Agent Based Model for Measuring the Implication of Technological Change on Telecentre's Operation

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Abstract

Technological change (TC) can be seen as the driving force of the telecentres' operation. However, telecentres' poor usage and operation arises concerns on the continued relevance of these centres. Evidence on its impacts are needed so that budget allocation for resources and program improvements can be justified. The paper aims to present an agent-based model that was developed to show the impact of TC on telecentre's usage. Results on the effective usage of telecentre in different types of scenarios were shown. Mathematical verification technique was used to evaluate the simulation 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

Keywords: Technological change factors, telecentre effective usage, computational model

1.0 INTRODUCTION

Telecentres, also known as community technology centers, multimedia community centers and cyber centers have been described as successful ICT projects in many developing countries such Malaysia, India, and Philippines [1]. Previous findings have shown that through telecentres, communities have the opportunity to improve access to information, create jobs, improve soft and hard skills, create study opportunities, and increased household income [1,2,3,4]. Telecentres have also been found to enhance community's socio economic condition by improving information circulation through e-government services, e-health and e-banking [5]. In spite of the benefits created by telecentres, several studies have reported a decline in demand for telecentres' usage [5,6]. Among the factors that contribute to the problem include lack of interest, low efficiency of telecentres thus, resulting in a low demand for telecentre services [6]. Telecentres' sustainability, according to Stoll [7] is based on effectiveness of usage. Hence, telecentres effectiveness has been measured by the ability of achieving the community's demands in terms of different factors such social, economic and political growth and able to sustain for long term [6]. For example, one study explored different techniques such as principal agent, feasibility failure, and business techniques appraisal for measuring performance of telecentres [7]. In another study, simulation model was explored to identify relationships between factors [8][9]. One of the important factors that affects telecentre's performance is technological change [10][11]. The change of can happen through invention, innovation, and diffusion. In particular, innovations on technology infrastructure can provide improvements in terms of operation costs, IT services, and information accessibility and in turn increase telecentres' usage [7][11][12].Telecentres sustainability has been an important issue focused by governments and one of the factors that influence sustainability is effectiveness [13]. Several researchers have addressed different factors related to telecentres effectiveness and among them are lack of usage, technology infrastructure, services, technology adoption, and information accessibility [2][9][6][13]. The contributed factors showed that the telecentres, being an ICT project. Heeks [9] observed that rapid changes in ICT and technologies affect telecentres usage. Most researches on telecentres' effectiveness have not focused on technology change (TC) factors, thus this study aims to investigate the impact of TC with effective utilization of telecentres through formal analysis approach.

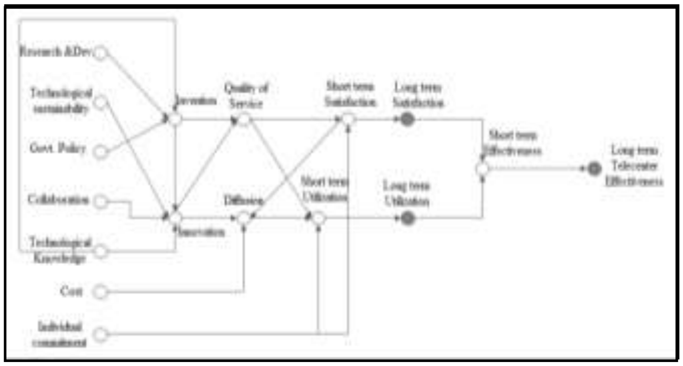

Figure 1 Relationship of TC factors and telecentre effectiveness

2.0 METHODOLOGY

The agent-based model was constructed in three stages: Abstraction, Formalization, Simulation and Evaluation. In the first stage, factors of telecentre's effectiveness and factors related to TC were identified from past studies (Table 1). All of the factors are grouped into four categories, Invention, Innovation, Diffusion and Government Policy.

Table 1 General system parameters

Category	Factors
	Patent right
	Knowledge base
INVENTION	Research and Development
	Learning Rate
	Speed of Diffusion
	Emergent Technology
INNOVATION	Research and Development
	Education System qualities
	Patent right
	Entrepreneur
	Cost
	Reward
	Venture Capital
	University Industrial Collaboration
	Knowledge base
	Market
	Current Investment
	Uncertainty
	State of Technology
	Competition
	Government Policies
	Economics
	Funds
	Skills
	Demand
DIFFUSION	Innovation
	Uncertainty
	Communication Channels
	Rate of adoption
	Relative advantage
	Complexity
	Compatibility
	Cost
	Benefits
	Social Environment
GOVERNMENT POLICY	Trade Liberalization
	Funding
	Incentive
	Tax
	Intellectual Property

The factors gathered were many and to use of them would be a complicated process and would not be fruitful. According to [19][20][21], a computational model should a be simple consisting only significant factors. Thus, based on factors in Table 1, not all will be used to generate the computational model. The ones used are shown in Table 2.

Table 2 Parameter Abbreviation

Factors	Abbreviation
(INVENTION)	**INV**
Research and Development	Rd
Knowledge base	Kb
Patent right	Pr
(INNOVATION)	**INO**
Cost	Ct
Markets	Mk
Competition	Cm
Benefits	Bf
Price	Pc
(DIFFUSION)	**DIF**
Communication Channels	Cc
(GOVERNMENT POLICIES)	**GVP**
Taxes	Tx
Funding	Fd
Incentives	Ic
UTILIZATION	**UTZ**

In stage two (formalization), the relationships between technological change and telecentre effectiveness are constructed (Figure 1). The overall structure of the relationships represents the conceptual model. Based on Figure 1, Invention is referred to as an act or process of introducing something new or making a significant change to an existing system is a major factor that influence TC [10][14]. Invention can be affected by three external factors of Research & Dev, Technological Knowledge, Government Policy (Govt. Policy) and one internal factor, Innovation. Innovation in turn can be affected with the changes in Invention, Technological and Technological Knowledge. External factors, Costs, and internal factors, Innovation and Short Term satisfaction contribute to diffusion [12][13][14]. Short-term telecentre effectiveness is depends largely on Utilization and Satisfaction, and Long term Telecentre effectiveness is contributed by prolonged short term effectiveness [10][15][16].

A number of mathematical equations are established from Figure 1. These are:

$Iv(t) = w_{iv1} * Tk(t) + w_{iv2} * Gp(t) + Rd(t) * w_{iv3}$ Eq 1

$In(t) = Iv(t) * (w_{iv1} * Cb(t) + w_{iv2} * Tk(t) + Ts(t) * w_{iv3})$ Eq 2

$Df(t) = \beta * In(t) + ((1-\beta) * Ss(t)) * Cs(t)$ Eq 3

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

$Ss(t) = Qs(t) * Ic(t)$ Eq 5

$Ls(t) = Ls(t-1) + \tau * (Ss(t) - Ls(t-1)) * Ls(t-1) * \Delta t.$ Eq 6

$Su(t) = Ic(t) * (\Omega * Qs(t) + (1-\Omega) * Df(t)$ Eq 7

$Lu(t) = Lu(t-1) + \Omega * (Su(t) - Lu(t-1)) * Lu(t-1) * \Delta t.$ Eq 8

$Sv(t) = \gamma * Ls(t) + (1-\gamma) * Lu(t)$ Eq 9

$Lv(t) = Lv(t-1) + \sigma * (Sv(t) - Lv(t-1)) * Lv(t-1) * \Delta t.$ Eq 10

Eq 1 to Eq 10 shows relationships between factors. The following describes the relationships found in each equation:

Eq1 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 [13][14][17].

Eq 2 represents how technological sustainability, collaboration, Invention and technological knowledge enhance diffusion as well as the quality of service. As shown in Eq 3, 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 [10][18].

Eq 4 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 [4] .

Eq 5 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. The relationship in Eq 6 signifies an accumulated effect of *Ss* on *Ls* and *τ* was used to regulate the condition over time.

In Eq 7, *Qs* and *Ic* play a dependent role with Df on the realization of Su. 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. As for Eq 8, the equation signifies an accumulated effect of *Su* on *Lu* and Ω was used to regulate the condition over time. While, the relationship as identified by the Eq 9 denotes that, *Ls* and *Lu* play an independent role in the realization of *Sv*. Thus, short term effectiveness can be realized if any of those factors play role and *γ* is a constant used to regulate the condition. Eq 10 denotes that *Lv* is derived from the accumulated effect of *Sv*. Thus, Long term effectiveness can be realized if there is a progressive change in short term effectiveness and *σ* is a constant used to regulate the condition.

Based on the equations (Eq 1 to Eq 10), Matlab was used to simulate results. In order to regulate the various conditions depict by this 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 0.49 denoted low contributions, 0.5 is a moderate value while any values above 0.5 denote high contributions and 1 is the highest.

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 output of this phase is simulation traces and these results are shown in the following section.

3.0 SIMULATION RESULTS

Three major cases were simulated for telecentre effectiveness and the results for each scenario are shown below.

Scenario #1: High Effectiveness

In this scenario, effectiveness was examined by varying the impacts of the various factors. In order to realize high effective usage of telecentre, the impact of all the input variables (technological development, technological adoption, collaboration, favorable government policies, infrastructural sustainability change and individual commitment) denoting technological changes must be considerably high [10][16]. Table 3 present the input values used and Figure 1 shows the results.

Based on the Figure 2, 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 policy in terms of funding and reduction in tax rate as well as collaboration and individual commitment can play active roles in telecentre effectiveness. In addition, excellent technological adoption and moderate infrastructural facilities will definitely contribute to high effectiveness [21].

Table 3 Initial Values for Case 1

Factor	Values
Rd	0.9
Gp	0.8
Is	0.9
Cb	0.8
Tk	0.8
Ic	0.9

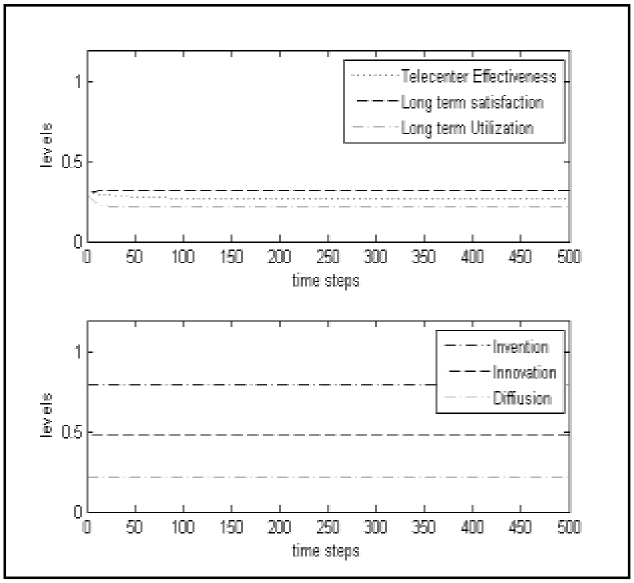

Figure 2 Case 1 Results

Scenario #2: Moderate Effectiveness
At this stage, variables are set to moderate levels in other to examine possible scenarios that yield moderate effectiveness. In order to have moderate effectiveness, the impact of the various factors may vary according to the assigned values described below. Table 4 present the input values used in this case. The results obtained is shown in Figure 3.

Table 4 Initial Values for Case 2

Factors	Values
Rd	0.6
Gp	0.5
Is	0.6
Cb	0.5
Tk	0.7
Ic	0.5

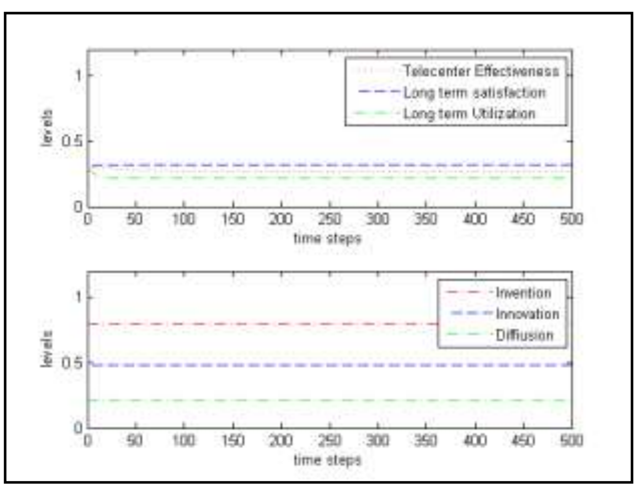

Figure 3 Case 1 Results

The results presented in Figure 3 showed that progressive changes in effective usages increases moderately when variables hold moderate values.

***Scenario* #3: Low Effectiveness**
Possible scenarios that can result to low effectiveness of telecentre is examined. This case aims to examine the effective usage of telecentre when variables are set to low levels. Table 5 presents the input values and Figure 4 shows the simulation results.

Table 5 Initial Values for Case 3

Factors	Values
Rd	0.2
Gp	0.2
Is	0.3
Cb	0.3
Tk	0.2
Ic	0.1

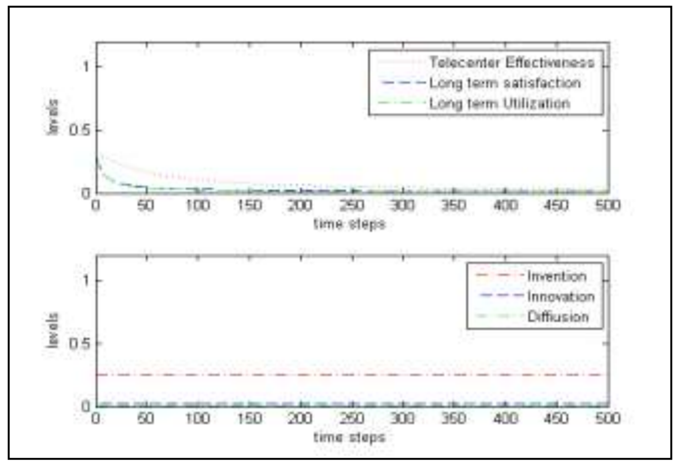

Figure 4 Case 3 Results

Results indicate that low changes in technology coupled with poor government and individual commitment will result to poor effective usage of telecentre.

4.0 VERIFICATION RESULTS

The mathematical verification technique has been adopted to evaluate the simulation model. The mathematical verification aims to proof correctness of the model when different conditions are applied [20]. The equations of the model are considered on the results of the simulation and on those related long term satisfaction, long term utilization, and long term effectiveness.

Thus, this was done by assuming constant values for all variables (including the external factors). 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:

$dLs(t)/dt = \tau ls * (Ss - Ls) * Ls * (1-Ls)$ .... (11)
$dLu(t)/dt = \omega lu * (Su - Lu) * Lu * (1-Lu)$ .... (12)
$dLv(t)/dt = \sigma tv * (Sv - Lv) * Lv * (1 - Lv)$ .... (13)

Next, the equations are identified describing:

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

Assuming the adaption rates for all the conditions is equal to 1, then, these are equivalent to:

$(Ss = Ls) \vee (Ls=0) \vee (Ls=1)$ ....(14)
$(Su = Lu) \vee (Lu=0) \vee (Ls=1)$ ....(15)
$(Sv = Lv) \vee (Lv=0) \vee (Lv=1)$ ....(16)

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 14). By combining these three conditions, it can be represented in a set of mathematical expression as:

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

$(Ss = Ls \vee Ls = 0 \vee Ls = 1) \wedge (Su = Lu \vee Lu = 0 \vee Lu = 1) \wedge$
$(Sv = Lv \vee Lv = 0 \vee Lv = 1)$ ....(17)

The expression can be further elaborated using Distributive Law. That is:

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

$(Ss = Ls \wedge Su = Lu \wedge Lu=0 \wedge Sv = Lv) \vee, ..,$
$\vee (Ls = 1 \wedge Lu = 1 \wedge Lv = 1)$ ……...(18)

This, therefore provide possible combinations of equilibria point that can be further analyzed. However, due enormous possibilities that can be inferred from 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 Eq 17, it follows that
$Sv = \gamma * Ls + (1-\gamma) * Lu$
Therefore, $Sv = Lu$.

Case #2: $Lu = 0$
From Eq 7, it means that
$Sv = Ls$

5.0 CONCLUSION

This study presents the simulation results through the implementation of the working parameters. The results of the simulation provided clear understanding of how the varying levels of TC can enhance or discourage the effective usage of telecentre. 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.

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