Mathematical Evaluation on Telecentre Effective Usage Model

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***Abstract*—In Malaysia, ICTs have been identified as a crucial enabler in the knowledge-based economy to facilitate the acquisition, utilization, and dissemination of knowledge towards enhancing the economic and social values of society. Numerous programmes have been organized, developed, designed and executed to optimize the usage of these ICT Public access centres (telecentres). This paper presents a computational model that addresses important factors contributing to the effective usage of telecentres. Simulation was used to show the behaviors produced by the model. Several cases of different scenarios showed various patterns being produced thus, indicating that the model is able to reproduce interactions among selected scenarios in the literature. In addition, the model was evaluated using mathematical analysis and automated verification.**

***Index Terms*—Mathematical Evaluation; Telecentre; Effective Usage Model.**

I. Introduction

Obtaining access to Information Communication Technologies (ICTs) and using them actively has been linked to the advantages of demographic and socio-economic characteristics, namely; income, education, geographic location (urban-rural), skills, awareness, political and cultural perspectives. In this context, it is equally important to ensure that all clusters of society in Malaysia have equitable access to ICT and have the adequate capacity to improve their socio-economic status, as a result from the digital access. To consolidate this initiative, the National Strategic Framework for Bridging the Digital Divide (NSF-BDD) was formulated [1]. The formation of ICT public access centres (telecentres) across the country is one of the initiatives under the NSF-BDD programmes. There are more than 2000 telecentres have been established to support the BDD programmes [2]. However, a number of telecentres have been under-utilized and even reaching a point of closure due to several factors. Thus, it is important to understand the underlying mechanism that leads to those events and take necessary steps to avoid the risk. The aim of this paper is to present a computational model that can be used to simulate the dynamics of telecentre effective usage as one of the methods to provide early insights of overall telecentre's operation and its possible outcomes.

II. Important Concepts in Effective Usage of Telecentre

There is a number of factors associated with users' attitudes and motivation towards telecentre usage [3]. These factors can be classified into three categories namely openness, readiness, and ICT programmes. In general, openness refers to a tendency to accept new ideas, methods, or changes. In the context of telecentre usage, Turpin and Ghimire [4] define it as the capacity of users to access and share information and applies it for productive practices. This includes the ability to comprehend the importance of ICT in achieving one's goal, acquiring ICT skills and knowledge, and participating in telecentre's activities [5]. ICT awareness is about the ability to understand the importance of ICT tools and applications and hence lead to the usage of ICT facilities [6,7]. ICT awareness therefore is characterized by their ability to use ICT facilities and applications to solve problems. In order to drive openness and ICT awareness, relevant ICT programmes have to be organized. The programmes serve as platforms to gain openness and ICT awareness [2].

The above-mentioned factors are related to perceived control, self-efficacy, competence and motivation as described by [3]. Perceived control refers to the ability of the users to readily acquire ICT skill and knowledge and seek to be more efficient in getting information and use the skills to improve their socio-economic well-being [3]. Self-efficacy denotes the users' ability to achieve the desired goals when they have the skills and knowledge in ICT. Competence factor reflects the users' needs to improve their technical skills and knowledge. Motivation factors are what motivate themselves in enriching their capabilities. These cover both intrinsic and extrinsic factors. In addition to those factors, other external factors that are pertinent to telecentre effective use are social and economic policy [8,9], external support [5,10], and community engagement [11].

Policies, both social and economic, that support such ICT-based projects indicate government's strong support and seriousness in the effort to leverage the ICT uptake by the rural dwellers [6,12]. Similarly, external support, particularly in terms of financial and responsible personnel from the government, private institutions and non-governmental organizations is also important in ensuring the life of a telecentre project [8,13,12].

In short, the following relations can be identified from the literature; (1) community engagement, policies (social and economic), support, and ICT programmes are among important external factors to ensure effective telecentre usage; (2) improvement in ICT awareness and ICT competence will increase community's motivation to deploy ICT in their daily living; (3) social and economic development are related to the executed policies, competence, support, community engagement; and (4) a combination of local long-term socio and economic development will reflect the effectiveness of telecentre usage.

III. MODELING APPROACH

The characteristics of the proposed model are based on the factors discussed in the previous section. These factors are translated into several interconnected nodes (Figure 1).

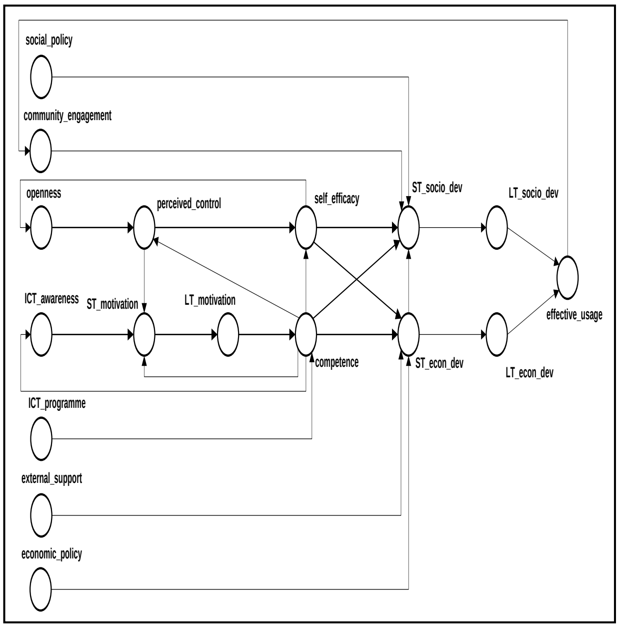

Figure 1: Conceptual Model Telecentre Effective Usage

The nodes are represented as variables that can contain values ranging from 0 (low) to 1 (high). The interaction will determine a new value, either by a series of accumulations (temporal relation) or an instantaneous interaction for each node. In this paper, only temporal relations are shown, namely; ICT awareness (*Ca*), community engagement (*Ce*), long-term economic (*Le*) and social (*Ls*) development, and effective usage (*Eu*). In addition, the rates of change for all temporal relationships are determined by flexibility parameters β_C, φ_C, β_L, θ_S, θ_U, respectively.

$$\frac{dCa(t)}{dt} = \beta_c.\left(Cp(t) - Ca(t)\right).\left(1 - Ca(t)\right) \qquad (1)$$

Here, ICT awareness level builds or reduces over time. When community programme *(Cp)* is higher than the ICT awareness level multiplied with the contribution factor, β_C then the ICT awareness level increases. Otherwise, it decreases depending on its previous level and contribution factor. This condition also can be used to explain the other temporal relations in accord with their respective parameters and attributes.

$$\frac{dCe(t)}{dt} = \varphi_c.\left(Eu(t) - Ce(t)\right).\left(Ce(t)\right).\left(1 - Ce(t)\right) \qquad (2)$$

$$\frac{dLe(t)}{dt} = \beta_L.\Big(\mathrm{Pos}\big(Ed(t) - Le(t)\big).\left(1 - Le(t)\right) - \mathrm{Pos}\Big(-\big(Ed(t) - Le(t)\big).Le(t)\Big)\Big) \qquad (3)$$

$$\frac{dLs(t)}{dt} = \theta_S.\Big(\mathrm{Pos}\big(Ss(t) - Ls(t)\big).\left(1 - Ls(t)\right) - \mathrm{Pos}\Big(-\big(Ss(t) - Ls(t)\big).Ls(t)\Big)\Big) \qquad (4)$$

$$\frac{dEu(t)}{dt} = \theta_u.\left(Sg(t) - Eu(t)\right).Eu(t).\left(1 - Eu(t)\right) \qquad (5)$$

$$Sg(t) = \left(\frac{1}{1+e^{-\alpha(Cb(t)-\tau)}} - \frac{1}{1+e^{\alpha.\tau}}\right).\left(1 + e^{-\alpha.\tau}\right) \qquad (6)$$

$$\text{and} \quad Cb(t) = \varphi_u.Ls(t) + (1 - \varphi_u).Le(t)$$

where α is a steepness factor, φ_u is a proportionate rate and τ a threshold parameter.

In this choice, a common practice is followed (logistic function) but other types of combination functions can be specified as well. The operator Pos for the positive part is defined by Pos$(x) = (x + |x|)/2$, or alternatively; Pos$(x) = x$ if $x \geq 0$ and 0 else. Using all defined formulas, a simulator has been developed for experimentation purposes; specifically to explore interesting patterns and traces that explains the behaviour of the formal model. All simulation results were generated and stored in spread sheets for further analysis.

IV. SIMULATION RESULTS

The proposed model was tested through several scenarios to generate a number of simulation traces. However, for the sake of brevity, only three types of scenarios are discussed: a realistic effective usage case (A), a one-off execution case (B), and a non-supportive case (C). The initial settings for ICT programme, external support, social and economic policies based on the three scenarios respectively are: A (consistent, consistent, high impact, high impact), B (one-off, one-off, low impact, low impact), and C (inconsistent, inconsistent, low impact, low impact). In addition, there are several dynamic parameters that were used to simulate different characteristics. These include the following settings: $t_{max} = 500$ (to represent a monitoring activity up to 730 days), $\Delta t = 0.3$, regulatory rates = 0.5, initial temporal values = 0.5, and flexibility rates = 0.2. These settings were obtained from several experiments to determine the most suitable values for the model. Figure 2 visualizes a condition when all external factors are consistent, for example, these are; 1) the ICT training programmes are organized as scheduled, 2) good support from various agencies, and 3) effective policies) [2,3,6,20,22].

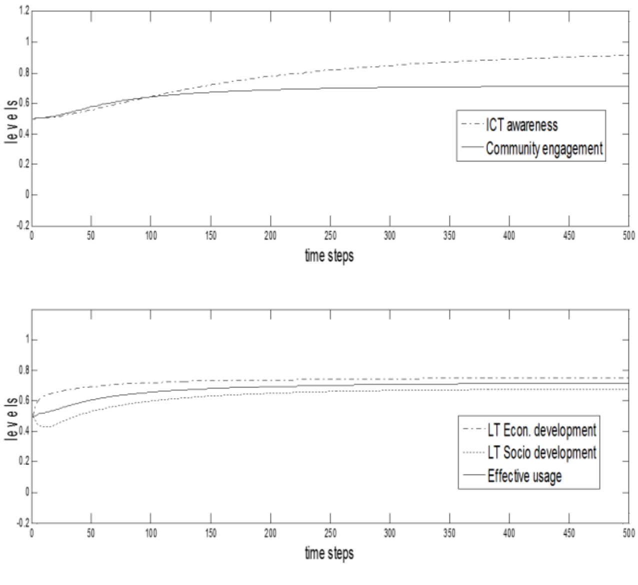

Figure 2: Simulation Trace for Case #1

Facing such encouraging conditions, it will later boost the development of both, social and economic development in the long run. As a result, the effective usage will increase, which later improve the effect of ICT usage through more positive community engagement. This condition occurs when members of the society believe that ICT usage gives more positive impacts towards improving their quality of life [3,20,23]. In Figure 3 different scenarios can be seen when a new kind of condition to simulate one-off training programmes and external support was introduced. This condition comprises of two parts: the first part is one with very high constant value (up to 90 time steps), and is followed by the second one, with a very low constant value (until the end of simulation steps).

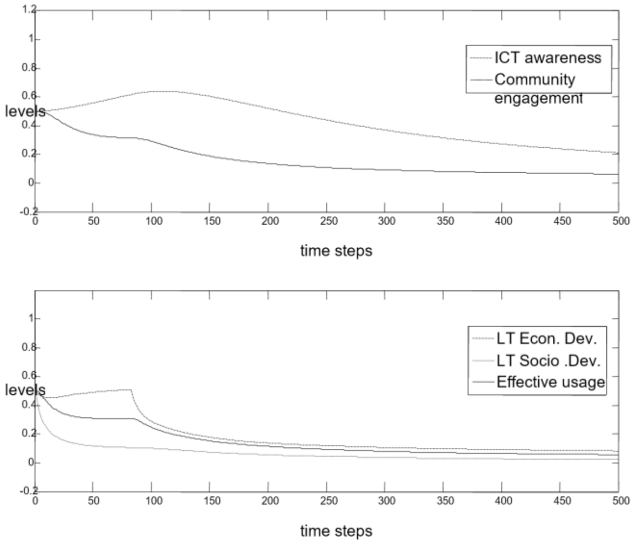

Figure 3: Simulation Trace for Case #2

The simulation results show that the ICT awareness and local economic development levels slightly rising up at the beginning of the simulation steps, and later gradually decreasing along with several other indicators [14,19,20,23]. It reflects a condition when the telecentre is no longer functioning to serve the community after its first inception. Moreover, a number of ineffectiveness of the telecentre usages can be traced back from this very problem. In addition, another case was simulated where all initial values were very low (Case # 3). The effective usage level in this case decreases which shows the direct impact of low ICT awareness and community engagement levels among the community [14,19,20,21,23]. This case represents the effect of having a telecentre just as a quick win project but there is no long-term plan being designed to support its operation [19,20,23]. In comparison to the real situation, to the knowledge of the authors, a model that represents the most of highlighted claimed cases was not yet available. However, there is an attempt to model the causal relationship of ICT intervention with quality of life [23]. Nevertheless, it is yet to be tested. This is an attempt to construct computational underlying properties through simulations and to evaluate these properties based on existing cases. Furthermore, this new concept explores to bridge different methods in investigating interesting phenomena in social sciences and humanities.

V. MATHEMATICAL ANALYSIS

This section addresses the formal analysis of the mathematical model and the simulation results presented above by means of a mathematical analysis of the equilibria of the model. The equilibria describe situations in which a stable situation has been reached. Those equilibria are interesting as it should be possible to explain them using the knowledge of the domain that is modelled [11,15,16]. As such, the existence of reasonable equilibria is an indication for the correctness of the model. To analyze the equilibria, the available temporal and instantaneous equations are filled with values for the model variables such that the derivatives or differences between time point t and $t + \Delta t$ are all *0*. The dynamic part of the model written in differential equation format is as follows:

$$\frac{dOp(t)}{dt} = \gamma_o.\left(Se(t) - Op(t)\right) \tag{7}$$

$$\frac{dCa(t)}{dt} = \beta_c.\left(Cp(t) - Ca(t)\right).\left(1 - Ca(t)\right) \tag{8}$$

$$\frac{dLm(t)}{dt} = \varphi_l.\Big(Pos\big(Sm(t) - Lm(t)\big).\big(1 - Lm(t)\big) - Pos\Big(-\big(Sm(t) - Lm(t)\big).Lm(t)\Big)\Big) \tag{9}$$

$$\frac{dCp(t)}{dt} = \alpha_c.\Big(\big(\sigma_c.Lm(t) + (1 - \sigma_c).Cr(t)\big) - \theta_c.Cp(t)\Big).\big(1 - Cp(t)\big).Cp(t) \tag{10}$$

$$\frac{dCe(t)}{dt} = \varphi_c.\left(Eu(t) - \beta_c.Ce(t)\right).\left(Ce(t)\right).\left(1 - Ce(t)\right) \tag{11}$$

$$\frac{dLs(t)}{dt} = \beta_l.\Big(Pos\big(Ed(t) - Ls(t)\big).\big(1 - Ls(t)\big) - Pos\Big(-\big(Ed(t) - Ls(t)\big).Ls(t)\Big)\Big).Ep(t) \tag{12}$$

$$\frac{dLe(t)}{dt} = \theta_S.\Big(Pos\big(Ss(t) - Le(t)\big).\big(1 - Le(t)\big) - Pos\Big(-\big(Ss(t) - Le(t)\big).Le(t)\Big)\Big).Sp(t) \tag{13}$$

$$\frac{dEu(t)}{dt} = \theta_u.\left(Sg(t) - Eu(t)\right).Eu(t).\left(1 - Eu(t)\right) \tag{14}$$

For an equilibrium it has to hold that all of the derivatives are zero:

$$\frac{dOp(t)}{dt} = \frac{dCa(t)}{dt} = \frac{dLm(t)}{dt} = \frac{dCp(t)}{dt} = \frac{dCe(t)}{dt} \tag{15}$$

$$= \frac{dLs(t)}{dt} = \frac{dLe(t)}{dt} = \frac{dEu(t)}{dt} = 0 \tag{16}$$

Assuming all parameters are nonzero, this provides the following equilibrium equations:

$$Pos\big(Sm(t) - Lm(t)\big).\big(1 - Lm(t)\big) = 0 \tag{17}$$

$$-Pos\Big(-\big(Sm(t) - Lm(t)\big).Lm(t)\Big) = 0 \tag{18}$$

Notice that Pos(x) > 0, so Equation 17 is equivalence:

$$Pos(Sm - Lm).(1 - Lm) - Pos(-(Sm - Lm).Lm) = 0 \tag{19}$$

This provides cases:

$$(Sm \leq Lm \wedge Sm \geq Lm) \vee (Sm \leq Lm \wedge Lm = 0) \vee (Lm = 1 \wedge Sm \geq Lm) \vee (Lm = 1 \wedge Lm = 0) \tag{20}$$

The latter case cannot exist, and as $0 \leq Lm \leq 1$ the other three cases are equivalent to $Sm=Lm$. Table 1 provides the summarization of these equillibria.

Table 1
Equilibrium Equations for Respective Variables

Concept	Equilibrium
Op	*Se = Op*
Ca	*Cp =Ca or Ca =*1
Lm	*Sm = Lm*
Cp	$(\sigma_c Lm - (1-\sigma_c).Cr)/\theta_c$ or *Cp = 1 or Cp=0;* $\theta_c \neq 0$
Ce	Eu/β_c or *Ce* = 0 or *Ce*=1; $\beta_c \neq 0$
Ls	*Ed=Ls* or *Ep=0*
Le	*Ss=Le or Sp =0*
Eu	*Sg=Eu* or *Eu=0* or *Eu=1*

Note that for each of the distinguished cases, further information can be found about the equilibrium values of other variables using the other non-dynamic-equations. Theoretically spoken this amounts to almost $8^4 = 256$ possible equilibria. Note that the last equation (24) is isolated from the others, and therefore can be handled separately. But for the other three still 27 possibilities remain. Also given the other Equations (13) to (20) with the 10 input variables, this makes it hard to come up with a complete classification of equilibria. However for some typical cases the analysis can be pursued further.

Case #1: *Se=Op*
$Pc = w_c.Cp + w_o.Se$
$Ss = (\rho_d.(w_d.Ed + w_s.Ce) + (1-\rho_d).(w_e.Op + w_p.Cp)).Sp$

Case #2: $Ce = Eu/\beta_c$
$Ss = (\rho_d.(w_d.Ed + w_s.Eu/\beta c) + (1-\rho_d).(w_e.Op + w_p.Cp)).Sp$

Case #3: $Cp = (\sigma_c Lm - (1-\sigma_c).Cr)/\theta_c$
$Sm = \rho_s.Ca + (1-\rho_s).(\sigma_c Lm - (1-\sigma_c).Cr)/\theta_c$
$Se = \alpha_s.(\sigma c Lm - (1-\sigma c).Cr)/\theta c + (1-\alpha_s).Pc$
$Pc(t) = w_c.(\sigma c Lm - (1-\sigma c).Cr)/\theta c + w_o.Op$

VI. AUTOMATED VERIFICATION

In order to verify whether the model indeed generates results that adhere to related cases, a set of properties have been identified from related literatures. These properties have been specified in a language called Temporal Trace Language (TTL).The special software environment developed for TTL, features both a Property Editor for building and editing TTL properties, and a Checking Tool that enables formal verification of such properties against a set of (simulated or empirical) traces [8]. This checking tool provides support for the automated analysis of simulated traces. A number of simulations including the ones described in previous section have been used as basis for the verification of the identified properties and were confirmed. Note that *tb* and *te* are the initial and final time points of the simulation period.

A. VP1: Monotonic Increase of Effective Usage

For all time points t1 and *t2* between *tb* and *te* in trace γ1 if at t1 the value of the effective usage is R1 and at t2 the value of the effective usage is R2 and t1 < t2, then R1 ≤ R2.

VP1 ≡∀γ: TRACE, ∀R1, R2: REAL, t1,t2:TIME, ∀A1:AGENT
[state(γ,t1)|= effective_usage(A1, R1) & state(γ,t2)|= effective_usage (A1, R2) &
tb ≤ t1 ≤ te & tb ≤ t2 ≤ te & t1< t2 ⇒ R1 ≤ R2]

By checking property VP1, one can verify whether the effective usage increases monotonically over a certain time interval. For example, when the four exogenous factors out to increase over the second half of the trace, the telecentre effective usage level will also increase gradually throughout time [3,12].

B. VP2: Monotonic Decrease of Effective Usage for Any Telecentre Operation When Inconsistent Programmes Exogenous Factors Have Been Implemented.

When the inconsistent programmes occur for ICT programme and external support, and low impact social and economic policies have been implemented throughout time, then it will reduce the level of telecentre effective usage in future.

VP2 ≡ ∀γ:TRACE,t1,t2:TIME,D1,D2,E1,E2,F1,F2,G1,G2,H1, H2:REAL,X:AGENT
[state(γ, t1)|= ICT_Programme(X, D1) & state(γ, t2)|= ICT_Programme (X, D2) & state(γ, t1)|= External_Support(X,E1) & state(γ, t2)|= External_Support (X,E2) & state(γ, t1)|= Socio_Policy(X,F1) & state(γ, t2)|= Socio_Policy (X,F2) & state(γ, t1)|= Economic_Policy(X,G1) & state(γ, t2)|= Economic_Policy (X,G2) & state(γ, t1)|= Effective_Usage (X,H1) & state(γ, t2)|= Effective_Usage (X,H2) & t' > t &
D1 ≥ D2 & E1 ≥ E2 & F1 ≥ F2 & G1 ≥ G2] ⇒ H1 ≥ H2

Property VP2 can be used to verify telecentre effective usage condition when the exogenous factors (e.g., ICT programme, external support, social and economic policies) that cause effective usage of telecentre operation are decreasing throughout time [6,14,18].

VII. CONCLUSION

In this paper, an approach to model behaviors on telecentre's effective usage is presented. The computational model was simulated using three different cases that describe the level of positive and negative contribution towards telecentre's effective usage over time. The simulation traces exhibit patterns that are consistent with reports found in past literatures. The resulting model can be considered as an alternative method to analyze a telecentre's effective usage when various scenarios occur. This could also provide a basis for conducting an inception study to understand the working model of related telecentre's operation.

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REFERENCES

[1] Yogeesvaran, K., 2007. National Strategic Framework for Bridging Digital Divide and the Need for Upgrading and Expanding ICT Infrastructure, MyBroadband 2007 Conference & Exhibiton MATRADE Exhibition Convention Centre, Kuala Lumpur, Malaysia.
[2] Ibrahim, Z., A. Sulaiman, and T. M. Faziharudean. 2002. The Roles of Community Based Telecenters in Bridging the Digital Divide in Rural Malaysia, *World Academy of Science, Engineering and Technology*.
[3] Zahurin, M. A., S. O. Wan Rozaini, M. Y. Shafiz Affendi, and Y. Nor Iadah. 2010. A Conceptual Model for Psychological Empowerment of Telecentre Users, *Computer and Information Science*. 3(3): 71-80.
[4] Turpin, T. and A. Ghimire. 2012. The Social Dynamics Underpinning Telecentres in Nepal: Feedback and Absorptive Capacity in a National Innovation System. *Science Technology Society*. 17 (2): 275-294.
[5] Colle, R. 2005. Memo to Telecentre Planners. Electronic *Journal of Information Systems in Developing Countries*. 21(1): 1–13.
[6] Azman, H., Z. Amir, T. Maasum, S. H. Stapa, J. Mustafa, K. Ibrahim, N. A. Zabidi, and N. M.Yusof. 2008. Social transformation for the 21st century: Impact of e-Community Centers on E-literacy in Rural

Malaysia, *International Symposium on Information Technology (ITSim 2008)*, 3. 1-8.

[7] Lwoga, E. T. A.S. Sife, L.S. Busagala, and W. Pand-Chilimo. (n.d.). The Role of Universities In Creating ICT Awareness, Literacy and Expertise: Experiences from Tanzanian Public Universities, Universities Taking a Leading Role in ICT Enabled Human Development. *Directorate for ICT Support*. 35-41.

[8] Kumar, R. and M. L. Best. 2006. Social Impact and Diffusion of Telecenter Use: A Study from the Sustainable Access in Rural India Project. *The Journal of Community Informatics*. 2(3).

[9] Walsham, G. 2010. ICTs for the Broader Development of India: An Analysis of the Literature. *The Electronic Journal on Information Systems in Developing Countries.* 41(4):1-20.

[10] Proenza, F. 2001. Telecenter Sustainability: Myths and Opportunities. *Journal of Development Communication*. 12(2):110–24.

[11] Rao, S. S. 2008. Social Development in Indian Rural Communities: Adoption of Telecentres. *International Journal of Information Management*. 28:474–482.

[12] Gurstein, M. 2003. Effective Use: A Community Informatics Strategy Beyond the Digital Divide. *First Monday*. 8(12).

[13] Fatuma, S. 2010. Modeling Connectivity for e-Learning in Tanzania : Case-study of Rural Secondary Schools. *Blekinge Institute of Technology Licentiate Dissertation Series*. 1650-2140.

[14] Nor Iadah, Y., M. A. Zahurin, I. Huda, A. R. Rafidah, and S. O. Wan Rozaini. 2007. Rural Internet Centre (RIC) as Catalysts for Building Knowledge-based Society: The Case of Northern States of Malaysia, in *D. Schuler (ed) Online Communities and Social Computing*. 485-490.

[15] Nor Iadah, Y., M. Y Shafiz Affendi, M.A. Zahurin, I. Huda, K. Mohd Khairudin, M. D. Zulkhairi, A.G. Nor Farzana, A. R. Rafidah, H. Syahida and R. Abdul Razak. 2010. The influence of community characteristics towards telecentres success. *Computer and Information Science*. 3(2):116-120.

[16] Norizan, A. R. 2009. Empowering the Rural Communities via the Telecentres. *European Journal of Social Sciences*. 9(3).

[17] Bosse, T., C. M. Jonker, M. L. Van Der and J. Treur. 2007. A Language and Environment for Analysis of Dynamics by Simulation. *International Journal of Artificial Intelligence Tools*.16:435-464.

[18] Eason, G., B. Noble and I. N. Sneddon. 1955. On certain Integrals Of Lipschitz-Hankel Type Involving Products Of Bessel functions. *Phil. Trans. Roy. Soc. London*. A247: 529-551.

[19] Sumbwanyambe, M. A. Nel and W. Clarke. 2011. Challenges and Proposed Solutions towards Telecentre Sustainability: A Southern Africa Case Study. *IST-Africa Conference Proceedings, IEEE*.1-8 (2011, May).

[20] Attwood, H., K. Diga, E. Braathen and J. May. 2013. Telecentre Functionality In South Africa: Re-Enabling The Community ICT Access Environment. *The Journal of Community Informatics*. 9(4).

[21] Mohamad, A. B., I. Huda, K. Mohd Khairudin, Y. Nor Iadah, M. A. Zahurin, M. D. Zulkhairi and Y. Azman. 2013. Community Characteristics for Self- Funding and Self-Sustainable Telecenter. *AWERProcedia Information Technology & Computer Science*. 3:1666-1671. [Online], From: http://www.world-education-center.org/index.php/P-ITCS. [Accessed on 26 October 2015]

[22] Meng, C. C., B. A. Samah and S. Z. Omar. 2013. A Review Paper: Critical Factors Affecting the Development of ICT Projects in Malaysia. *Asian Social Science*. 9(4):42.

[23] Attwood, H., K. Diga, and J. May. 2014. The complexities of establishing causalit y between an ICT intervention and changes in quality of life: CLIQ in South Africa. *ICT Pathways to Poverty Reduction*. 179.