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MOBILE PHONE PENETRATION AND ECONOMIC GROWTH IN KENYA: A SYSTEMS DYNAMICS APPROACH IN THE CONTEXT OF THE KENYAN VISION 2030

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Abstract

System dynamics modelling is a scientific method for modelling complex, nonlinear natural, economic and technical systems. This research assesses the Kenyan mobile industry thus, identifying success factors and challenges for Kenya to substantially increase its economic growth outputs. Based on a Systems Dynamics approach, a Mental Model (Causal Loop Diagram) has been prepared as a step towards building a model to simulate the expected effect of mobile phone usage on economic growth. A computer simulation provided a mathematical model, providing practical insight into the dynamic behavior of the observed system, i.e. the analysis of economic growth and observation of mutual correlation between individual parameters. The results of the simulation are shown in graphical form. The dynamic model of the effects of mobile phone penetration on Kenya's economic growth has been verified by comparing simulation results with existing data on economic growth.

Key words: Mobile phone penetration, economic growth, system dynamics, structural model, development diagram

1.0 Introduction

This paper investigates the impact of mobile phone usage on economic growth in Kenya. Economic growth based on mobile service activity is an important determinant in both the developing and the developed world. A recent paper (Amos, Rodrigues and Wafula, 2018) looked at mobile industry governance in Kenya. Here we follow the econometric approach by, (Adrianaivo and Kpodar, 2011) and (Lee, *et al*, 2009) on the impact of mobile penetration on GDP per capita growth. In Kenya mobile telecommunication industry has witnessed a tremendous growth over the last few years, by June 2014 the total number of mobile subscriptions was recorded as 32.2 million up from 31.8 million. However, there is a wide variation in mobile diffusion as well as GDP growth across various counties in Kenya, raising issues of socio-economic disparities and how technology diffusion may help in convergence of growth process among various counties. (Sanjay, 2013) proves how system dynamics modelling can contribute in a meaningful way to the area of innovation diffusion research. Empirical studies have found several factors such as per capita income, income inequality, population density, age profile of population, competition and regulatory structure have a positive impact on mobile penetration (Yamakawa, *et al.*, 2013, Chakravarty, 2007). The relation between inequality and mobile penetration has been found to be mixed. In some studies, mobile penetration, was found to be negatively related to income inequality; whereas, it is positively related to inequality in the early stages of diffusion (Roller and Waverman, 2001, Hytennin and Toivanen, 2011). In the developing country context mobile phones serve dual purposes: one, as consumption good for the rich and two, as a production good for the poor. Case studies from the Africa and Asia have shown the usefulness of mobiles as a production good (Jensen and Robert 2007, Aker et al 2008, Muto, *et al*,2008). For this reason, income inequality may influence the spread of mobile penetration in the early stages. Although the impact of economic and demographic factors on mobile penetration has been established, there is not much clarity on the relationship between mobile phone penetration, economic growth and the extent to which this leads to convergence of growth process. The mobile industry of Kenya is therefore an exemplifying case for this phenomenon.

2. Review of literature

The telecom services have been recognized the world-over as an important tool for socioeconomic development of a nation. Telecommunication is one of the prime support services needed for rapid growth and modernization of various sectors of the economy. (Sanjay, 2017) developed a system dynamics model of humanitarian supply chain in order to capture causal dynamics and inter linkages and suggested some critical intervention strategies for enhancing overall performance. It has become especially important in recent years because of the enormous growth of information technology and its significant potential for the impact on the rest of the economy. The telecom sector, which has the multiplier effect on the economy, has a vital role to play in economy by way of contributing to the increased efficiency.

In 2015 mobile technology added $3.1 trillion in economic value-added terms to the world economy, a contribution of 4.2% to global GDP (GSMA Intelligence analysis, 2016). This figure comprises four elements the:

i. direct contribution of mobile operators
ii. direct contribution of the rest of the mobile ecosystem
iii. indirect impact on the broader economy
iv. increase in productivity brought about by the use of mobile technologies.

The global app economy continues to show rapid growth, with forecasts suggesting that by 2016 the revenues from apps and related products and services could total more than $140 billion.

Key studies such as those by (Waverman, *et al.,* (2005), (Lee, *et al.,* (2009), and (Qiang and Rosotto, 2009) have demonstrated a clear connection between mobiles and economic growth and/or between telecoms more generally and economic growth. They all address the "endogeneity" problem: that a correlation between telecoms (indeed, all ICTs) and economic growth is readily demonstrable; but it is important to tease out the direction of causality: economic growth causes increased levels of ICTs in a country (we buy more tech as we get richer); the issue is the extent to which the technology causes economic growth.

As truly ubiquitous technology, ICT has an impact on societies in multiple and extremely complex ways. (Amrita & Garg, 2016) showed how in this era of globalization, adoption of

information technology (IT) is one of the critical contributing factors for companies' competitiveness and growth. Difficulties in monitoring, evaluating and assessing the relationship between ICT and society are aggravated in the context of development and poverty, as pronounced regional and local differences establish a highly fragmented landscape and thereby undermine efforts to apply single conceptual framework. The need and demand for improved understanding of the ICT, and indeed Information Society, in the broader socio-economic context of Sub-Saharan Africa is the basic driver in this study.

To address these deficiencies, just as researchers of building physics, statistical and hybrid based energy models (Shipworth, 2005; Motawa & Banfill, 2010; Oladokun,*et al*., 2012a; 2012b) advocated, we propose the use of the governance-socio-techno-economic system (GOVSOC_TECON) to solve the problem of complexity due to high inter-dependencies, chaotic and non-linearity of the variables involved as well as feedback loop structure of mobile phone and economic growth influencing variables by contributing to the dynamic nature of the system under investigation. Obviously, it is necessary to acknowledge that the complex issue of mobile phone usage and economic growth must be understood as a system since the characteristics of the parts making up this system could not be viewed individually. In an earlier study conducted by (Oladokun,*et al*., 2012a), it was found out that system dynamics (SD) was well placed in modelling the system based on its ability to handle all the characteristics of the model under discussion. In addition, SD was capable of being used as learning laboratory for policy evaluation and optimisation since it had been previously used under different domains (Davis & Durbach, 2010; Chi *et al*., 2009). Thus we use SD as both the methodology and tool vide the GOVSOC_TECON framework for mobile phone usage and economic growth.

This research includes not only the fundamental nature of causality and complexity, but also how one could influence the nature of change in complex systems. One approach to influencing change is to model the relationships between causes and changes as mediated by the complex systems in which the cause-change relationships arose. This could enable, in effect, feedback loops from experienced or projected changes to interventions that influence causes directly or indirectly. The study reviewed several frameworks and models that had been developed and applied to guide these efforts both in the developing and developed countries in order to develop

a generic governance-socio-techno-economic model to analyze the relationship between mobile phone usage and economic growth in Kenya in the case of the Vision 2030 Implementation.

3. Mobile phone usage and economic growth

Although many parts of the world have experienced rapid growth in the number of mobile phone users during the last decade, the African continent paints an even brighter picture, with the numbers of mobile phone subscribers surging from 39 percent in 2008 to 72 percent in 2012 (ITU, 2013). As scholars strived to evolve a comprehensive understanding of the Internet, the literature on mobile telephony has burgeoned into an interdisciplinary study of mobile technology as it interacts with the social order (Geser, 2002; Castells, *et al*., 2007).Yet characterizations of the effects of mobile technology have often been abstract and nonspecific.
Castells and associates summarized a vast amount of work on 'mobile network society' with the proposition that it represents an enhancement of the social structure by new, wireless communication technologies. The enhancements that provide the evidence for this claim are largely based on characteristics of the technology: micro-coordination of schedules made possible by the ability to communicate while moving and the establishment of new businesses that provide mobile technology.

The Internet monopolized scholarly attention during the 1990s, while the rapid diffusion of mobile phones in the early 2000s instigated a parallel shift in scholarly work on new information and communication technologies. Yet understanding of these new media has been hampered by the absence of the longitudinal studies that are required to document change in behaviour. In (Donner, 2008) a comprehensive review of over 200 recent studies of mobile telephony in the developing world revealed no survey of the social impacts of mobile phones conducted over more than one time period. In short, while there is much speculation and many case studies of mobile telephony, systematic scholarly studies of social change are few, if any. In the absence of longitudinal data, it is difficult to proffer evidence-based claims regarding social change.

While governments, enterprises, and civil actors around the world are attempting to realize the benefits of Information and Communication technologies (ICTs) for economic, social, and political development, scholars are still striving to come up with a coherent conceptual

framework that embraces all relevant aspects of this multidisciplinary endeavour (Heeks, 2006). Mobile phones, a rarity in many developing countries at the turn of the century, now seem to be everywhere. Between 2000 and 2012, the number of mobile phones in use worldwide grew from fewer than 1 billion to around 6 billion. The mobile revolution is transforming livelihoods, helping to create new businesses, and changing the way we communicate. The mobile phone network is already the biggest "machine" the world has ever seen, and now that machine is being used to deliver development opportunities on a scale never before imagined. Developing countries are increasingly well placed to exploit the benefits of mobile communications, given that levels of access are rising around the world. Research shows that mobile networks are having a growing impact on the economy. (Sanjay, 2012) showed how the application of system dynamics modelling and simulation coupled with soft computational neural networking can improved the holistic understanding of the dynamic structural complexities and forces of telecom diffusion. One of the earliest and frequently cited studies on the subject was carried out by three consultants from the Law and Economics Consulting Group. Using data from 92 countries between 1980 and 2003, they found that an increase of 10 mobile subscriptions per 100 people raised GDP growth by 0.6 percent (Waverman, *et al*, 2005). A similar study using data through 2006 found that a 10 percent increase in mobile penetration in developing countries was correlated to a 0.8 percent increase in economic growth (Qiang and Rossotto, 2009). Several studies also find that growth in mobile networks is positively correlated to foreign direct investment (Lane, *et al*., 2006; Williams, 2005). Table 3.1 shows mounting evidence of the microeconomic impact of mobile networks in specific countries and industries. The benefits typically accrue from better access to information brought about through mobile and are typically related to lower transactions costs, savings in travel costs and time spent travelling, better market information, and opportunities to enhance one's livelihood (Jensen,2007);(Salahuddin,*et al*., 2003); (Aker,2008).

Table 3.1 **Mobile and the Millennium Development Goals** *(source: ITU: Information communication for development, 2012)*

MDG	Example
Poverty and hunger	A study on grain traders in Niger found that cell phones improved consumer welfare (Aker 2008). Access to cell phones allowed traders to obtain better information about grain prices across the country without incurring the high cost of having to travel to different markets. On average grain traders with cell phones had 29 percent higher profits than those without cell phones. In the Niger example, demand sprang up organically rather than through a specific program.
Universal education	According to a survey of teachers in villages in four African countries, one-quarter reported that the use of mobile phones helped increase student attendance. A main factor was that teachers could contact parents to enquire about their child's whereabouts (Puri, *et al*, n.d.). Mobile phones have also been used in Uganda to track school attendance so that school administrators can see patterns in attendance, for instance by village, by day of the week, and by season. Tracking attendance for pupils indirectly also tracks absenteeism among teachers (Twaweza, 2010)
Gender equality	A study looking at gender differences in the availability and use of mobile phones in developing countries reported that 93 percent of the women who had mobiles felt safer because of the phone, 85 percent felt more independent, and 41 percent had increased income or professional opportunities (GSM Association 2011). The report found that closing the mobile gender gap would increase revenues for mobile operators by $13 billion.
Child health	A program using text messaging to identify malnutrition among rural children in Malawi is notable for its impact on the speed and quality of the data flows. A using a system called RapidSMS, health workers in rural areas were able to transmit weight and height information in two minutes instead of the two months needed under the previous system. The data entry error rate was significantly improved to just 2.8 percent from 14.2 percent in the old system. The improved information flow enabled experts to analyze data more quickly and accurately, identify children at risk, and provide treatment information to the health staff in the field.
Maternal health	One of the earliest uses of mobile technology to improve maternal health took place in rural districts of Uganda in the late 1990s. Traditional birth attendants were provided walkie-talkies, allowing them to stay in contact with health centers and obtain advice. An assessment of the program found that it led to roughly a 50 percent reduction in the maternal mortality rate (Musoke,2002).
HIV/AIDS	In Kenya weekly text messages were sent to AIDS patients to remind them to take their antiretroviral drugs (Lester,*et al*., 2010). Those who received the text messages had significantly higher rates of taking the drugs than those who did not receive them. The study noted that SMS intervention was less expensive than in-person community adherence interventions on the basis of

	travel costs alone and could theoretically translate into huge health and economic benefits if scaled up.
Environment	According to one forecast, mobile technology could lower greenhouse gas emissions 2 percent by the year 2020 (GSM Association 2009). This reduction can be met through, among other things, widespread adoption of various mobile enabled technologies such as smart transportation and logistics, smart grids and meters, smart buildings, and "dematerialization" (replacing the physical movement of goods and services with online transmission). Mobile phones can also be used as tools for environmental monitoring. In Ghana, for example, cab drivers in Accra were outfitted with mobile phones with GPS and a tube containing a carbon monoxide sensor to test pollution levels.
Partnership	MDG target 8F states: "In cooperation with the private sector, make available benefits of new technologies, especially information and communications." Mobile phone penetration in low-income economies has grown from less than one per 100 people in 2000 to almost one per every three by 2010 largely as a result of private sector investment. Of some 800 telecom projects in developing countries with private sector participation between 1990 and 2009, almost three quarters involved greenfield operations primarily in mobile telephony.

The MDGs have helped the development community to focus. There has been a significant shift from presenting achievement as the outcomes of projects and programs to discussing the movement of whole nations and groups of people to the MDG targets. This has to be reflected in the discussion of ICTs. Many of the newer ICTs have had five years of pilots and "experimentation". If ICTs are to contribute to the 2015 goals and beyond, they have to be mainstreamed to be replicated and scaled where they are appropriate and relevant in order to meet the sustainable development goals (SDGs). This study aims to help prioritize responses to these changes.

Experience has shown that ICT/technology-push projects were not the best contributions to fulfilling the MDGs. MDG-led development co-operation, pulling in ICTs where appropriate and efficient, had more impact on poverty. Part of this shift from push to pull depended on mainstreaming, to a large extent on articulating ICTs potential to different audiences. A few development agencies, such as USAID, have seen ICTs being embedded into mainstream programs, but most other agencies are finding the process more difficult. One of the difficulties

was the barrier of insufficient information; questions over the actual impact of an ICT intervention, and of its potential to scale, replicate and to be sustainable.

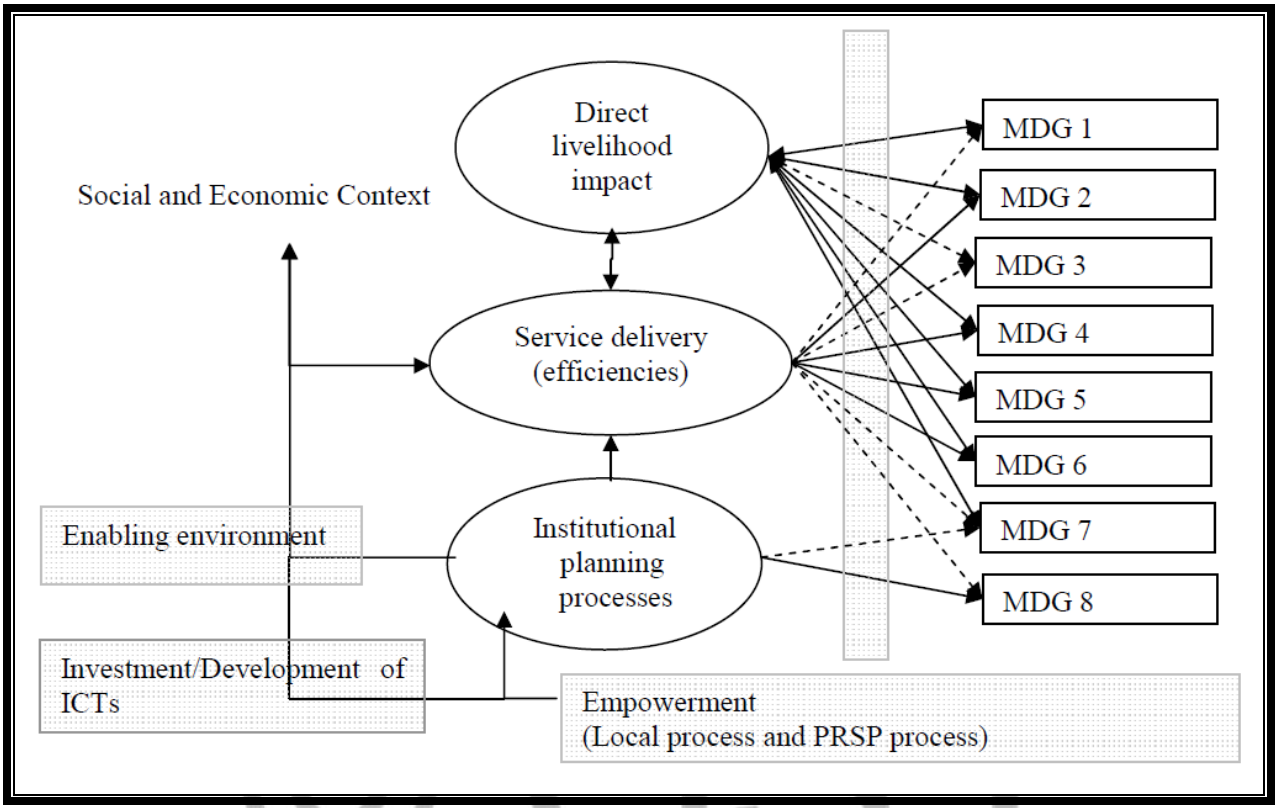

Figure 1: Key Processes that Form the MDG Outcomes and the Key Empowerment "Filter"*(Source: OECD, 2005)*

The pull of the MDGs for the "services" of ICTs, as shown in Figure 1, proposed the basic concept that the outcomes of the MDGs were to be reached through three basic processes; livelihood enhancement, efficiency in delivering services, and efficiencies and voice in the planning processes.

The economic and social context was important to the relative contributions, and where pro-poor growth had been prioritized, that enhance the economic contribution. Similarly, the social context becomes important in that it can often determine the opportunities for voice and empowerment. Empowerment, particularly in the form of the Poverty Reduction Strategy Programs (PRSPs), can be thought of as a filter that determines the flow and ultimately the impact of the processes.

4. System dynamic structural and mental model of Mobile phone usage and economic growth

Qualitative modelling is a starting point in the modelling process. A structured and integrated casual loop diagram follows a mental presentation of the observed system (Munitic, A. and P. Ristov, 2009).

In systems dynamics modelling, the generic system archetypes operating in the mobile industry of Kenya from 2005 to 2015 were identified, and the time-variance of mobile output, providers and average mobile output discussed. The paper presents development of a system dynamics model of mobile output, which is based on: (i) mobile service process at industry level in Kenya, and (ii) features of the system archetypes operating in the mobile industry. We further presents quantification of the mobile industry as a feedback control system.

The system dynamics model of the existing structure of the mobile industry system of Kenya was formulated, conceptualizing the problem of mobile activity variations and growth in terms of the various system variables. The model was particularly for the total mobile output. The mobile industry as a whole was conceptualized as one large corporation, whose annual production is the mobile output captured in national statistics every year. Conceptualization of the model variables was generally based on deductions made in the qualitative data analysis. However, more ideas were added in the formulation of the model structure, in order to replicate a real life mobile industry as closely as practicable. The model variables and their units of measurement were derived from the basic variables.

The modelling process took the following steps: (i) review of mobile service provision process in Kenya; (ii) estimation of demand for mobile service facilities in the economy of the country; (iii) articulation of the existing feedback control structure using level rate diagrams and difference equations; (iv) functional definition of the model variables; and (v) simulation runs. After several simulation runs to ensure the soundness of the model mobile services provision, validity of the model was tested using behaviour replication tests, parameter tests and extreme conditions test.

The causal loop diagram (CLD)for the mobile phone industry and economic growth is shown in Figure 2.

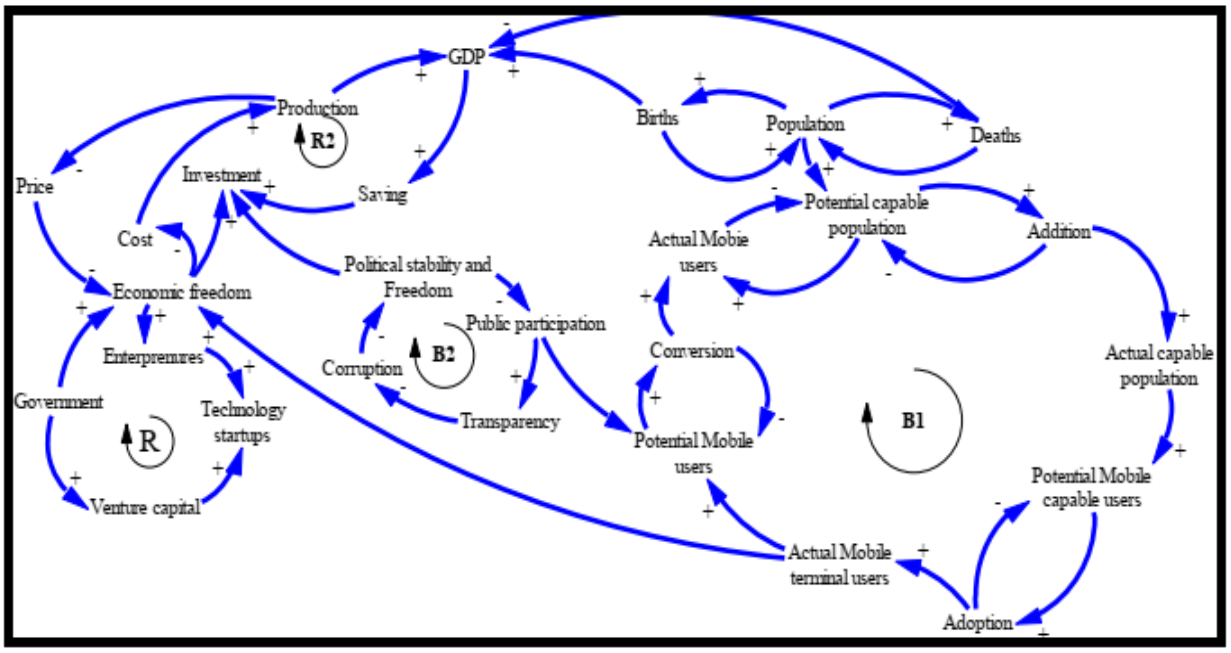

Figure 2: Causal loop diagram for the mobile phone service and economic growth

To get an integrated view of the model, we start with the main variable-Number of Mobile Users which represents the subscribers of the basic telecommunication services. Households subscribe to telecom services. An increase in the number of households leads to increase in the number of subscribers and depletes the potential subscribers. This bi-directional relationship forms a loop with negative polarity i.e. negative feedback loop. An increase in economic growth increases the income level of the people and hence the subscriber base for telecommunication services. As the number of subscribers of a telecommunication services increases, the amount of information traffic and frequency of request for connection establishment increase. This causes congestion, which deteriorates network performance. However, if the service provider synchronizes the infrastructural build-up i.e. setting up of switches, access loops and trunks, with the pace of building up of subscriber base, congestion reduces.

Quality of the access loop decides the type of services; a service provider can provide what subscriber has subscribed for. Economically, the access loop cost is one of the major components of total infrastructure cost of telecommunication services. Hence, as the quality of access loop improves, the variety of services being provided increases as well as the cost of services.

Increase in cost of providing service enhances the price of subscription of the service, which in turn shows its negative effect on subscriber level based on their price elasticity of demand for services. The price for services gets lowered with increase in industry experience, service providers experience and economy of scale. Variety of services is not only governed by the quality of access loop but by the threat of competition also. If there is no expected competition in the market place, then monopolists do not feel motivated to provide higher quality services even though the access loop is capable of supporting such services. Similarly, even with high threat of competition, the service provider may not be able to provide multiple services immediately because of the low quality of the access loop. Similarly, threat level of competition and variety of services both dictate the time for deployment of services.

The CLD further demonstrates the Kenyan economic sectors interaction. In the model, GDP, saving and investment are also main functions of the model. As to be seen, saving depends on income. Different economic and political factors such as corruption, political rights and civil liberties as effective factors on investment are considered. Simulated behaviour of indicators in comparison with their reference modes were emphasized to test and show if unexpected behaviour and relationships are correct.

Economic systems, being complex adaptive systems, are composed of numerous numbers of components which have the specific internal relationships. The components of this section consist of Gross Domestic Product (GDP), saving, investment, public participation, and inflation as shown. This model evaluates Kenya's economic system and demonstrates how it is possible to integrate a simple static economic model within a dynamic framework using systems dynamics methodology.

5 Simulation and verification of the model of the effect of mobile phone usage on Kenya's economic growth

From the subscriber perspective, the number of potential mobile subscribers is projected to move towards stagnation starting from year 2020 onwards, showing a substantial decline in the aggregate number of potential subscribers, By the year 2020, the mobile subscribers in Kenya is

projected to reach up to 40 million users covering approx 87% of total Kenyan population. In the next five-year period i.e. 2020-2025, though, an extra 5 million new customers are projected to join in, remarkably reduced compared to more than 10million new subscribers adding up every year during the period 2015-2020. However, the absolute number of potential subscribers will keep on moving, albeit at a very slow rate, on account of increasing population (market potential projected to grow at CAGR 1.8 percent per annum). Inclusion of incremental population trend of a country and its ensuing effect over the number of subscribers is a remarkable creative departure of our model from other developed mobile or telecom models. It is important to note that when we use the estimated GAGR value of user's growth in Kenya (i.e. CAGR 20%) estimated by CAK and the other agencies, in place of historical coefficient values, we arrive at approximate similar estimate (i.e. 40 million subscribers by 2030).

One can also notice positive feedback loops between potential number of mobile users, mobile users, and sales rate. However, as one moves along the mobile users path, the respective stock values of potential mobile users diminish as shown in figure 3 indicating a negative feedback loop at work.

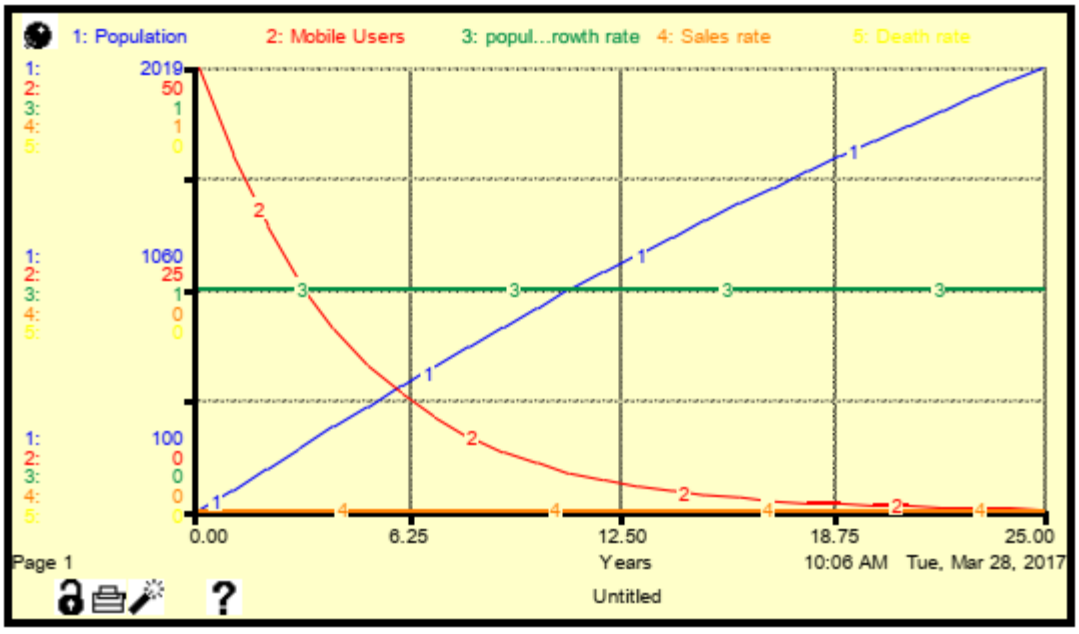

Figure 3: Mobile Adopters Sector

As a consequential output of above dynamics, one can expect a corresponding propagation in the growth curves of individual revenue estimates for mobile operators, as shown in figure 4. It is

important to note that the revenue realization stock also have an outward flow of decline in revenue (estimated @30%) calculated as Adjusted Total APRU (Average revenue per user) and which has effectively moderated the operators revenue curves as the time progresses in figure 4. It is quite important to understand the correlation between growth and a falling ARPU.

Behaving as a contagion effect, related to this revenue sector, we can observe a gradually increasing but moderated Industrial Economic value of mobile industry as a whole and one may take notice of the shift happening to appreciation and loss curves at the first time point after base year 2009-10. This effect thus shifts the relative phase of appreciation ratio and loss ratio despite the slope of aggregate ARPU remaining unchanged rather appreciating which is understandable due to the fact that new spectrum allocation will be supposedly fetching more subscription and revenue to the operators.

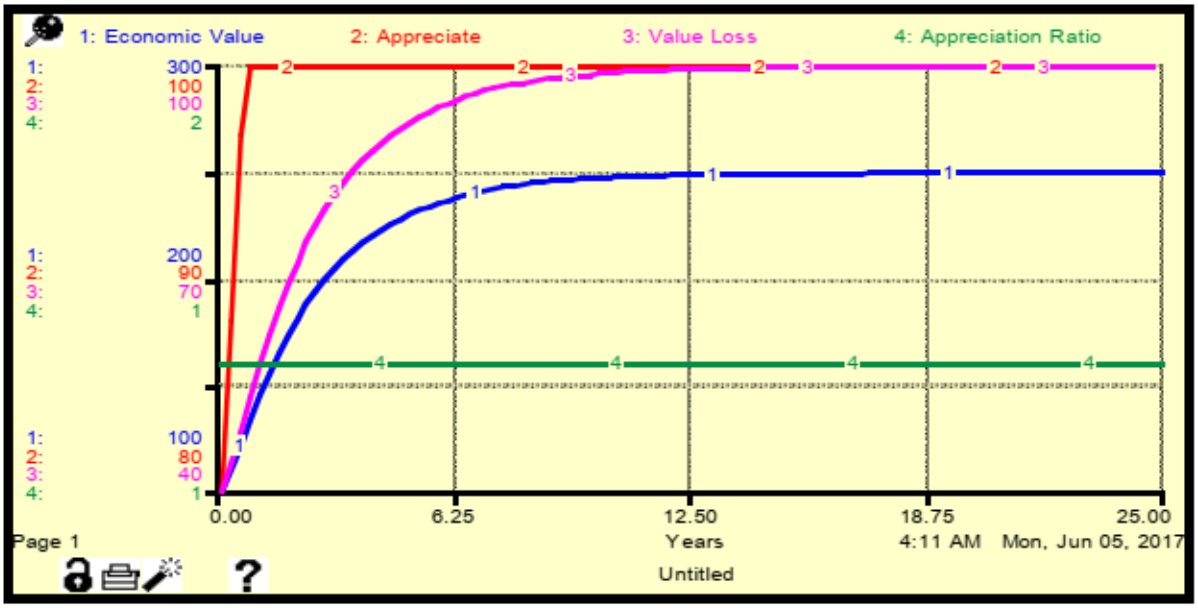

Figure 4: Revenue Sector

Coming to the GDP and Infrastructure sector as shown in figure 5, it is observed that Kenyan GDP will make remarkable gain due to strong fundamental economic structures as projected by government sources and it would in turn presumably result in growth of mobile providers as seen in figure 5. This rise in the infrastructure can however be directly attributed to the contribution made by the Mobile industry Revenue sector (estimated value @6% per annum). We can thus see a positive feedback loop emerging between GDP Revenue-Infrastructure sectors.

The telecom services have been recognized the world-over as an important tool for socioeconomic development of a nation and has the multiplier effect on the economy, playing a vital role by way of contributing to the increased efficiency. Concerning the GDP-Number of good policies relation, there is a strong positive feedback. The GDP growth ratio which is estimated to have contributed 5.6 % of total GDP in 2005-15 and expected to mount up to 10% by 2020. This step effect has been deliberately shown to project the quantum of contribution made by mobile industry revenue towards national GDP. As can be observed, over a longer time, technological obsolescence would require more construction of more infrastructures e.g. new towers.

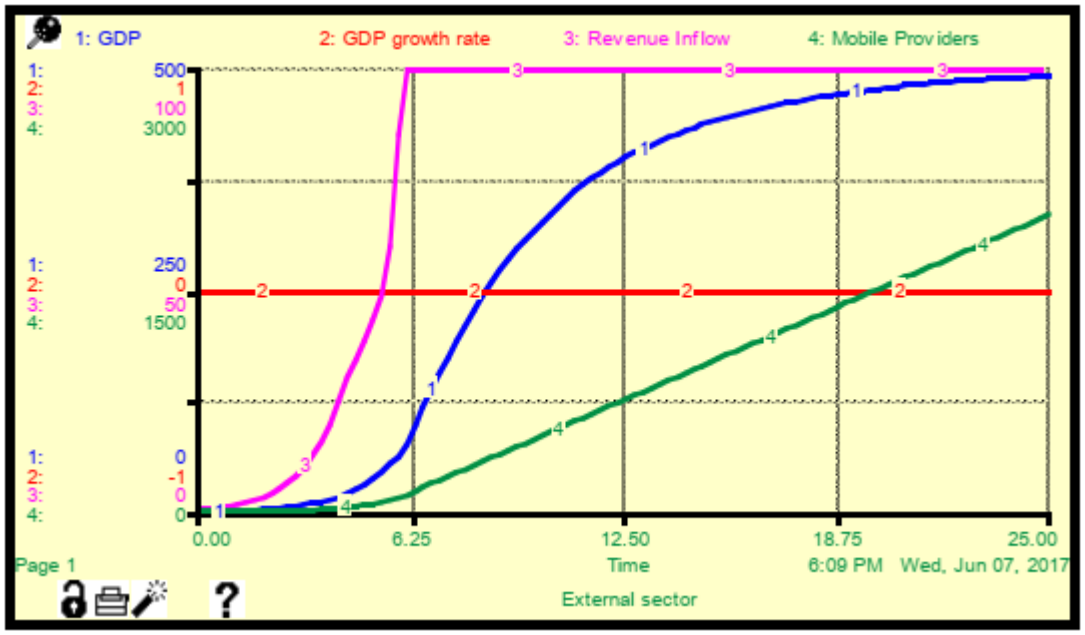

Figure 5: External Sector

Looking at the number of operators in relation to GDP and revenue growth in figure 6. Considering the merit of maturing competition and the shift of margin due to new entrants (projected to grow @50% per annum from the current volume of 2 operators/circle), the revenue growth for most providers will remain constant most probably starting to increase by year 2020 itself, despite the fact that there may also be some sort of industrial consolidation (exit ratio pegged @10%).

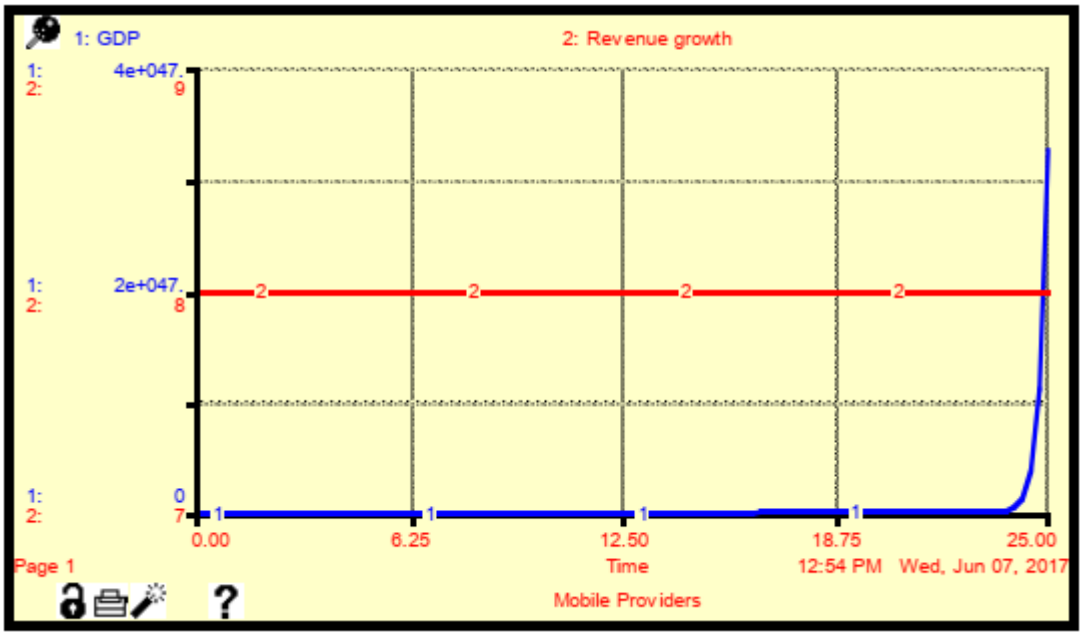

Figure 6: External Sector mobile revenue contribution

6. Conclusion

We have developed a system dynamics model of mobile activity in Kenya. The model is soundly constructed and valid. It is therefore suitable for understanding influences of various policy interventions on the behaviour of the mobile industry of Kenya.

The reference mode of the model represents the existing feedback control structure in the mobile industry. Simulations from the reference mode reveal that Unsatisfied Demand in the economy of Kenya is the underlying force behind mobile output variations and growth trends. Action of system archetypes operating in the mobile industry of Kenya can be sufficiently explained. Therefore, the unsatisfied demand feedback loop is the main area which policy design for the mobile industry of Kenya should focus on.

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