend to be a sharp fall in satisfaction and utilization resulting in the corresponding decrease in effectiveness over time (Figure 4.3). In the simulation, the values assigned are between the range of 0 and 1(range for computational modeling). Zero (0) denotes no contribution at all, any value slightly greater than 0 but less than 0.5 is considered low values that can be assigned to determine the state of observed condition at a very low possibility. Similarly, moderate values are assumed to explain what happen to the observed phenomenon, if their contribution is moderate. Also, values assigned between 0.5 but less than or equal to 1 are considered high values to explain what happen if the contribution of the variable are high. Meanwhile, in order to implement these ideas, formal equations (differential equations) are established which depends on the relationships and the actual contribution of the factors to one another. The nature of the operators in between the equations depends on whether both factors contribute dependently or independently to one another. If the factors contribute dependently, then multiplication is used as operator but if otherwise, addition is used as operator and the sum of the variables on both sides must not be greater than one (1), the subtraction is only used for the temporal parameters.

In addition, the constants introduced are used to regulate the equation as each variables play unequal role, the contribution of one factor to the output might be dependent or independent, so to regulate computation by the Matlab, these are introduced. However, for the mathematical verification, cases obtained through the literature that was implemented in the programming was considered, especially, how the temporal values at both satisfaction and utilization relate to effectiveness that can over range of period result to long term effectiveness indicating a balance level of telecenter effectiveness's usage as indicated in the simulation outline.

However, this study was conducted to ascertain the effect of TC factors on telecenters' effectiveness. In the process of solving the problem under the study various factors were identified related to telecenter effectiveness and computational model was developed. The model was simulated with a Matlab using three different scenarios.

5.2 Contribution

This study was contributed to academic research whereas a formal model (computational model) was developed to illustrate the factors that contributing to TC and impact on the effectiveness usage of telecenter. Moreover, there (14) factors were highlighted and all these factors are used to construct the model. In addition, provided and simulated scenarios that suitable to be used by decision makers to examine the TC impact on telecenter effectiveness.

5.3 Recommendation for Future Work

Future research studies need to determine other TC factors that have some impacts on telecenter effectiveness. Implementation of the model in reality must be conducted to show its relevance and thorough evaluation is needed to show its reliability and effectiveness.

REFERENCES

Ab Aziz, A. (2011). *Exploring Computational Models for Intelligent Support of Persons with Depression.* Vrijie Universiteit Amsterdam. Retrieved from http://hdl.handle.net/1871/26393.

AbdulWahab. (2012). *A Modified of the Unified Theory of Acceptance and Use of Technology (UTAUT) from Users' Perspective of Telecentre in Nigeria.* Universiti Utara Malaysia.

Abdulwahab, & Dahalin, Z. M. (2010). A Conceptual Model of Unified Theory of Acceptance and Use of Technology (UTAUT) Modification with Management Effectiveness and Program Effectiveness in Context of Telecentre. *African Scientist*, *11*(4), 267-275.

Abdulwahab, & Zulkhairi, M. (2011). Effectiveness of Telecentre using a Model of Unified Theory of Acceptance and Use of Technology (UTAUT): Structural Equation Modelling Approach. *Journal of Emerging Trends in Computing and Information Sciences, 2*(9), 402-412.

Adam, Newell, R. G., & Stavins, R. N. (2002). Environmental policy and technological change. *Environmental and resource economics, 22*(1-2), 41-70.

Adner, R., Polos, L., Ryall, M., & Sorenson, O. (2009). The case for formal theory. *Academy of Management Review, 34*(2), 201-208.

Alasow, M. A., Udomsade, J., & Niyamangkoon, S. (2010). *People attitude towards telecenter utilization in Roi Et Province of Thailand.* Paper presented at the In Education and Management Technology (ICEMT), 2010 International Conference on (pp. 595-599). IEEE.

Amoroso, D. L., & Ogawa, M. (2013). Comparing Mobile and Internet Adoption Factors of Loyalty and Satisfaction with Online Shopping Consumers. *International Journal of E-Business Research (IJEBR), 9*(2), 24-45.

Antonelli, C., Crespi, F., & Scellato, G. (2013). Internal and external factors in innovation persistence. *Economics of Innovation and New Technology, 22*(3), 256-280.

Antràs, P., Garicano, L., & Rossi-Hansberg, E. (2006). Offshoring in a knowledge economy. *The Quarterly Journal of Economics, 121*(1), 31-77.

Avgerou, C. (2010). Discourses on ICT and Development. *Information Technologies & International Development, 6*(3), pp. 1-18.

Aziz, A. A., Klein, M. C., & Treur, J. (2010). An integrative ambient agent model for unipolar depression relapse prevention. *Journal of Ambient Intelligence and Smart Environments, 2*(1), 5-20.

Bailey, A., & Ngwenyama, O. (2009). *Social ties, literacy, location and the perception of economic opportunity: Factors influencing telecentre success in a development context.* Paper presented at the System Sciences, 2009. HICSS'09. 42nd Hawaii International Conference on (pp. 1-11). IEEE.

Bailey, A., & Ngwenyama, O. (2013). Toward entrepreneurial behavior in underserved communities: An ethnographic decision tree model of telecenter usage. *Information Technology for Development, 19*(3), 1-19.

Bailur, S. (2006). Using stakeholder theory to analyze telecenter projects. *Information Technologies & International Development, 3*(3), pp. 61-80.

Baily, M. N., Manyika, J., & Gupta, S. (2013). US Productivity Growth: An Optimistic Perspective. *International Productivity Monitor, 25,* 3-12.

Baldwin, C., & Von Hippel, E. (2010). Modeling a paradigm shift: From producer innovation to user and open collaborative innovation. *Harvard Business School Finance Working Paper*(10-038), 4764-4709.

Bas, C., & Latham, W. (2009). *The Economics of Persistent Innovation: An Evolutionary View: An Evolutionary View* (Vol. 31): Springer.

Bashir, M. S., Samah, B. A., Emby, Z., Badsar, M., Shaffril, H., & Aliyu, A. (2011). Information and Communication Technology Development in Malaysia: Influence of competency of leaders, location, infrastructures and quality of services on telecentre success in rural communities of Malaysia. *Australian Journal of Basic and Applied Sciences, 5*(9), 1718-1728.

Benjamin, P. (2001). The Gaseleka Telecentre, Northern Province, South Africa. *Telecentres: Case studies and key issues, 12*(2), 75-84.

Benson, C. L., & Magee, C. L. (2012). A framework for analyzing the underlying inventions that drive technical improvements in a specific technological field. *Engineering Management Research, 1*(1), p2.

Best, M. L., & Kumar, R. (2008). Sustainability failures of rural telecenters: Challenges from the sustainable access in rural india (sari) project. *Information Technologies & International Development, 4*(4), pp. 31-45.

Bitra, L. G., & Arbez, G. (2007). *Modelling and Simulation : Exploring Dynamic System Behaviour*: Goldaming : Springer, 2007. 1. ed.

Bonadia, G. C., Ávila, I. M. A., Ogushi, C. M., & de Holanda, G. M. (2008). Modeling the Acceptance and use of Telecenters in Brazil. *Journal of Technology Management & Innovation, 2*(4), 86-97.

Brodnig, G., & Mayer-Schonberger, V. (2000). Bridging the gap: the role of spatial information technologies in the integration of traditional environmental knowledge and western science. *The Electronic Journal of Information Systems in Developing Countries, 1*. http://dialnet.unirioja.es/servlet/oaiart?codigo=3663781

Buhigiro, S. (2013). *The role of telecentres in promoting socio-economic development in Rwanda.* University of the Witwatersrand. Retrieved from http://hdl.handle.net/10539/12464

Carley, K. M. (1996). Validating computational models. *Paper available at http://www. casos. cs. cmu. edu/publications/papers. php*.

Cheang, S., & Lee, J.-D. (2010). *Evaluation telecenter performance in social sustainability context: A Cambodia case study.* Paper presented at the Advanced Information Management and Service (IMS), 2010 6th International Conference on (pp. 135-141). IEEE.

Chen, W., & Wellman, B. (2005). Minding the cyber-gap: the Internet and social inequality. *The Blackwell companion to social inequalities. Malden, Mass.: Blackwell*(1), 523-545.

Cheuk, S., Atang, A., & Lo, M.-C. (2012). Community Attitudes towards the Telecentre in Bario, Borneo Malaysia: 14 Years on. *International Journal of Innovation, Management and Technology, 3*, 682-687.

Clausen, T., Pohjola, M., Sapprasert, K., & Verspagen, B. (2012). Innovation strategies as a source of persistent innovation. *Industrial and Corporate Change, 21*(3), 553-585.

Crabtree, P. (2006). A FRAMEWORK FOR UNDERSTANDING TECHNOLOGY AND TECHNOLOGICAL CHANGE. *The Innovation Journal: The Public Sector Innovation Journal,, 11*(1), 1 - 16.

Cyr, D., Head, M., & Ivanov, A. (2006). Design aesthetics leading to m-loyalty in mobile commerce. *Information & Management, 43*(8), 950-963.

Dawid, H. (2006). Agent-based models of innovation and technological change. *Handbook of computational economics, 2*, 1235-1272.

Dey, B. L., Newman, D. R., & Pendergast, R. (2010). Ethnographic approach to user-centred evaluation of telecentres. *International Journal of Innovation in the Digital Economy (IJIDE), 3*(1), 22-39.

Di Stefano, G., Gambardella, A., & Verona, G. (2012). Technology push and demand pull perspectives in innovation studies: Current findings and future research directions. *Research Policy, 41*(8), 1283-1295.

Dillon, A., & Morris, M. G. (1996). User acceptance of new information technology: theories and models. *Annual Review of Information Science and Technology, 31*, 3-32.

Dolfsma, W., & Seo, D. (2013). Government policy and technological innovation—a suggested typology. *Technovation, 33*(6–7), 173-179. doi: http://dx.doi.org/10.1016/j.technovation.2013.03.011

Doloreux, D., & Shearmur, R. (2012). Collaboration, information and the geography of innovation in knowledge intensive business services. *Journal of economic geography, 12*(1), 79-105.

Doshi, K., & Gollakota, K. (2011). Diffusion of Technological Innovations in Rural Areas. *Journal of Corporate Citizenship*(41), 69-82.

Feldman, M. P. (2002). The Internet revolution and the geography of innovation. *International Social Science Journal, 54*(171), 47-56.

Fischer, C., & Newell, R. G. (2008). Environmental and technology policies for climate mitigation. *Journal of Environmental Economics and Management, 55*(2), 142-162.

Flanagan, K., Uyarra, E., & Laranja, M. (2011). Reconceptualising the 'policy mix' for innovation. *Research policy, 40*(5), 702-713. doi: http://dx.doi.org/10.1016/j.respol.2011.02.005

Galanakis, K. (2006). Innovation process. Make sense using systems thinking. *Technovation, 26*(11), 1222-1232. doi: http://dx.doi.org/10.1016/j.technovation.2005.07.002

Garrido, M., Sey, A., Hart, T., & Santana, L. (2012). Literature review of how telecentres operate and have an impact on e-inclusion *This publication is a Technical Report by the Joint Research Centre of the European Commission*: European Union.

Garside, B. (2009). *Village voice: towards inclusive information technologies*. International Institute for Environment and Development (IIED), London.

Gillingham, K., Newell, R. G., & Pizer, W. A. (2008). Modeling endogenous technological change for climate policy analysis. *Energy Economics, 30*(6), 2734-2753.

Godin, B. (2006). The Linear model of innovation the historical construction of an analytical framework. *Science, Technology & Human Values, 31*(6), 639-667.

Gomez, R. (2012). *Libraries, telecentres, cybercafes and public access to ICT: International comparisons*: Hershey, PA : Information Science Reference. 2012.

Gomez, R., Pather, S., & Dosono, B. (2012). Public access computing in South Africa: Old lessons and new challenges. *The Electronic Journal of Information Systems in Developing Countries, 52*(1), 1-16

Gould, E., & Gomez, R. (2010). New challenges for libraries in the information age: A comparative study of ICT in public libraries in 25 countries. *Information Development, 26*(2), 166-176.

Grübler, A., Nakicenovic, N., & Victor, D. G. (1999). Modeling technological change: implications for the global environment. *Annual Review of Energy and the Environment, 24*(1), 545-569.

Gurstein, M. (2007). *What is Community Informatics:(and why Does it Matter)?* (Vol. 2): Polimetrica sas.

Harris, R. (2001). *Telecentres in rural Asia: Towards a success model*. Paper presented at the International conference on Information Technology, Communications and Development (ITCD).

Heeks, R. (2008). ICT4D 2.0: The next phase of applying ICT for international development. *Computer, 41*(6), 26-33.

Heeks, R., & Bhatnagar, S. (1999). Reinventing government in the information age: International practice in IT-enabled public sector reform. *Information commmunication and society, 3*(1), 49-74.

Hekkert, M. P., Suurs, R. A., Negro, S. O., Kuhlmann, S., & Smits, R. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change, 74*(4), 413-432.

Hlungulu, B. (2010). *Building a semantic web based e health component for a multipurpose communication centre.* (Doctoral dissertation), University of Fort Hare.

Hritonenko, N., & Yatsenko, Y. (2013). Modeling of Technological Change *Mathematical Modeling in Economics, Ecology and the Environment* (pp. 53-78): Springer.

Hudson, H. E. (2001). Telecentre evaluation: Issues and strategies. *Telecentres: Case studies and key issues, 16*, 169-181.

Hung, S. C., & Tu, M. F. (2011). Technological change as chaotic process. *R&D Management, 41*(4), 378-392.

Ibrahim, H., Yasin, A., & Dahalin, Z. M. (2010). Financial sustainability issues in Malaysia's telecentres. *Computer and Information Science*, *3*(2), P235.

Irving, C. J., & English, L. M. (2011). Community in cyberspace: Gender, social movement learning, and the internet. *Adult education quarterly*, *61*(3), 262-278.

Jacobsson, S., & Bergek, A. (2011). Innovation system analyses and sustainability transitions: Contributions and suggestions for research. *Environmental Innovation and Societal Transitions*, *1*(1), 41-57.

Jaffe, A. B., Newell, R. G., & Stavins, R. N. (2003). Chapter 11 Technological change and the environment. In M. Karl-Göran & R. V. Jeffrey (Eds.), *Handbook of Environmental Economics* (Vol. Volume 1, pp. 461-516): Elsevier.

Jensen, M., & Walker, D. (2001). Telecentre technology. *Telecentres: Case studies and key issues, 19*, 213-225.

Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development. *Computers & Education, 55*(3), 1259-1269.

Johnson-Laird, P. (2012). *The Oxford Handbook of Thinking and Reasoning: Inference in mental models*. Oxford Univesrsity Press.

Jorgenson, D. W. (2001). Information technology and the US economy. *The American Economic Review, 91*(1), 1-32.

Khilji, S. E., Mroczkowski, T., & Bernstein, B. (2006). From Invention to Innovation: Toward Developing an Integrated Innovation Model for Biotech Firms*. *Journal of product innovation management, 23*(6), 528-540.

Kiesling, E., Günther, M., Stummer, C., & Wakolbinger, L. M. (2012). Agent-based simulation of innovation diffusion: a review. *Central European Journal of Operations Research, 20*(2), 183-230.

Krell, T. C. (2000). Organizational longevity and technological change. *Journal of Organizational Change Management, 13*(1), 8-14.

Kumar, & Best, M. (2006). Impact and Sustainability of E-Government Services in Developing Countries: Lessons Learned from Tamil Nadu, India. *The Information Society, 22*(1), 1-12.

Kumar, & Best, M. L. (2007). Social impact and diffusion of telecenter use: A study from the sustainable access in rural India project. *The journal of community informatics, 2*(3).

Kuo, H. M., Chen, C. W., & Hsu, C. H. (2012). A study of a B2C supporting interface design system for the elderly. *Human Factors and Ergonomics in Manufacturing & Service Industries, 22*(6), 528-540.

Lahlou, S. (2008). Cognitive technologies, social science and the three-layered leopardskin of change. *Social science information, 47*(3), 227-251.

Lashgarara, F., Karimi, A., & Mirdamadi, S. M. (2012). Effective factors on the villagers' use of rural telecentres (case study of Hamadan province, Iran). *African Journal of Agricultural Research, 7*(13), 2034-2041.

Latchem, C., Walker, D., Dhanarajan, G., Oestmann, S., Dymond, A. C., Short, G., . . . Evans, D. (2001). *Telecentres: Case studies and key issues: Management: Operations: Applications: Evaluation*: Commonwealth of Learning.

Law, A. M. (2007). *Simulation Modelling & Analysis*: Boston : McGraw-Hill.

Lee, A. H., Kang, H.-Y., & Chang, C.-C. (2011). An integrated interpretive structural modeling–fuzzy analytic network process–benefits, opportunities, costs and risks model for selecting technologies. *International Journal of Information Technology & Decision Making, 10*(05), 843-871.

Lin, H.-F. (2007). Knowledge sharing and firm innovation capability: an empirical study. *International Journal of Manpower, 28*(3/4), 315-332.

Louis Lee, N., Goodwin, G. P., & Johnson-Laird, P. (2008). The psychological puzzle of Sudoku. *Thinking & Reasoning, 14*(4), 342-364.

Ma, T., Chi, C., Chen, J., & Shi, Y. (2009). A Simulation Model of Technological Adoption with an Intelligent Agent *Cutting-Edge Research Topics on Multiple Criteria Decision Making* (pp. 188-193): Springer.

Ma, T., & Nakamori, Y. (2008). *Coping with uncertainties in endogenous technological change models.* Paper presented at the Systems, Man and Cybernetics, 2008. SMC 2008. IEEE International Conference.

Madon, S., Reinhard, N., Roode, D., & Walsham, G. (2009). Digital inclusion projects in developing countries: Processes of institutionalization. *Information Technology for Development, 15*(2), 95-107.

Makri, M., Hitt, M., & Lane, P. J. (2010). Complementary technologies, knowledge relatedness, and invention outcomes in high technology mergers and acquisitions. *Strategic Management Journal, 31*(6), 602-628.

Meng, C. C., Samah, B. A., & Omar, S. Z. (2013). A Review Paper: Critical Factors Affecting the Development of ICT Projects in Malaysia. *Asian Social Science, 9*(4), p42.

Mishra, G. (2013). *Role of telecenters in empowering citizens: A case study of 'Mahiti Mitra'project in Kutch district of Gujarat, India*. Paper presented at the Global Humanitarian Technology Conference: South Asia Satellite (GHTC-SAS), 2013 IEEE.

Naik, G., & Joshi, S. (2010). Making E-Governance centers financially sustainable in rural India: A conceptual design for action research. *IIM Bangalore Research Paper*(317).

Naik, G., Joshi, S., & Basavaraj, K. (2010). *Market creation and poverty alleviation through telecenters*. Paper presented at the Proceedings of the 4th International Conference on Theory and Practice of Electronic Governance.

Naik, G., Joshi, S., & Basavaraj, K. (2012). Fostering inclusive growth through e-governance embedded rural telecenters (EGERT) in India. *Government Information Quarterly, 29*, S82-S89.

Nusair, K. K., & Kandampully, J. (2008). The antecedents of customer satisfaction with online travel services: a conceptual model. *European Business Review, 20*(1), 4-19.

Peters, B. (2009). Persistence of innovation: stylised facts and panel data evidence. *The Journal of Technology Transfer, 34*(2), 226-243.

Pick, J. B., & Nishida, T. (2014). Digital divides in the world and its regions: A spatial and multivariate analysis of technological utilization. *Technological Forecasting and Social Change*. doi: http://dx.doi.org/10.1016/j.techfore.2013.12.026

Pidd, M. (2003). *Tools for thinking*. Chichester, UK: Wiley.

Prahalad, C. K., & Mashelkar, R. A. (2010). Innovation's holy grail. *Harvard Business Review, 88*(7/8), 132-141.

Proenza, F. J. (2001). Telecenter sustainability: Myths and opportunities. *The Journal of Development Communication*, *12*(2), 94-109.

Qureshi, S. (2013). Information and Communication Technologies in the Midst of Global Change: How do we Know When Development Takes Place? *Information Technology for Development, 19*(3), 189-192.

Qureshi, S., & Trumbly-Lamsam, T. (2008). *Transcending the digital divide: A framing analysis of information and communication technologies news in Native*

American tribal newspapers. Paper presented at the Hawaii International Conference on System Sciences, Proceedings of the 41st Annual.

Rajalekshmi, K. G. (2007). E-governance services through telecenters: The role of human intermediary and issues of trust. *Information Technologies & International Development, 4*(1), pp. 19-35.

Rao, S. S. (2008). Social development in Indian rural communities: Adoption of telecentres. *International Journal of Information Management, 28*(6), 474-482.

Raymond, W., Mohnen, P., Palm, F., & van der Loeff, S. S. (2010). Persistence of innovation in Dutch manufacturing: Is it spurious? *The Review of Economics and Statistics, 92*(3), 495-504.

Razak, N. A., Hassan, Z., & Din, R. (2010). *Bridging the Digital Divide: An Analysis of the Training Program at Malaysian Telecenters.* Paper presented at the International conference on arts and culture WSEAS (Organization).

Rega, I., & Poglia, E. (2010). What do local people think about telecentres? A key issue for sustainability. *Unpublished Ph. D. dissertation. University of Lugano, Lugano*.

Robinson, L. (2009). A summary of diffusion of innovations. *Enabling Change*.

Rogers. (2003). *Diffusion of Innovations, 5th Edition*: Free Press.

Rogers, E. M., & Shukla, P. (2001). The role of Telecenters in development communication and the digital divide. *Journal of Development Communication, 2*(12), 26-31.

Roman, R. (2003). Diffusion of innovations as a theoretical framework for telecenters. *Information Technologies & International Development, 1*(2), pp. 53-66.

Roman, R., & Colle, R. (2002). *Themes and issues in telecentre sustainability* (Vol. 10): Institute for Development Policy and Management, University of Manchester.

Rothenberg-Aalami, J., & Pal, J. (2005). Rural Telecenter Impact Assessments and the Political Economy of ICT of Development (ICT4D). *Berkeley Roundtable on the International Economy (BRIE)*, 146.

Rothwell, R. (1994). Towards the fifth-generation innovation process. *International marketing review, 11*(1), 7-31.

Ruttan, V. W. (1997). Induced innovation, evolutionary theory and path dependence: sources of technical change. *The Economic Journal, 107*(444), 1520-1529.

Sey, A., & Fellows, M. (2009). Literature review on the impact of public access to information and communication technologies. *Center for Information and Society, University of Washington; no.6, 25 p*.

Shakeel, H., Best, M., Miller, B., & Weber, S. (2001). Comparing Urban and Rural Telecenters Costs. *The Electronic Journal of Information Systems in Developing Countries, 4*, 1-13.

Shi, G., & Pray, C. (2012). Modeling agricultural innovation in a rapidly developing country: the case of Chinese pesticide industry. *Agricultural Economics, 43*(4), 379-390.

Sokolowski, J. A., & Banks, C. M. (2011). *Principles of modeling and simulation: a multidisciplinary approach*: John Wiley & Sons.

Solow, R. M. (2000). *Growth theory: an exposition* (2 ed.): New York : Oxford University Press.

Stoll, K. (2008). The Future of Telecenter Sustainability: A Multi-Sector and Multi-Stakeholder Approach.

Suarez-Villa, L. (2000). *Invention and the Rise of Technocapitalism*: Lanham [u.a.] : Rowman & Littlefield,.

Sumbwanyambe, M., Nel, A., & Clarke, W. (2011). *Challenges and proposed solutions towards telecentre sustainability: a Southern Africa case study.* Paper presented at the IST-Africa Conference Proceedings, 2011.

Sun, Fang, Y., Lim, K. H., & Straub, D. (2012). User satisfaction with information technology service delivery: A social capital perspective. *Information Systems Research, 23*(4), 1195-1211.

Sun, & Ron. (2008). *Introduction to computational cognitive modeling*: Cambridge : Cambridge University Press.

Sutcliffe, A., & Wang, D. (2012). Computational modelling of trust and social relationships. *Journal of Artificial Societies and Social Simulation, 15*(1), 3.

Tolk, A. (2010). *Engineering Management Challenges for Applying Simulation as a Green Technology.* Paper presented at the Proceedings of the 31st Annual

National Conference of the American Society for Engineering Management (ASEM).

Tschang, T., Chuladul, M., & Le, T. T. (2002). Scaling-up information services for development: a framework of increasing returns for telecentres. *Journal of International Development, 14*(1), 129-141.

Tushman, M. L., & O'Reilly, C. A. (1996). Ambidextrous organizations: managing evolutionary and revolutionary change. *California management review, 38*(4), 8.

Wang, Y.-S., & Shih, Y.-W. (2009). Why do people use information kiosks? A validation of the Unified Theory of Acceptance and Use of Technology. *Government Information Quarterly, 26*(1), 158-165.

Weinhardt, J. M., & Vancouver, J. B. (2012). Computational models and organizational psychology: Opportunities abound. *Organizational Psychology Review, 2*(4), 267-292.

Whyte, A. V. (2000). *Assessing Community Telecentres : Guidelines for Researchers*: Ottawa : International Development Research Centre.

Windrum, P., & Birchenhall, C. (2005). Structural change in the presence of network externalities: a co-evolutionary model of technological successions. *Journal of evolutionary economics, 15*(2), 123-148.

Worboys, M. F. (2001). Modelling changes and events in dynamic spatial systems with reference to socio-economic units.

Yates, B. L. (2004). Applying diffusion theory: Adoption of media literacy programs in schools. *SIMILE: Studies In Media & Information Literacy Education, 4*(2), 1-12.

Yen, C.-H., & Lu, H.-P. (2008). Effects of e-service quality on loyalty intention: an empirical study in online auction. *Managing Service Quality, 18*(2), 127-146.

Zamani-Miandashti, N., Pezeshki-Rad, G., & Pariab, J. (2013). The influence of telecenters on rural life and their success correlates: Lessons from a case study in Iran. *Technovation, 34*(5), 306-314.

Zulkefli, I., & Sulaiman, A. (2009). The Influence of Malaysian Telecenters on Community Building. *Electronic Journal of e-Government, 7*(1), 77-86.