

A Conceptual Model for ICT for Economic Development Using Complex Adaptive System Approach: Case of a Micro and Small Enterprise (MSE) Association

MINDILA A. N[‡], RODRIGUES A.J., MCORMICK D., MWANGI, D.W

ABSTRACT

The purpose of the paper is to contribute towards providing a methodology which researchers in Information and Communication Technology (ICT) for development can use to design result-oriented programs. In this paper CAS theory is presented as the underlying theory for ICT for economic development. Complex Adaptive System (CAS) theory has been used to assist in understanding and managing complexity (Holland 1992; Fuller and Moran 2001] in many fields. The paper presents a conceptual model for ICT for economic development, a theoretical model, emanating from complexity science that treats economic development in firms or communities of practice as CASs offering an inter-disciplinary approach that is holistic as opposed to reductionist. This conceptual model is a convergence of theories in development. The convergence and integration is not a mere aggregation or addition of the theories, but the model provides a framework within which the variables identified by the different theories interrelate dynamically, influence each other and display a new ontology within which to analyze ICT for economic development. The theoretical model conceptualizes ICTs as interventions at influence points in a CAS (Parsons and Hargreaves 2009] and captures their role in structural transformation. The theoretical model is a convergence, reconciliation and integration point for theories in development. The implication of developing the ICT for economic development conceptual model means that the operationalization of the variables emanating from many theories used and the influence of specific ICTs on the model components needs to be addressed in further research. The conceptual ICT for economic development model contributes to the wide search for appropriate methodologies by researchers in ICT for development.

Keywords: Complexity, CAS, development theories, economic development, ICT

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1.0 INTRODUCTION

Economic development as a field has taken on different view points from researchers. There has been an attempt to transform neo-classical theories of growth into theories of economic development based on the assumption that the processes of economic growth are synonymous with the processes of economic development (Brinkman and Brinkman 2001). As a result, most research done in the field of ICT for development placed emphasis on increases in income per capita, productivity, high levels of savings and job creation (Gholami et al. 2005; Lee et al. 2005) using economic growth theories as the point of reference. Todaro and Smith (2006) similarly raise concern over the

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underlying theories used for economic development. In their work they argue that unlike economic growth which is a stage, economic development is a process that would involve change that includes an entire social system characterized by structural transformation and evolution.

Speaking of development evolving its own distinctive analytical and methodological identity is a truism especially if researchers in ICT have to successfully realize the true analysis of the impact of ICT on development. Researchers like Kleine (2009) have expressed the same concern arguing that development should be thought of in a more holistic way so that the impact of ICT can be correctly analyzed. Choudhury and Hogue (2004:801) commenting on methodologies used for analyzing economic development state that “Mathematical models that do not take explicit account of interactions in domains of culture and institutional interventions cannot act as guide to policy formulation”. Todaro and Smith (2006) argue that development is a field with emerging theories and data that challenge the traditional thinking.

The focus then for ICT for development researchers should then shift from achieving the stages within development to understanding how structural transformations occur and focusing on the role that ICT plays. The complexity of the entire social system should not necessarily be a reason for researchers not to evaluate economic development as it ought to be. Misrepresentation makes countries work with policies and strategies that are misleading ultimately dragging efforts towards economic development. This then implies that for economic development to be assessed it has to be done in a different space from that of economic growth and key ideas that need not be dropped include “entire social system”, “the whole gamut of change” “transformation in structures” and “greater resources and choices”. This sends the researchers in ICT to rethink the base theories they chose to use to evaluate ICT for economic development. The results, impacts, interventions, programs and policies of ICT for development presented to policy makers can be misleading if research is not anchored on the right theories. This calls for a complete paradigm shift, where appropriate theories are needed whatever difficulties the analysis may present. Alternative theories and methodologies are required where the focus is an entire social system and its change and the place of ICT in the entire social system and its change. The practitioners, researchers and multilateral agencies of development are grossly optimistic about the potential of ICT for addressing development needs of enterprises in developing countries. Yet there is a lot of struggle in legitimizing ICT in development (Kleine, 2009).

ICT should be looked at as a player in the restructuring process and hence one that contributes to development through bringing about transformation, metamorphosis and structural transformation. Though ICT remains a key driver of productivity growth, it is the transformation of economic activity in response to the forces of ICT that generates the greatest gain because it enables transformation and restructuring of economic agents (Asia Pacific Economic Cooperation Secretariat 2001]. The difficult in methodologies and analysis are a great setback, yet if we are to talk about economic development then we cannot avoid the entire social system which is usually characterized by social capital, institutions, interactions, cultural issues, learning and innovations (Piasecki and Wolnicki 2004] and its change.

Through content analysis of researcher’s views and arguments this paper provides a working definition of ICT for economic development using CAS approach which in ICT for development research is a big step towards shaping its methodology. The struggle by development scholars with various multi-dimensional definitions of ICT for development will undoubtedly continue but this paper makes a contribution to ICT for development definition using CAS. Scholars in ICT for development using this definition of economic development as a CAS can adjust the methodologies they use to justify their work in development and be clear when they say ICT for development.

2.0 THEORY AND METHODOLOGY

This paper presents a conceptual model for ICT for economic development based on Complex Adaptive System (CAS) theory that was put forward formally in 1994 by John H. Holland (Li-qing and Shao-Rong 2007). A CAS as explained by Holland (1992) is a system that displays an evolving structure, where it changes and reorganizes its components to adapt to the surrounding.

Viewing economic development as a CAS disputes theories that advocate for linearity, order, predictability and knowable universal laws (Rihani, 2002). Rihani (2002) posits that the development process is a CAS because its behavior is defined to a large extent by local interactions between elements. Considering ICT for economic development as a CAS implies that we are considering a system with many elements involved in simultaneous interactions. As the elements interact they learn, adapt, change, evolve and reconstruct in response to internal and external inputs. That such a system has rules of interaction which are continuously revised as the elements interact. A CAS is non-linear and hence causality can only be understood by analyzing the complexity of interconnections among the variables in the system. It is a system that moves from one state to another with a sensitive dependence to

initial conditions (Holland 1992; Mendenhall and Macomber 1997; Capra 1996; Mendenhall et al. 2000; Lichtenstein 1997; Rihani and Geyer 2001).

De-lu et al. (2008) posit that a CAS has states of control parameters which include information flow rate, contact degree, level of anxiety inhibition and difference in the degree of power. These factors are important control points of a CAS. Parsons and Hangreaves (2009) refer to these factors as points of influence in a CAS and speak of boundaries, relationships, differences in levels of energy, dynamic deep structures and processes and underlying rules.

Employing the underlying concepts in CAS theory as conceptualized by researchers in the field of CAS, systematic conceptual models were developed that captured economic development as a CAS. ICT for economic development conceptual model was developed that draws its existence on the arguments of De-lu, et al. (2008) and Parsons and Hangreaves (2009) concerning control parameters and influence points in a CAS.

3.0 CONCEPTUAL MODEL

The theoretical model emanating from complexity that treats economic development in firms/communities of practice/networks of practice as CASs offers an inter-disciplinary approach that moves away from reductionism to holism. This conceptual model is a convergence of theories in development. The convergence and integration is not a mere aggregation or addition of the theories, but the model provides a framework within which the variables identified by the different theories interrelate dynamically, influence each other and display a new ontology within which to analyze economic development. Amartya Sen's capability approach (Sen 1999; Zheng 2009), institutional change theory (Campbell 2004; North 1996; Buitelaar 2007), structurization theories (Giddens 1984), social contingencies theories that contain social capital theories (Marshall 2004; Gefen 2002; Pavlou et al. 2003) network (Marshall 2004; Pang 2008; Pfohl and Buse 2000) and cluster theories (McCormick et al. 2003), learning and knowledge theories (Archibugi and Coco 2005; Tommassini 2002; Wasko 2005) and strategic management theories (De-lu et al. 2000) all converge into the CAS framework for economic development. They all seem to converge and interrelate in a CAS because the theories have been considered as CAS by researchers.

Resource-Based View (RBV) of the firm in strategic management literature focuses on firm internal endowments in terms of resources, capabilities and dynamic capabilities for their growth and development (Porter, 1985). De-lu et al.(2008) writing on the same, views strategic flexibility as a Complex Adaptive System (CAS) that consist of both the adaptive agents (the firms and individuals) and flexible elements that include resource flexibility, capability flexibility, organization flexibility and production flexibility. By establishing a learning mechanism, where they are able to adapt and influence the environment, enterprises build a dynamic competence and sustainable competitive advantage. Resources are stocks of available factors that are owned or controlled by a firm or community whereas resource flexibility means available resources and those not available currently but which communities could use by taking certain actions (De-lu et al. 2008). This takes in cognizance the complex interaction of external structural factors and internal dynamics of the firms. The interaction provides the firms with an opportunity to take certain actions that leverage on their actual endowment. Considering the system that a firm finds itself operating in as a CAS presents a methodological solution which strategic management scholars can employ to analyse the extent of importance of the strategic flexibility of firms or enterprises.

Social contingencies theories on the other hand provide the starting point of a CAS, where a myriad of interactions is expected. The myriad of interactions cannot happen without social contingencies. The social contingency conceptual model is based on social contingency theories that consist of network and clusters theories, social capital theories and trust theories. Network and cluster theories argue that firms may choose to collaborate for a joint purpose or they may find themselves collaborating as a requirement (McCormick et al. 2003). This means that inter-organizational networks may be in the form of business associations, labor unions, civic associations, welfare organizations, research consortiums, outsourcing arrangements and franchises (Marshall 2004; Moyi 2003; McCormick et al. 2003). Researchers in this field have suggested that firms associate or collaborate for reasons that include and not limited to: (a) Overcoming asymmetries (b) Increasing individual power in negotiations and lobbying with government, unions and other interest groups (c) Pooling resources and share administrative costs (d) Gaining legitimacy, image and visibility (e) Sharing skills and knowledge (f) Attaining economies of scale on the matters of procurement, loan acquisition and insurance plans, fundraising (g) Attain collective action so as to stabilize resource flows, cycles and other uncertainties by standardizing procedures (h) Training (i) Increase their power in the market and (j) Providing market information (Fountain 2001; McCormick et al. 2003).

On the other hand networks can be consciously formed to effectively assist in the solution of collective problems and in the promotion of collective learning and institutional building. For either occasions, whether by necessity or consciously formed, the networks need to be open, with strong social capital so as to ensure continuous learning and

institutionalization of collective action (Elsner, 2004). What keeps the networks together is what researchers have referred to as social capital. People still share because of collective action and they forego the tendency to free ride due to the influence of social capital. Social capital has been defined as the presence of effective human networks and social cohesion, which are manifested in effective institutions and processes where people can co-operate for mutual advantage (Landman, 2005). Social capital is characterized by generalized trust, anticipation of reciprocity, agreed social norms, participatory and transparent decision making and leader accountability (Allen et al. 2005). Development experts note the importance of social capital as a foundation for economic development. Social capital resides in the fabric of the relationships between individuals and in individual's connections with their communities (Putnam, 1995).

Institutional change theories for development explain what Complex Adaptive System (CAS) theory refers to as a systems ability to evolve where it is able to learn, adapt, change, and reconstruct itself in response to external and internal environmental inputs. CAS theory further argues that a system evolves by credit assignment and rule discovery (Mendenhall and Macomber 1997; Capra 1996; Holland 1992). The system continually revises its rules of interaction because each element is embedded in perpetually novel surroundings arising from the changing behavior of the other elements (Rihani 2002; Holland 1992). The rules are made up of smaller pieces or building blocks, the way the building blocks are discovered and recombined bring about newly invented rules that are better. This description depicts similarities with institutional change theories. Campell (2004) attributes institutional change to a mechanism called bricolage. This concept of bricolage focuses attention on a creative process in which actors, referred to as institutional entrepreneurs or bricoleurs, make decisions about how to improve and recombine the institutional elements at their disposal. These are described as creative and innovative persons who are strategically positioned within a set of relations and institutions, who discover and recombine rules in essence innovating new ways of doing things.

Another characteristic of a CAS is its ability to learn and adapt (Holland 1992; Mendenhall and Macomber 1997; Capra 1996; Mendenhall et al. 2000; Lichtenstein 1997). Wu Tong (2002) and McElroy (2000) posit that knowing and learning are delivered in a Complex Adaptive System (CAS) environment Learning involves relationships that provide mechanisms by which knowledge is communicated and adopted because knowledge exists within and between individuals and within and between any groups. The learning process is characterized by dropping or adding particular relationships and as this process continues culture is created and maintained (Reich and Kaarst-Brown 2003). It is the learning that facilitates enterprise growth and development (Styhre, 2003).

This implies that knowledge activities are dynamic in nature in the sense that they are embedded in social relationships. It involves a myriad of agents involved in interactions that results in self re-organization of knowledge and integration. Knowledge emerges in the culture, practices and concepts used by the agents involved in the interactions (Wu Tong 2002; McElroy 2000; Lin and Tseng 2005; Tommassini 2002).

All these theories have been presented by development scholars as key for development in enterprises and communities of practice. This paper seeks to reconcile theories in economic development ascertaining the place and importance of each one of them. This is made possible by taking up a system thinking approach and viewing economic development as a Complex Adaptive System (CAS). The theoretical model emanating from complexity that treats economic development in firms/communities of practice/networks of practice as Complex Adaptive Systems (CASs) offers an inter-disciplinary approach that provides a framework within which convergence of theories in development is provided.

3.1. Economic Development as a CAS

Figure 1 presents an instance of economic development, in a situation where economic development is considered as a CAS. The system aspires to reach a state never reaching but always approaching. Two agents are represented but in a real situation the agents are many.

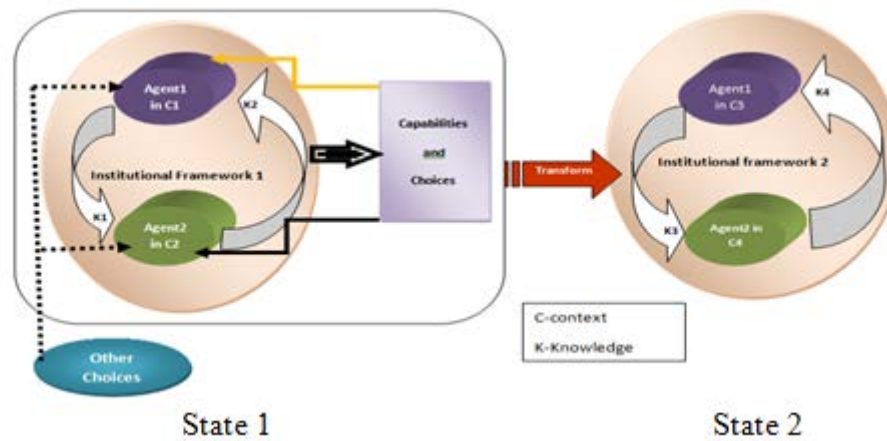


Figure 1. An integrated CAS theoretical framework for economic development in enterprises/communities of practice/networks of practice.

The two agents 1 and 2 are live and adaptive. The agents in this case could be a Medium and Small Enterprise (MSE) and agent 2 could be a micro finance institution that the MSE is engaged with. The agents engage in an array of simultaneous interactions, these simultaneous interactions are initiated and sustained by social contingencies. The agents are immersed in a myriad of different contexts, represented as C1 and C2. The context in this case represents capabilities, resources and features and what Sen's capability model refers to as a vector of commodities and what strategic management theories refer to as strategic flexibility that takes into account the endowments of the community/enterprise and other endowments it can access courtesy of its connections (Sen 1999; De-lu et al 2000). When the agents interact they exchange knowledge. When knowledge is exchanged, learning occurs. Learning that occurs through exchange of knowledge is externally enabled which in CASs is referred to as rule discovery or what is referred to as bricolage in institutional change theory (Campbell 2004; Lichtenstein 1997). This is when new knowledge is combined with what an enterprise has to create new knowledge. Without the external input the system continues to learn by improving its internal processes and routines which is referred to as credit assignment (Lichtenstein, 1997). The interaction, knowledge exchange and learning all occur in an institutional framework which defines the rules of exchange. What the capability approach calls conversion factors are represented by the social contingencies, institutional framework, knowledge and learning. When exchange of knowledge and learning occurs the agents are exposed to new capabilities which they can choose. What the agents decide to choose at any particular time forms what the capability approach refers to as vector of functionings whereas the CAS calls a state (Sen 1999; Holland, 1992). The agents are always transiting from one state to another as shown in figure 1. The transition is non-linear depends on feedback and as one variable changes the rest of the variables in the system are affected. The system evolves into new structures, the institutional framework evolves, the capabilities evolve, the resources evolve, the features evolve, the knowledge base evolves, learning capability evolves, the social contingencies evolve etc. This act of evolving and creating new structures is economic development.

When ICT for economic development is analysed, it is analysed within this economic development theoretical model which is a CAS. Rihani (2002) posits that interventions in a CAS are those small interventions in terms of allowing interactions to proceed freely, openly internally within the agents and externally between the agents. Any intervention in the CAS can be influential because it can cause patterns to be shifted. Parsons and Hargreaves (2009) argue that many points of influence exist in a CAS and recognizing the characteristics of each point of influence expands one's range of options. When analyzing a situation to understand possible points of influence one has to think in terms of boundaries, differences in levels of energy (in this case it is differences in knowledge) and relationships (interconnections and exchanges). The rules that define the structure are also points of influence. It is important to identify points of influence that make up the deep structures that underpin the dynamics of a system.

Based on the concept of interventions in a CAS, where economic development is the CAS for the study, the points of influence need to be clearly marked. Once the points of influence are identified then interventions can be made. This study treated ICTs as interventions at the points of influence in order to understand and achieve ICT for economic development.

3.2. Convergence of Development Theories

The CAS theoretical framework for economic development encompasses Amartya Sen's capability approach, institutional change theory, structurization theories, social contingencies theories that contain social capital theories,

network and cluster theories, learning and knowledge theories and strategic management theories. These theories enable movement of the CAS in figure 1 to move from state 1 to state 2. The way in which these theories interrelate is captured in Figure 2.

Social contingencies mechanism base model would define interactions and elements in a CAS. They involve social capital theories and network and cluster theories. Positive institutional change base model in a CAS would represent the rules of engagement, rule discovery and credit assignment which would encompass structurization theories and institutional change theories. Strategic flexibility base model represents the context or initial conditions which are actualized through Sen's capability theory and strategic management theory. Knowledge identification and management would be represented by adaptation and learning in a CAS and actualized by knowledge and learning theories.

The above paragraph attempts to atomize the components for the sake of understanding but in the real world they have a holistic look that gels together as in figure 1 and 2. The moving from one state to another is also explained in Sen's capability theory and institutional change theory.

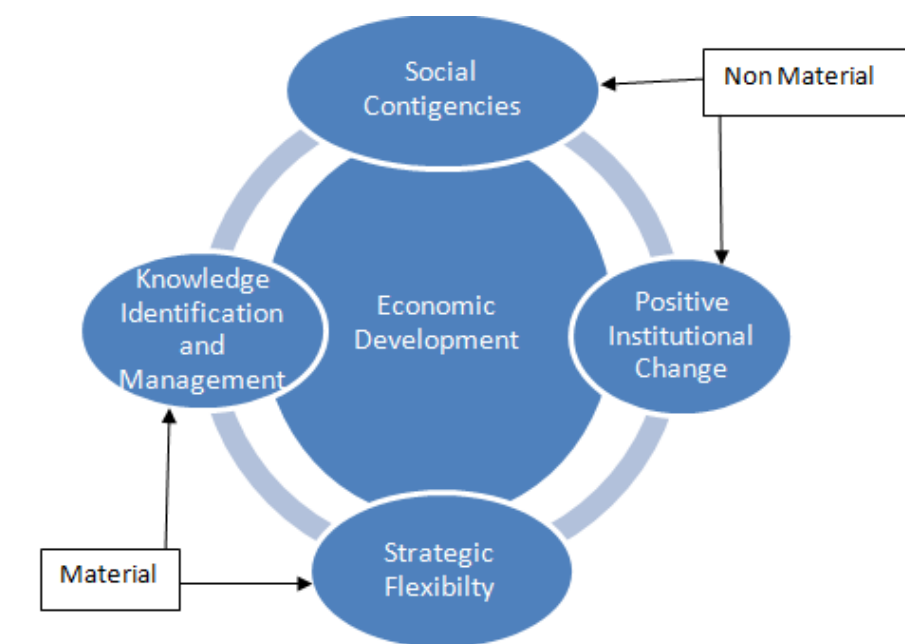


Figure 2: The convergence of development theories in a CAS for economic development

The processes involved in Figure 2 behave as a CAS and are occasioned by interaction of agents that are heterogeneous in nature. These could be organizations, people, technology and others as defined by the situation at hand. The links between the agents could be of different strength and weight. There are feedback loops formed as the agents interact. The transition to a new state is enabled by innovation (knowledge, learning, creativity) and the underlying local rules. Knowledge, learning and creativity are represented by the strategic flexibility model and the knowledge identification and management. The underlying rules are represented by the institutional arrangement and change and the Social Contingencies Mechanism (SCM). The SCM also represents the actual interactions that occur.

3.3 ICT for Economic Development Conceptual Model

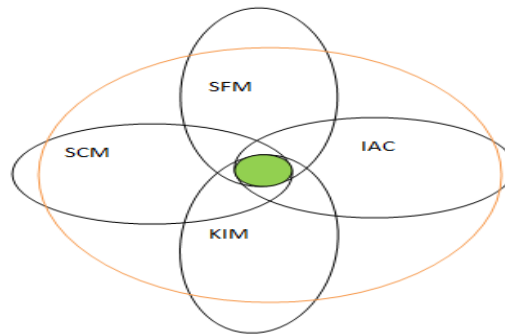


Figure 3: The ICT Ring



Figure 3, the ICT ring is a conceptual model that represents ICT intervention in a CAS. The CAS here is economic development which is represented by the complex interaction of strategic flexibility model, institutional arrangement and change model, the social contingencies mechanism model and the knowledge identification and management model. ICT is an intervention that enables shifting of patterns in the structures and processes that underlie the four basic models (Parsons and Hangreaves, 2009). Drawing Figure 3 in two dimension yields Figure 4 which represents the Integrated ICT for Economic Development Model (IICT4EDM).

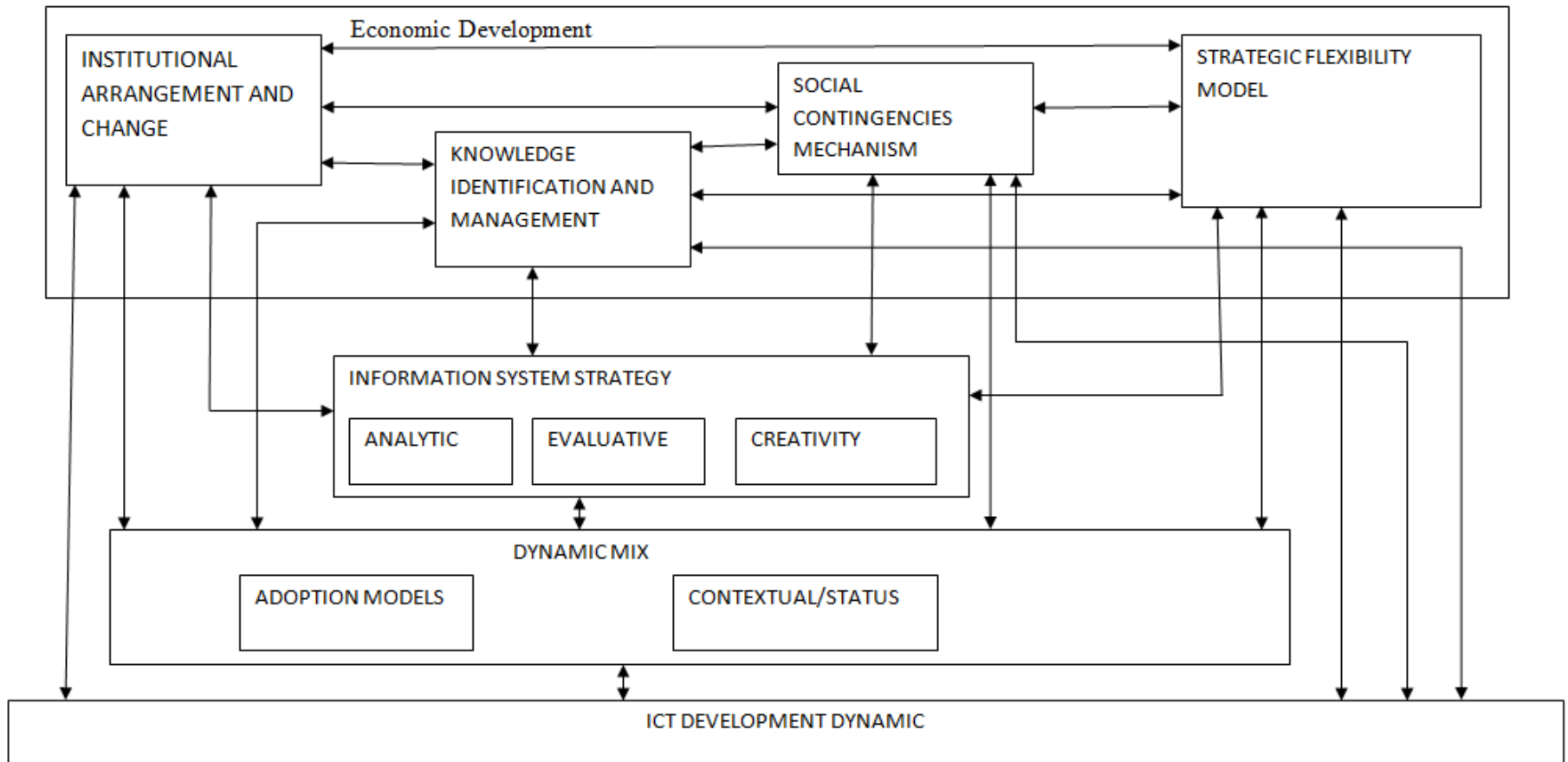


Figure 4: Integrated ICT for Economic Development Model (IICT4EDM)

Figure 4 illustrates a dissection into the ICT ring and reveals the linkage between the ICT development dynamic and the processes of economic development. The IICT4EDM illustrates the interconnectedness of the base models (Institutional Arrangement and Change, Knowledge Identification and Management, Social Contingencies Mechanism and Strategic Flexibility Model) and the interventions by ICT. The four base models are conceptualized as the influence points for ICTs since the interaction of the four base models enable a state to move from one to the other. The interactions is two way for ICT development dynamic and the base models because developments in ICT influence the processes in the base models and on the other hand any developments and changes in the base models will trigger new developments in the ICT development dynamic. The intervention of ICTs is looked at as assisting a restructuring process and hence its contribution to economic development. This implies that ICT contributes to the transformation of the four base models whose integration is economic development.

Giddens (1984) presents structure and agency as a duality where agents in their actions constantly produce and reproduce and develop social structures which both constrain and enable them. Figure 4 represents the concept of duality of structure as presented by Giddens (1984).

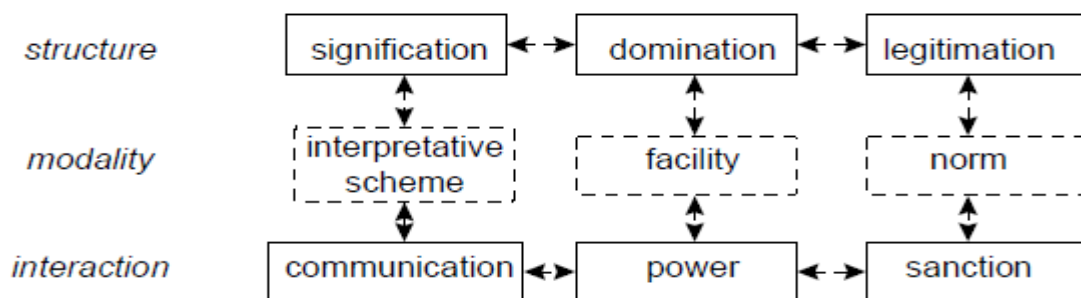
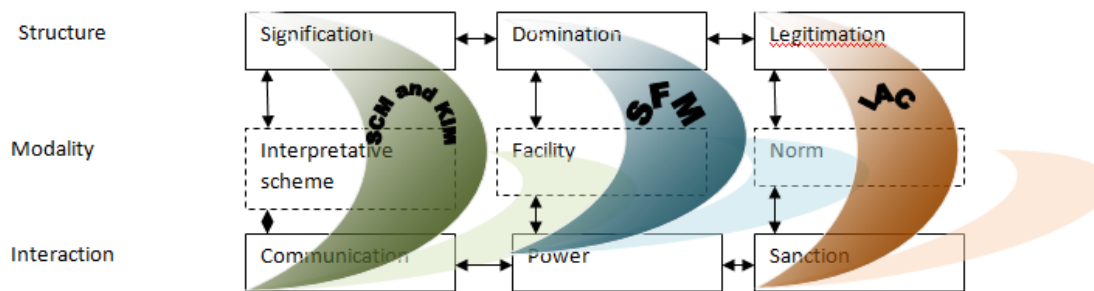


Figure 5: The Dimensions of the Duality of Structure (Source: Giddens (1984))

In Figure 5 as human actors communicate they draw on interpretive schemes to help them make sense of interaction, at the same time the interactions reproduce and modify the interpretative schemes which are embedded in the structure as meaning or signification. Similarly the facility to allocate resources is enacted in the power. Power being the capability of actors to encourage decisions to favor them and capability to mobilize biasness. Resources are used as a media for power. Facility then produces and reproduces social structure of dominance. Norms help determine what can be sanctioned in human interaction which iteratively produces structures of legitimization (Orlikowski, 1992). Economic development involves structural transformation. If the four base models were superimposed on Giddens dimensions of duality of structure then we could have it represented in Figure 6.



Key

SCM: Social Contingency Model

KIM: Knowledge Identification and Management

SFM: Strategic Flexibility Model

IAC: Institutional Arrangement and Change

Figure 6: Super-imposition of the base models on dimensions of duality of structure

Structuration is the process whereby the duality of structure evolves and is reproduced over time and space, which is structural transformation. Looking at figure 6 social contingency mechanism and knowledge identification and management will define the communication that will occur, in terms of who they will communicate to and what kind of interpretative scheme they will build. The knowledge the human agents have dictates the interpretative scheme they hold and the new knowledge they acquire alters the interpretative scheme they have. The social contingency mechanism and knowledge identification and management enable agents to continuously alter the interpretative scheme which is embedded in the social structure as signification or meaning. Now ICT affects social contingency mechanism and knowledge identification and management hence affecting how the interpretative scheme develops hence affecting signification. Similarly the signification developed affects ICT development.

Similarly strategic flexibility defines the tenets of power, where resources are the means and medium of exerting power. Power involves exploitation of resources both authoritative (derived from the coordination of the activity of human agents) and allocative (stem from control of material products or aspects of natural world) (Orlikowski, 1992). The strategic flexibility of a community represents both the allocative and authoritative resources. The state of the strategic flexibility will affect power which then affects facility to allocate resources which manifests as dominance in the social structure. ICT development dynamic affects strategic flexibility hence affecting power within a community, which manifests as dominance in the social structure. Institutional arrangement defines what is legitimized and by ICT affecting the processes of sanctions, contributes greatly to what is legitimized. What is legitimized again affects ICT development as people are more likely to follow the norm, or what they are used to.

The dynamic mix and the Information system strategy are components of the integrated ICT4EDM. These two components serve a special purpose in the model in that it caters for the diversity that occurs naturally among different communities that may seek to engage in ICT for economic development.

4.0 VALIDATION OF THE MODEL

4.1. The SCM Sub-Model

To assess the effectiveness of the ICT for economic development conceptual model, the paper delves deeper into the Social Contingence Mechanism (SCM) sub-model as shown in figure 2. In section 3.1 the paper asserts that for development to occur, the concerned agents have to engage in meaningful interactions. CAS as a theory does not go into the details of how these interactions are supposed to occur. But other social contingency theories (see section 3) explain how these interactions are supposed to occur. Figure 7 captures the social contingency theories that explain the issue of interactions in a CAS.

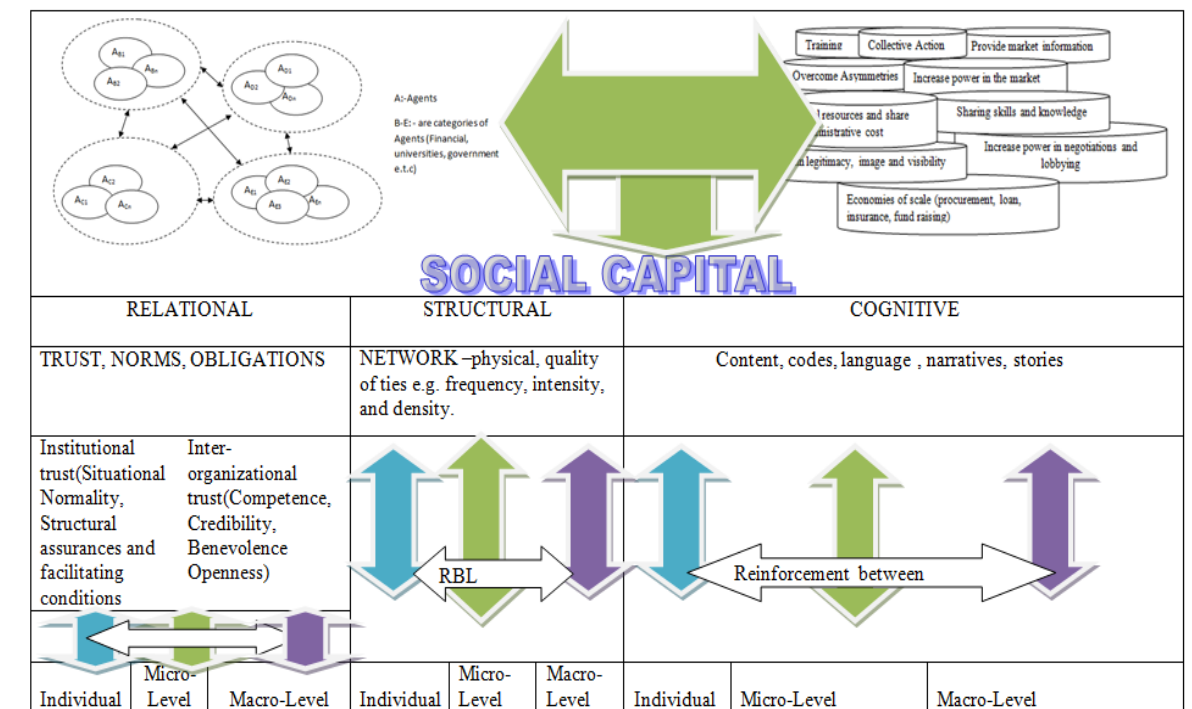


Figure 7: The Social Contingency Mechanism

Figure 7 illustrates the Social Contingency Mechanism (SCM) and it depicts three aspects of social capital i.e. structural, relational and cognitive that cut across three levels which are individual level, micro level and macro level. The individual, micro and macro in turn reinforce each other. Different agents are continually involved in various collaborations albeit for different reasons as illustrated. The glue and forces that bring them together and keep them together is the social capital as illustrated.

Employing the concept of De-lu, et al. (2008) and Parsons and Hangreaves (2009) concerning control parameters and influence points in a CAS, this paper posits that by using ICTs as an intervention in figure 7, which represents a section of control parameters and influence points in economic development that is a CAS, then we achieve ICT for economic development in part. The rest of the parts being intervention into the Knowledge Identification and Management (KIM), Institutional Arrangement and Change (IAC) and Strategic Flexibility (SF) sub-models (see Figure 3).

Table 1: ICT Interventions specific to SCM

ICT Support Technologies for Social Contingency Mechanism (SCM)	Impact	Supporting Literature
(i) Information systems controls that include input, process, output and storage controls	Ensure authentication	(Parvou 2002; Hsiao 2003].
(ii) Information system audit trails	These trails provide a way of documenting all transactions done from the first step to the very last step. They help auditors check for errors or fraud.	(Parvou 2002; Hsiao 2003].
(iii) Virtual private networks	Access to only authorized persons	(Parvou 2002; Hsiao 2003].
(iv) Use of security codes that ensures protection to stored data resources, system security monitors and biometric security systems		(Parvou 2002; Hsiao 2003].
(v) Third party monitoring mechanism that provides accreditation to organizations involved in e-commerce.	They provide perceived legal bonds, perceived feedback system and co-operative norms which then contributes to credibility and benevolence	(Parvou 2002; Hsiao 2003].

(vi) E-Governance	E-governance enables improvements in aspects of governance activity, image of government and tackling governance issues that include corruption, accountability, transparency, participation and process improvement	(Wafula et al 2007; Bhatnagar and Singh, 2009;Cecchini and Scott 2003]
(vii) Information technology enabling group processes such as Group Support Systems (GSS), Computer-Mediated-Communication (CMC) and Electronic Meeting Systems (EMS)	Extends communities beyond physical space, and to think of communities in terms of social networks or social relationships.	(Ridings et al 2002]
(viii) Computer and mobile phone games	Encourage acquisition of social values, norms and culture	(Kolko and Putnam, 2009]
(ix) Virtual social networks.	Promotion of ideas, norms, practices and behavior hence contributing to cognitive social capital. People's behavior can be changed or influenced by communicating through	(Pumar 2005]

4.2 System Dynamics Modelling for SCM

In a CAS many rules are active simultaneously and each of the rules may participate in influencing an outcome and each may influence the actions of other parts. This distributed many-ruled organization of a CAS places strong requirements on computer simulation. Complexity is systemic in principle where theorizing and abstracting meaning is model centered and where synthesis with dynamics rather than analysis is required (McKelvey, 2000).

The most direct approach is to provide a simulation in which many rules are active simultaneously enabling parallel computation (Holland, 1992). In view of achieving the necessary representation and simulation this paper employs system dynamics. System dynamics is used since it is a system based approach that provides tools which aid in the understanding of complex systems. System dynamics spans the gap between purely holistic methodologies and purely reductionist methodologies. It works between the two extremes hence poses both holistic and reductionist properties. The reductionist property it poses is as far as helping with understanding of phenomenon rather than problem solving (Sterman, 2000; Coyle 1996; Forrester, 1969).

Figure 8 captures the generic system dynamics model for SCM in an enterprise or community of practice. The major stocks in this model are the relational social capital, structural social capital, cognitive social capital, collaboration, macro-social capital, agents and micro-level social capital (see Figure 7). Each of them is explored to reveal the logic behind their structures and the variables that power them up.

The relational social capital stock relates with the structural social capital and the cognitive social capital through a co-flow structure. The in-flows to the structural social capital (*adding to*) and the cognitive social capital (*advancing*) are the driving force to the relational social capital in-flow (*enhancing*). As structural social capital increases and as cognitive social capital increases the values of relational social capital coincidentally increases too. The stocks openness, benevolence, credibility and competence are external resources to relational social capital. They are the actual reason for the accumulation of relational social capital and they act as catalysts in generating the *enhancing* flow of relational social capital.

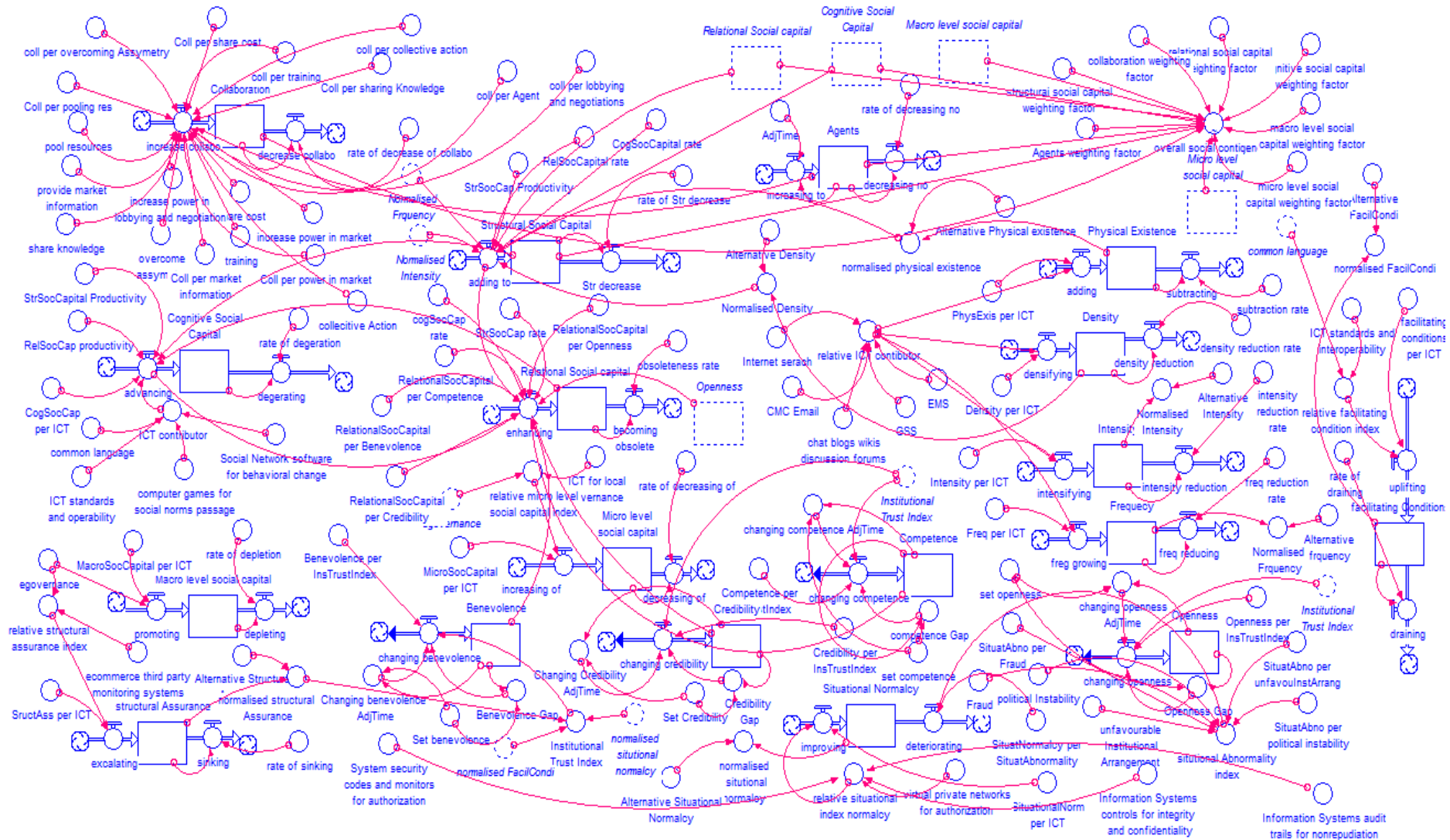


Figure 8: The System Dynamic Model for Social Contingency Mechanism (SCM)

Coll	Collaboration
CogSocCap	Cognitive Social Capital
StrSocCap	Structural Social Capital
RelSocCap	Relational Social Capital
AdjTime	Adjustment Time
Freq	Frequency
EMS	Electronic Meeting Systems
PhysExis	Physical Existence
GSS	Group Support Systems
CMC	Computer Mediated Communication
SituatAbno	Situational Abnormality
unfavouInstArrang	Unfavourable Institutional arrangement
FacilCondi	Facilitating Condition
MicroSocCapital	Micro Level Social Capital

Table 2: Key Abbreviations for Figure 8

The in-flow to the relational social capital is described in equation 1

$$\begin{aligned}
 \text{enhancing} = & (\text{Benevolence} \times \text{RelationalSocCapital per Benevolence}) \\
 & + (\text{Competence} \times \text{RelationalSocCapital per Competence}) \\
 & + (\text{Credibility} \times \text{RelationalSocCapital per Credibility}) \\
 & + (\text{Openness} \times \text{RelationalSocCapital per Openness}) + (\text{advancing} \times \text{cogSocCap rate}) \\
 & + (\text{adding to} \times \text{StrSocCap rate})
 \end{aligned}$$

Equation 1

The structures of the external resources benevolence, credibility, competence and openness take on a similar structure, the stock adjustment structure. Taking on one of these, the credibility resource, illustrates the way in which perception and opinions about credibility are adjusted.

The flow to credibility is defined by equation 2

$$\begin{aligned}
 \text{changing credibility} \\
 = & ((\text{Credibility Gap}) / (\text{Changing Credibility AdjTime})) \\
 & + (\text{Credibility per InsTrustIndex} \times \text{Institutional Trust Index})
 \end{aligned}$$

Equation 2

The first part of the equation $\text{Credibility_Gap} / \text{Changing_Credibility_AdjTime}$ shows that the flow is defined by dividing the difference between set credibility and actual credibility by the adjustment time. Here the adjustment is modeled as being affected by the value of credibility and the credibility gap. Whenever a discrepancy exists between the stock and the target, the flow will adjust the stock toward the target. Managers or those in charge of enterprises often seek to adjust the state of the system until it equals a goal or desired state.

The credibility flow has another contribution from the institutional trust index. Institutional trust index takes on a relative attractiveness structure. The index consists of a weighted average of structural assurance, situational normalcy and facilitating conditions as shown in equation 3.

$$\begin{aligned}
 \text{Institutional Trust Index} \\
 = & \text{normalised FacilCondi} + \text{normalised situational normalcy} \\
 & + \text{normalised structural Assurance} + \text{STEP}(20,3)
 \end{aligned}$$

ICT interventions in the relational social capital are encapsulated in the institutional trust index. From Figure 8, it is notable that system security codes and monitoring for authorization, information systems audit trails for non-repudiation, virtual private networks and information systems controls for integrity and confidentiality are interventions that act as external resources to situational normalcy. Similarly ecommerce and third party monitoring systems and e-governance are external resources that cause structural assurance to increase. ICT standards and interoperability contribute towards uplifting facilitating conditions.

Structural social capital is driven by a co-flow structure and an external resource structure. The co-flow structure involves the primary flows of relational social capital and cognitive social capital. As these primary flows increase they coincidentally cause the in-flow to structural social capital to increase. The external resource structure involves four stocks namely physical existence, density, intensity and frequency. These four stocks are the basis for which the flow to structural social capital is produced all of which have an associated productivity. These four external resources are the points of influence where ICT interventions are made. A weighted average of ICT components *relative ICT contributor* causes physical existence, density, intensity and frequency stocks to flow. These ICT components are internet, Computer Mediated Communication (CMC), GSS, EMS and chat, wikis, and discussion forums.

Cognitive social capital structure is composed of a co-flow structure and an external resource structure. Relational social structure and structural social capital are primary in-flows whose increase coincidentally increases the in-flow to cognitive social structure. The external resource *ICT contributor* is modeled as one that acts as a catalyst to the in-flow *advancing* of cognitive social capital. ICT contributor is a weighted average of computer games for social norms passage, common language, ICT standards and social network software for behavioral change.

Collaboration has an external resource structure that has several external resources responsible for its accumulation all with their respective productivity.

Overall social contingency takes on a relative attractiveness structure with weighted average of structural social capital, relational social capital, micro-level social capital, macro-level social capital, cognitive social capital, collaboration and agents.

4.3. The SCM for an MSE Association

The social contingency for Ziwani association was examined. Ziwani association is an MSE association that deals with motor repairs. The data collected was informed by the conceptual model and the generic system dynamic base models developed earlier (see Figure 7 and Figure 8). The observed objects and variables correspond directly to the system model components identified.

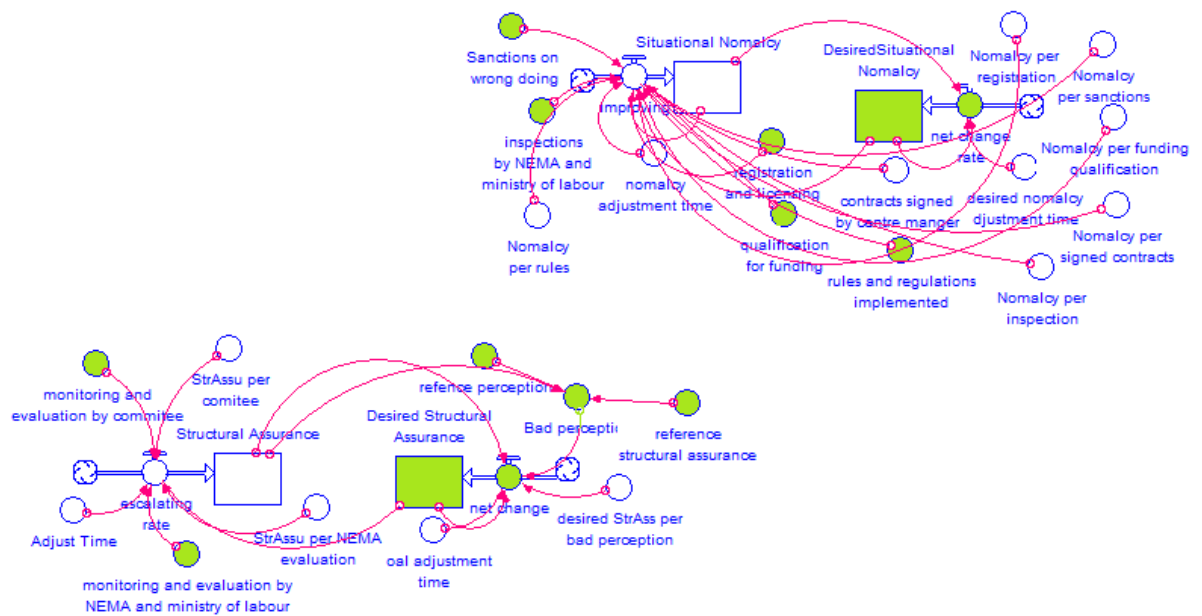


Figure 9: The Institutional Trust Section for Ziwani Social Contingency System Dynamics

The logic for ziwani structural assurance and situational normalcy shown in Figure 9 differs from the generic model in Figure 8. It takes on a floating goal structure, where the desired structural assurance depends on structural assurance and the desired situational normalcy depends on situational normalcy. Ziwani does not have obvious external reference points to determine desired structural assurance and desired situational normalcy. The net change in desired structural assurance is given by equation 4.

$$\begin{aligned}
 & \textit{net change} \\
 & = ((\textit{Structural Assurance} - \textit{Desired Structural Assurance}) / \textit{goal adjustment time}) \\
 & \times (\textit{Bad perception} \times \textit{desired StrAss per bad perception})
 \end{aligned}$$

Equation 4

Bad perception has an effect on desired structural assurance and its effect is a multiplication factor on desired structural assurance net change.

Ziwani association initiates corrective action in response to any discrepancy between desired state and actual state of structural assurance and situational normalcy.

The variables that are unique to ziwani structural assurance are monitoring and evaluation by committee and monitoring and evaluation by NEMA and ministry of labour. ICT interventions like e-governance and e-commerce third party monitoring systems are not used. The variables unique to ziwani situational normalcy are rules and regulations implemented, contracts signed by centre manager, registration and licensing, sanctions on wrong doing and inspections by NEMA and ministry of labour. The ICT interventions identified in the generic model in figure 8 are not employed. These include information system controls for integrity and confidentiality, information systems audit trails for non-repudiation, virtual private networks for authorization and system security codes and monitors for authorization that are supposed to build up situational normalcy. The reason could be the nature of association where they are very open and organizational trust seems to be more dependable. It is not so much that the ICTs are unavailable but the association does not seem to need them. Except when dealing with money transactions with customers and suppliers using mobile phone applications like M-pesa, Airtel Money and M-Shwari, these technologies are embedded from the mobile phone companies Safaricom and Airtel. For e-commerce third party

monitoring systems, again this comes into play when they carry out electronic money transactions where one can be able to retrieve their transactions, sort of transaction statements, from Safaricom using M-pesa application.

This is made possible because of developments in terms of ICT policies and content and applications in Kenya. This makes it possible for the institutional trust of Ziwani association with customers and suppliers enhanced.

The four stocks that make up organisational trust are, as shown in Figure 10, credibility, benevolence, competence and openness. The structure of organisational trust in ziwani differs from the generic structure in Figure 8. Ziwani does not have set values for desired credibility, desired benevolence, desired competence and desired openness. The structure takes on a floating goal structure where the desired values are themselves variables affected by current system values.

The unique variables to ziwani that contribute to organizational trust are apprenticeship which affects benevolence and openness, welfare affects benevolence, association with big companies affect credibility and competence whereas government vehicles repaired affect credibility and competence. The rest of the structure is similar to the generic model in Figure 8.

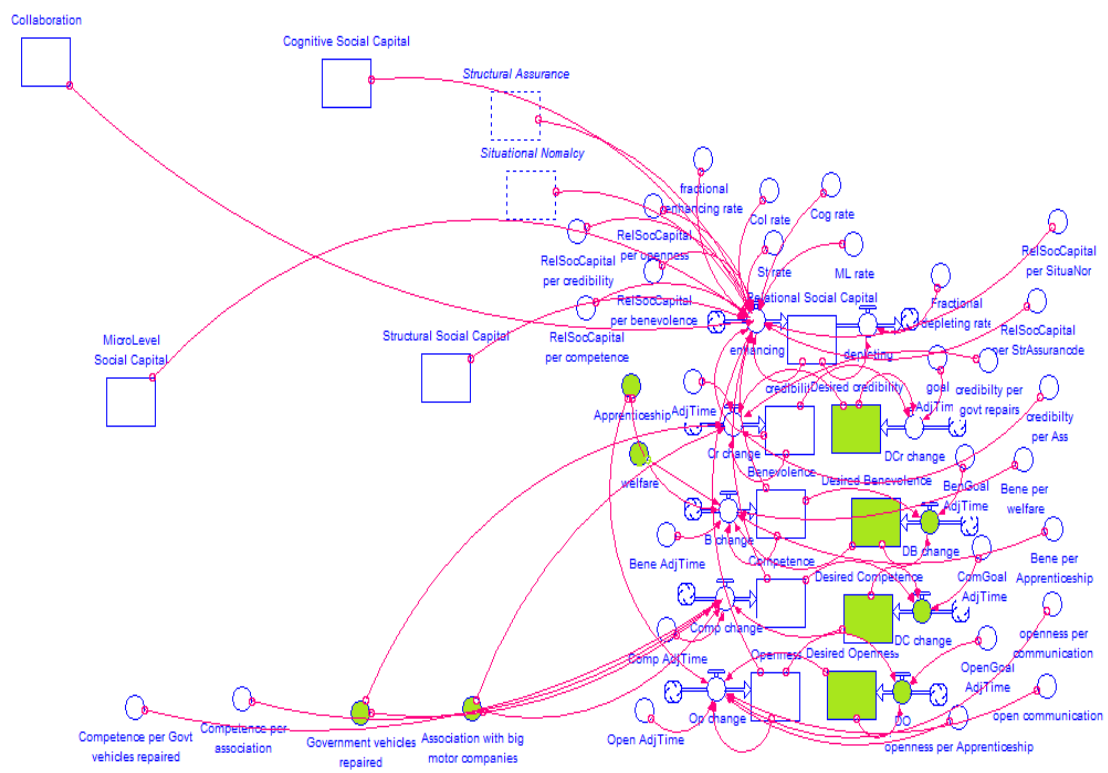


Figure 10: The Organizational Trust Section for Ziwani social Contingency System Dynamics

Figure 11 represents the collaboration sector of social contingency for Ziwani and it identifies unique variables contributing to collaboration. These variables are sourcing for spare parts, licensing, funding and effort by partners. The structure of collaboration is unique to Ziwani in the sense that strategic flexibility plays a major role. Collaboration does not grow forever, it initially exhibits exponential growth but slows down to the carrying capacity of strategic flexibility of the association. The fractional collaboration increase rate and the fractional collaboration decrease rate are not constants but change as collaboration approaches its possible collaboration enabled by its strategic flexibility. The assumption here is that strategic flexibility is neither consumed nor augmented. When the ratio collaboration/strategic flexibility is small the fractional collaboration increase rate is high.

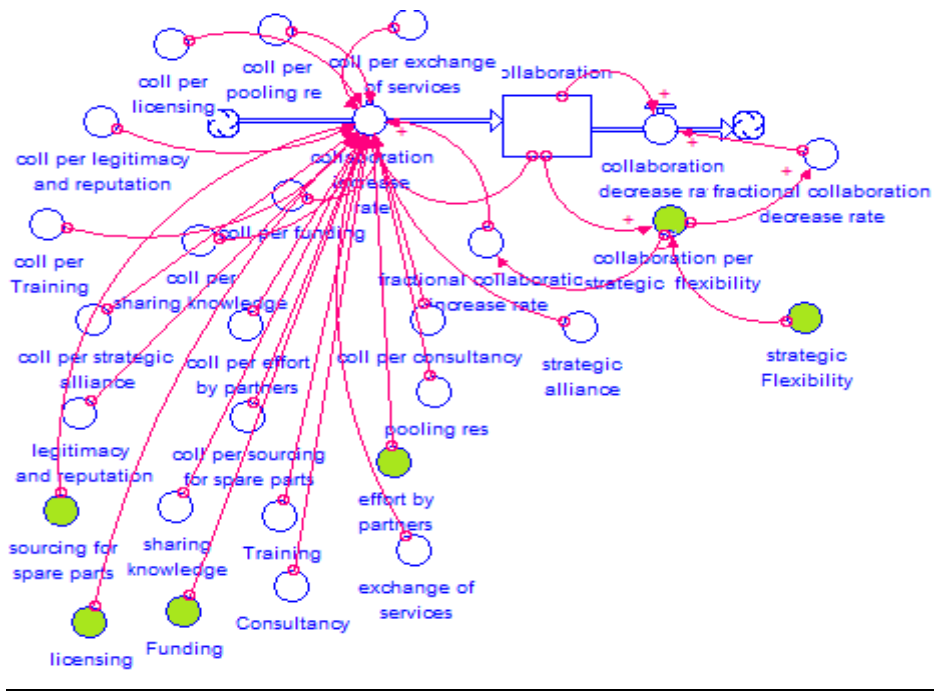


Figure 11: The Collaboration Section for Ziwani Social Contingency System Dynamics

Figure 12 illustrates the relationship between collaboration, strategic flexibility, fractional collaboration increase rate and fractional collaboration decrease rate. The first section shows positive feedback dominance where the fractional collaboration increase rate steadily rises as collaboration also rises up to when time is about 1.5. As collaboration continually increases the ratio collaboration/strategic flexibility increases and hence fractional collaboration increase rate starts to fall as fractional collaboration decrease rate increases and the value of collaboration slows down hence attaining a near S-shape.

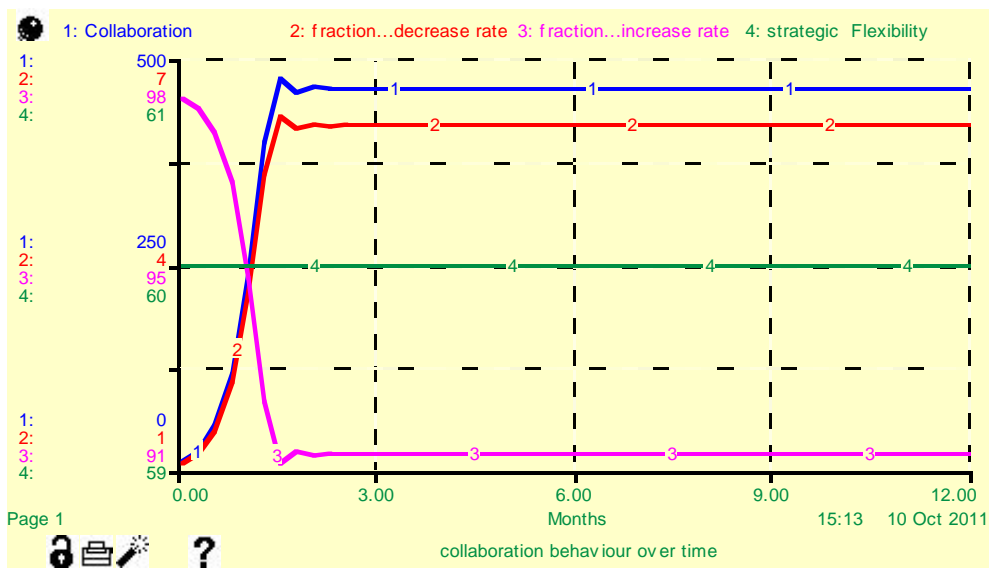


Figure 12: Collaboration Showing an S-Shaped Growth

In Figure 13, intensity, density, frequency and physical existence are variables modelled for ziwani as having reference values in the minds of the mechanics. This implies that the actual values of these variables are formulated by the setting a variable Y to its normal or reference value Y*, multiplied by the product of various effects. The general formulation is as given in equation 5.

$$Y = Y^* \times \text{Effect of } X_1 \text{ on } Y \times \text{Effect of } X_2 \text{ on } Y \times \dots \times \text{Effect of } X_n \text{ on } Y$$

Equation 5

The variable Y can be a rate that feeds into a rate. The nonlinear functions are often normalized by the normal or reference value of the inputs X_i. Where the effect of X_i on Y is given by equation 6

$$\text{Effect of } X_i \text{ on } Y = f(X_i/X_i^*)$$

Equation 6

Normalization ensures that when the inputs X_i equal their reference levels, the output Y equals its reference level. The formulation for intensity for example in figure 13 is as shown in equation 7

$$\begin{aligned} \text{Intensity} = & \text{Ref Intensity} \times (\text{Meetings} / (\text{Ref meetings})) \\ & \times ((\text{Mobile phone calls and sms}) / (\text{Ref mobile phone calls and SMS})) \\ & \times ((\text{exhibitions and demonstrations}) \\ & / (\text{Ref exhibitions and demonstrations})) \\ & \times (\text{seminars and workshops} / \text{Ref seminars and workshops}) \end{aligned}$$

Equation 7

The rest of the variables take on a similar structure. The variables that are unique to ziwani in contributing to structural social capital are meetings, seminars and workshops and exhibitions and demonstrations.

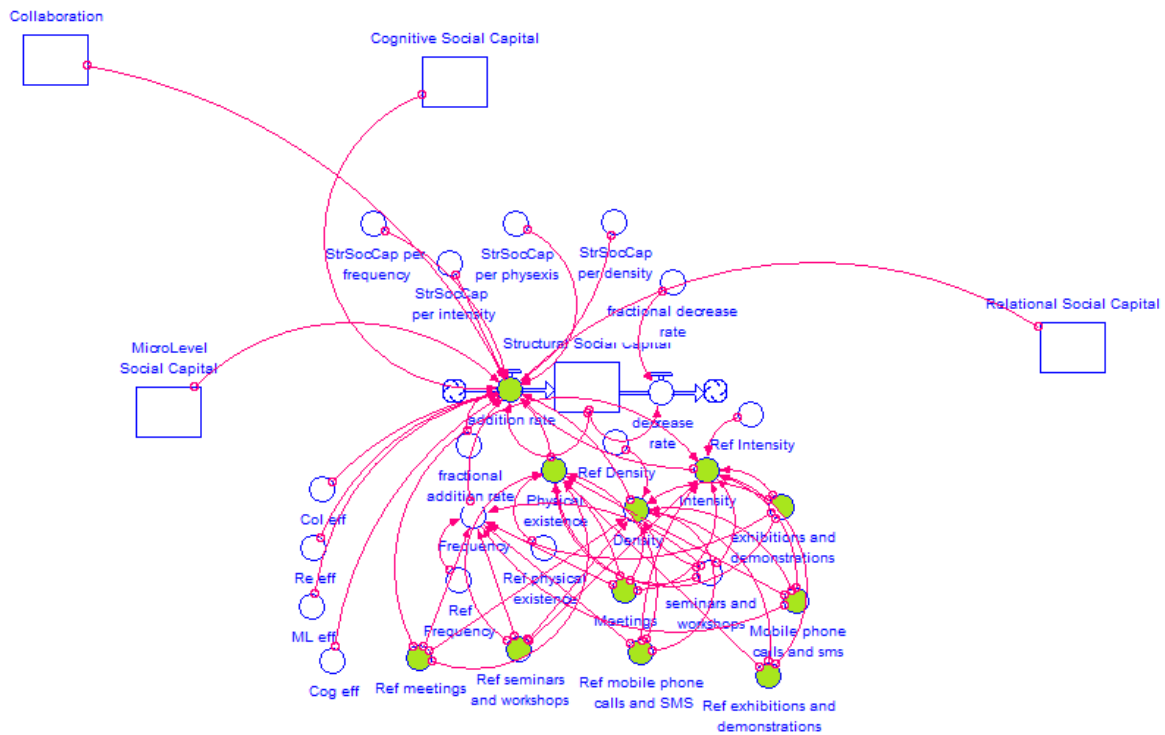


Figure 13: Structural Social Capital Section for Ziwani Social Contingency System Dynamic

ICT intervention for Ziwani is embodied in mobile phone SMS and calls which contribute to density, intensity and physical existence variables that make up structural social capital. This is attributed to effort by the Kenyan government and private companies in the telecommunication sector.

Internet, computer mediated communication through email, chat blogs, wikis and discussion forums, GSS and EMS are not identified as major contributors to structural social capital in Ziwani. This could be attributed to the fact that Ziwani associations use on internet is by the demonstration centre manager when sourcing for training material. At the firms level they haven't found reason for use this kind of technologies. This could be an opportunity to be opened up by players in training of MSEs.

Figure 14 shows the cognitive social capital sector which is advanced by collaboration, micro-level social capital, relational social capital and structural social capital. The culture and behavior of Ziwani mechanics is similar and this enhances cognitive social capital. The effect of social network software and computer games for social norms passage has no influence on cognitive social capital in Ziwani.

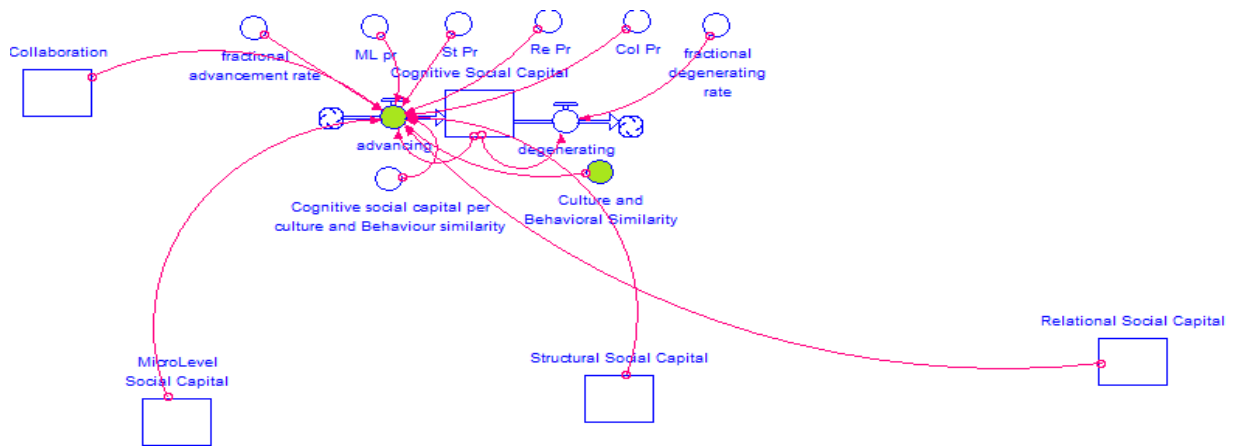


Figure 14: Cognitive Social Capital Section for Ziواني Social Contingency System Dynamics

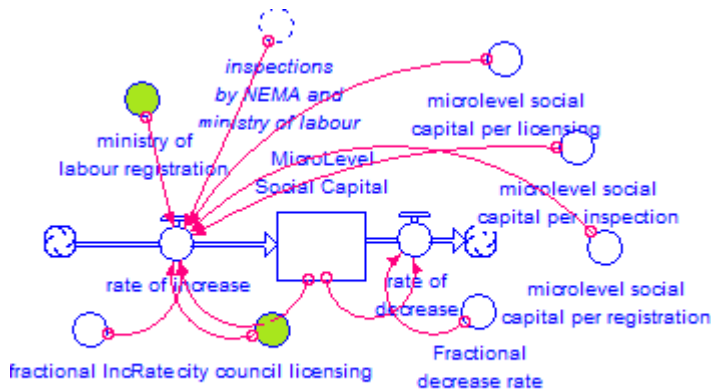


Figure 15: Micro-Level Social Capital Section for Ziواني Social Contingency System Dynamics

Figure 15 shows that Ziواني’s micro-level social capital is felt through city council licensing and inspections by NEMA and ministry of labor. Their approval gives the association confidence in their work knowing that they have a right standing with the authorities. ICTs in support of local governance are not present.

In Figure 16, the value of relational social capital increases in correspondence with the increasing values of situational normalcy, credibility, competence and structural assurance.

Figure 17 shows the key pillars of social contingency, collaboration decreases with time because of the structural design of collaboration in ziواني. Where the value of strategic flexibility is constant and since collaboration depends on it then with time collaboration decreases if the value of strategic flexibility does not increase.

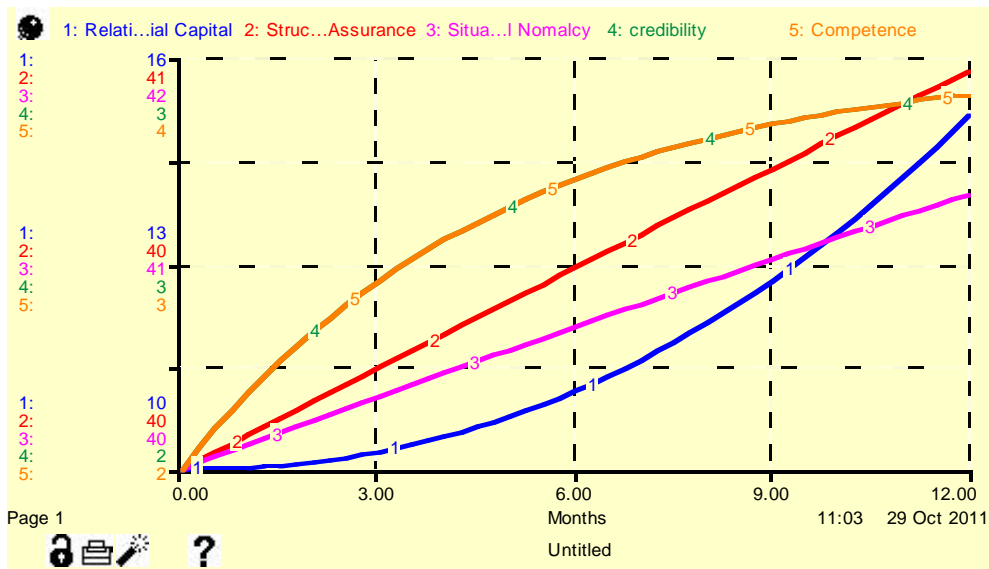


Figure 16: Relational Social Capital Behavior

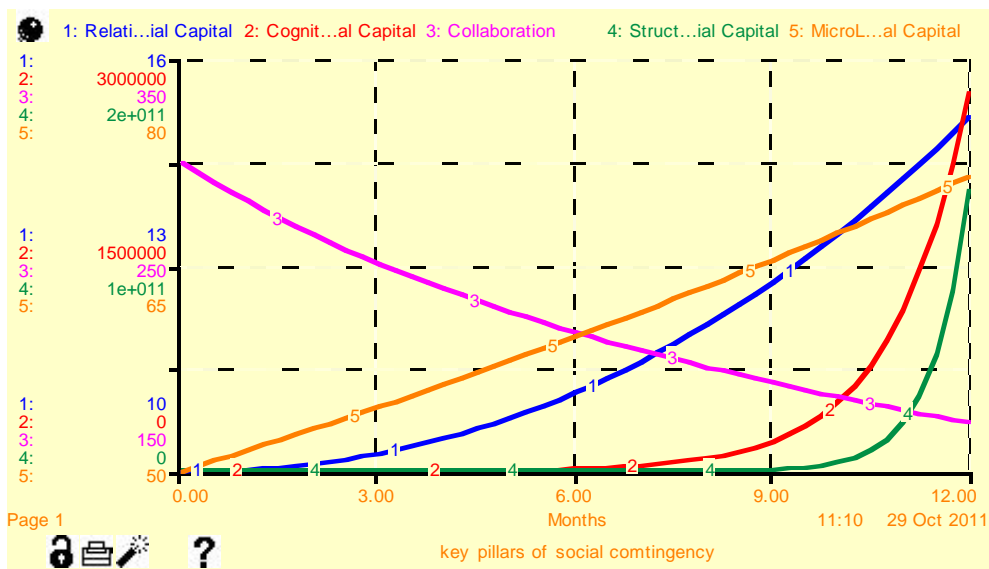


Figure 16: Behavior of the key pillars of Social Contingency

5.0 DISCUSSION AND CONCLUSION

The CAS theoretical framework for economic development together with Parsons and Hargreaves (2009) ideas of identification of influence points provide a theoretical base for the construction of the ICT for economic development framework where ICTs are modeled as interventions at points of influence in the CAS. The Integrated ICT for Economic Development Model (ICT4EDD) provides ICT for development researchers with a model that can be used. Policy makers and practitioners can evaluate their interventions and see what part of the model they are supporting. The role of ICTs in structural transformation which is germane in economic development is as captured and brings out the idea that ICT is a player in the restructuring process and hence one that contributes to development through bringing about transformation, metamorphosis and structural transformation.

Unlike the other development models the CAS approach helps capture the underlying structures of the inter-relationships between the variables involved, thanks to system dynamics modeling that brings out the synthesis more clearly. The rest of the development models address specific issues whereas the CAS approach incorporates all the aspects mentioned in other models hence a holistic approach.

The Ziwani association case reveals the practical aspect of the model, showing that operationalization of the model is possible and is effectively measurable.

Further research should focus on how to build the conceptual models of the remaining three base models, modeling and simulating them using system dynamics to reveal the structural underpinnings.

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