Title: **A diffusion Model with Applications to Broadband Internet.**

ABSTRACT

Broadband is an essential infrastructure of the 21st century and is a tremendous, undisputed force for economic growth and social change. Broadband service enables the overall efficiency of service delivery in such areas as education, health, financial inclusion, and providing access to government services for the most marginalized populations. However, while broadband is taken for granted in the global North, it remains a luxury in sub-Saharan Africa, in terms of access, cost, speed, and its effective usage. From extant research, it has been found that gaps exist in both the demand and supply sides of broadband, for which Market forces alone will never close, and that having internet access at home is not a luxury, but a necessity for modern life. This work reports on an exploratory system dynamics simulation model which was developed to study the phenomenon of the diffusion of broadband Internet. The Nigeria broadband space is the case study used here and provides the background to the model and is used for testing the model's ability to reproduce the various aspects of historical behavior.

keywords: Broadband, Broadband Deployment, Broadband Diffusion, Broadband Adoption, Broadband Usage and Impact, System Dynamics.

Introduction and Background: The internet is a tremendous, undisputed force for economic growth and social change. It is a tool for stimulating economic growth, especially in developing countries like Nigeria. As a matter of fact, the world bank in its report of 2016, titled: *"Exploring the relationships between broadband and economic growth"*, found correlation between broadband connectivity, and GDP growth. It found that a 10% increase in broadband correlates to an increase of 1.38%. Other than GDP growth, the internet has enabled the overall efficiency of service delivery in such areas as education, health, financial inclusion, as well as providing access to government services for the most marginalized populations.

Broadband is an essential infrastructure of the 21st Century. It is to the 21st century, what electricity was to the Industrial Age. It has transformative effect on how people live and work, and high-speed internet is critical to fully harnessing the benefits of the internet. It is in this light, that the Nigerian Government, recognizing how important broadband is, and coupled with her quest to diversify her economy—which is heavily dependent on oil—to a knowledge based economy, developed in 2013, a five-year strategy to drive broadband penetration to scale up growth to 30 percent by 2018. It was known as the National Broadband Plan of 2013. In the policy document, the government reckons that ***"the internet and broadband have been globally acknowledged as the foundation for transformation to a knowledge-based economy".*** As at 2019, the plan was not achieved at all. In 2020, the government released another similar plan known as the ***National Broadband Plan 2020-2025,*** together with the

development and implementation of a ***National Digital Economy Policy and Strategy*** which was unveiled in November 2019. All of these, when properly implemented would lead to creation of jobs, improved socio-economic development and sustained economic growth, amongst others.

This new plan, according to the Nigerian Minister of Communications and Digital Economy ***" is designed to deliver data download speeds across Nigeria, a minimum of 25Mbps in urban areas, and 10Mbps in rural areas, with effective coverage available to at least 90% of the population by the year 2025 at a price not more than N390per 1GB of data (2% of median income or 1% of minimum wage)".*** For the purpose of clarity, Broadband as defined in the context of this work, is characterized as high speed, always on access, at work, at home or on the move provided by a range of fixed line, wireless and satellite technologies to progressively higher bandwidth capable of supporting genuinely new and innovative interactive content, applications and services and the delivery of enhanced public services.

Problem Statement: Good as all these plans appear, historical records of projects and policy implementation failure, of this nature, in Nigeria, have been extremely high. All over sub-Saharan African Countries, the story is the same. Millions of dollars are being spent year in year out in order to deploy broadband capacities that would, when adopted, and effectively used, lead to some significant, well known and documented benefits. In Nigeria in particular, nearly a billion dollar was spent to deploy broadband internet capacity and even at that, the Nigeria National Broadband Plan of 2013 was a failure, and the National Broadband Plan of 2020, might very most likely follow a similar trajectory if it is handled in the same way and manner the 2013 plan was followed.

Right now, availability of service, as operationalized by means effective Coverage is the main problem that we aim to study and solve. ***For now, the coverage is put at about a little over 30%, and the goal is to attain 90% coverage by the year 2025.*** With coverage comes adoption and use, and by extension, the benefits that come with broadband use.

This research, while localized in Nigeria as the primary location and focus, the findings however, would be generic in nature, and may be—with minimal particularization-- equally useful to most Sub-Saharan African countries. **The problem of broadband internet service in sub-Saharan Africa, by whatever standard or metric you look at it, is a big problem and one for which we require urgent attention and action.**

The Objective: The objective of this work is to build an SD model representation of the problem, and use the insights as gained from the model, to identify leverage points, root causes of the factors militating against the full attainment, the best sequence and timing of policies, and efficient practices

that would lead to the attainment of the goal of 90% penetration, effective use, and the attendant benefits thereof.

Demand for Broadband

The overall, overarching goal is to achieve universal, affordable and good quality internet access by the year 2030.

From research (Kukatz) on broadband deployment and adoption, two major things have been learnt:

- Having internet at home is not a luxury, but a necessity for modern life.
- Gaps exist in demand and supply sides of broadband, and Market forces will never close this gap.

Broadband is accessed through **2 main modes:** Wireless (Mobile) and fixed broadband access.

For wireless, it is delivered on smartphones and tablets while for the fixed broadband, it is accessed via computers. In Nigeria, wireless access accounts for 99.8% of all broadband access, and only 0.2% is delivered via fixed broadband. The total cost of ownership, of fixed access, and the fact that it is not mobile, is the reason there is this low number of subscriptions for the fixed broadband access. So, for our purpose, we assume that all access is via wireless access.

Demand and Supply sides

The broadband space is best segmented into two, ***the demand side, and supply side***.

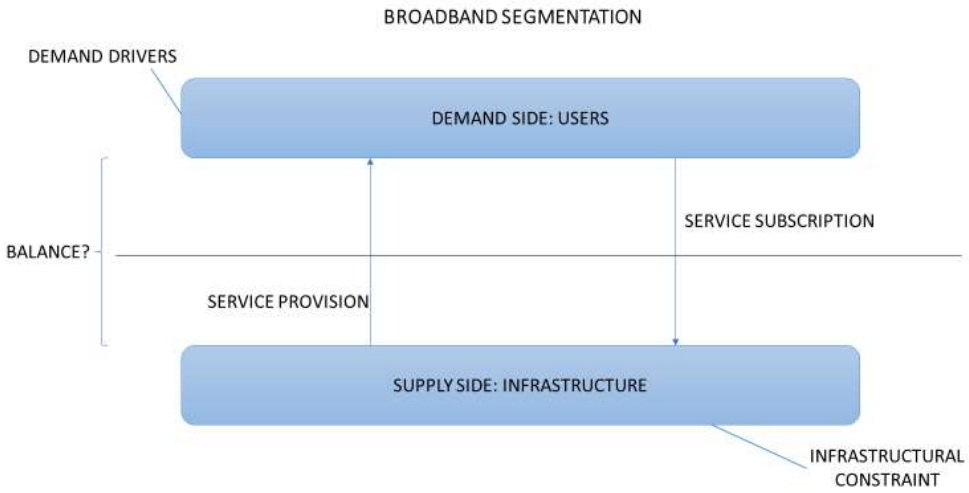

Figure 1. Demand and Supply sides of Broadband

Problem Identification and Reference mode

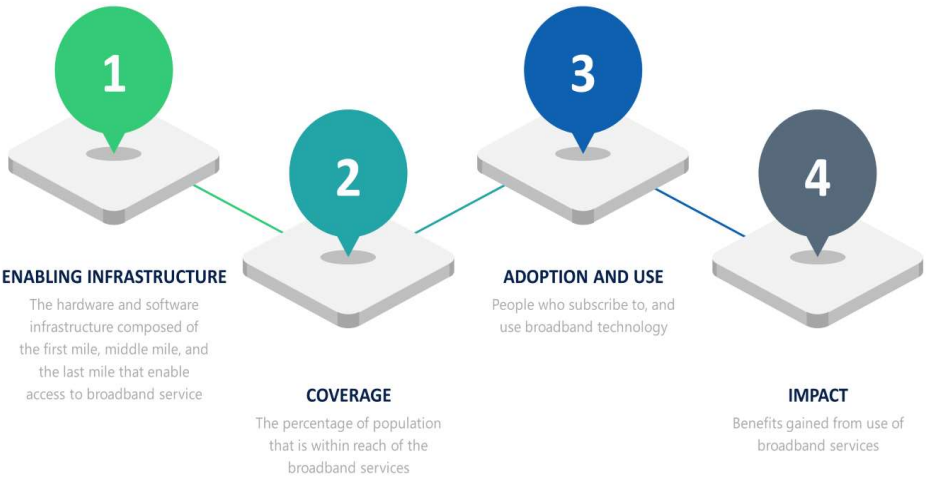

Figure. 2: Key progression stages of broadband deployment and its usage and impact .

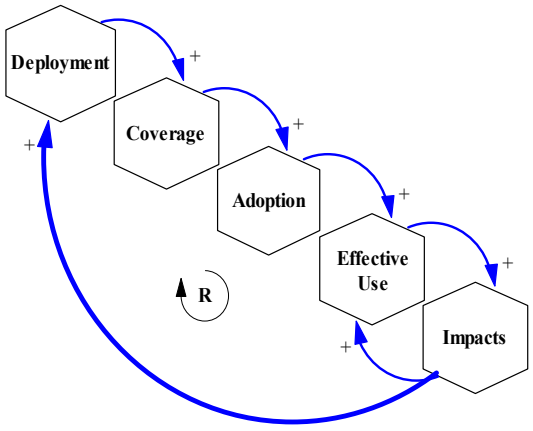

Figure 3. The major reinforcing loops

Research Design and Methodology

- The proposed research would employ the System Dynamics methodology.
- System Dynamics is a tool that is used to address complex problems involving delays, feedback, and non-linearity.
- The approach, is one that simulates the dynamic relationships in order to explore the consequences of different amounts of intervention, timing, delays, and feedback.
- The research, would employ the Dynamic Synthesis Methodology(DSM) as proposed by (Ddembe, W. W, 2002)
- The research combines both quantitative (Sterman, 2000) and qualitative research strategies in conceptualization, data collection, analysis and modeling.

Dynamic Hypothesis

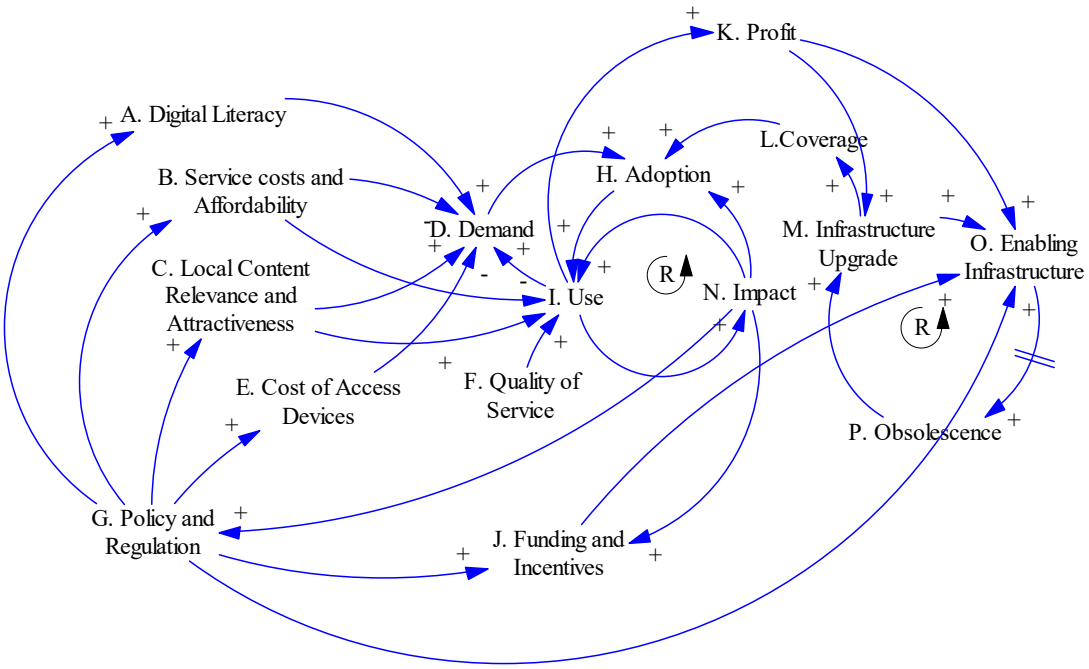

Figure 4: A Causal loop diagram,

The Dynamics of the factors that influence the Coverage, Adoption and Impact of Broadband is shown by the causal loop diagram as above. The structure is comprised of the following constituent variables: Adoption and Use of Broadband, Impact, Demand for Service, Funding and Incentives, Enabling Infrastructure, Obsolescence, Upgrade, Service Availability of Broadband, Service Cost, Local Content, Cost of Access Devices, and Digital Literacy. These Variables were elicited from the Nigeria National Broadband Plan document of 2020.

The aim again, is to carry out a holistic analysis of the structure and behaviour overtime. This holistic analysis is key to understanding the dynamics of broadband with the aim of determining the leverage points with which to improve upon the coverage, adoption and by extension, the impact that comes with broadband adoption and use.

Dynamic Hypothesis: As can be seen from the Figure 1 above, the main ***Demand Drivers*** for broadband in Sub-Saharan Africa are *Service Cost, Local Content, Cost of Access Devices, and Digital Literacy*. This demand for service, when coupled with availability, is largely responsible for adoption and use of the technology. Service availability is made possible by the enabling broadband infrastructure, which provides the requisite service. The developed World of the Global North is already implementing 5G, when a lot of the areas here only have 3G coverage, with 4G only available in the developed urban areas. The installed 3G have not even yielded the necessary return on investment and they are obsolete already. Broadband technology, just like lots of technology, evolves very fast, making obsolescence a major issue. Adoption and effective use of broadband technology then leads to benefits realization by means of some impact. This impact includes but not limited to digital inclusion, economic growth opportunities, improved efficiency of services, etc.

Model Structure

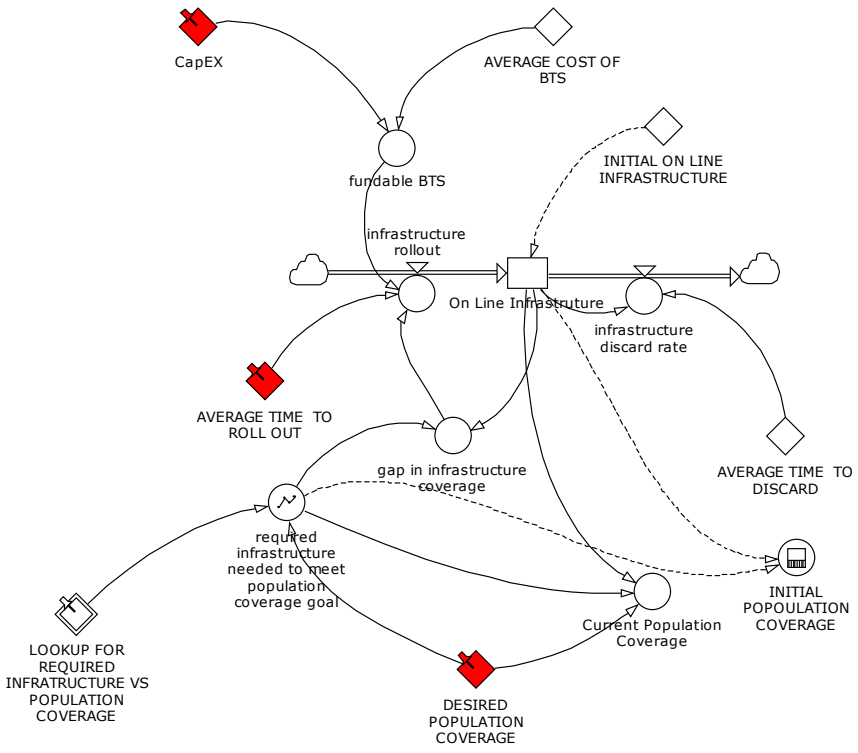

Figure 5: Infrastructure Sub-component

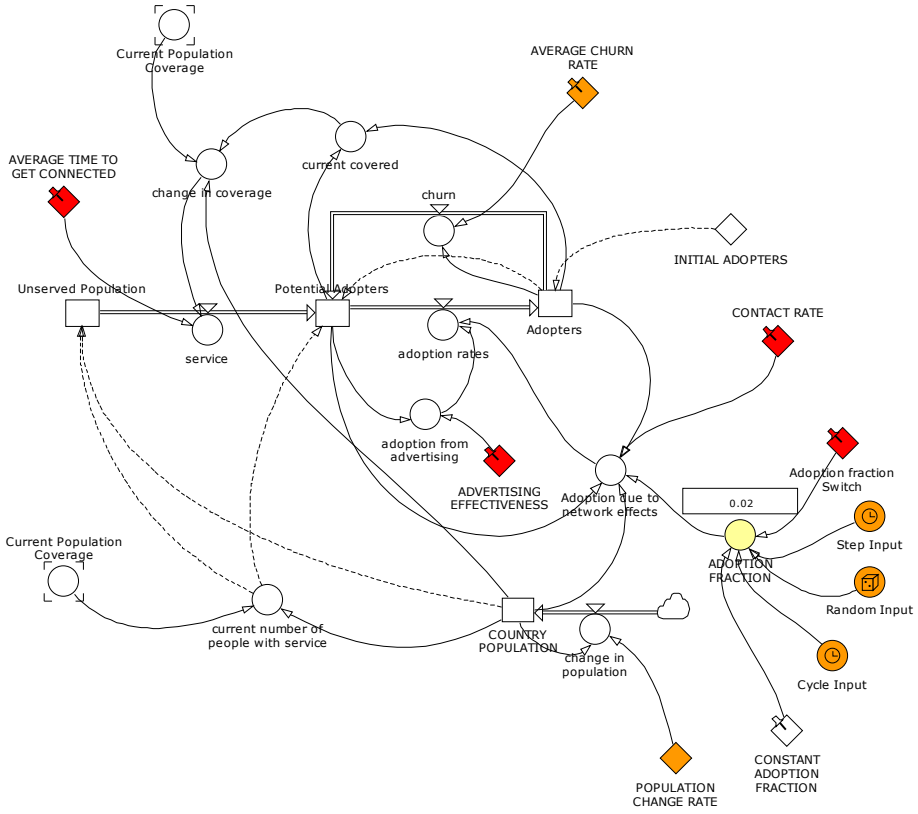

Figure 6: Adoption and Diffusion sub-component

Explanation of Model behavior

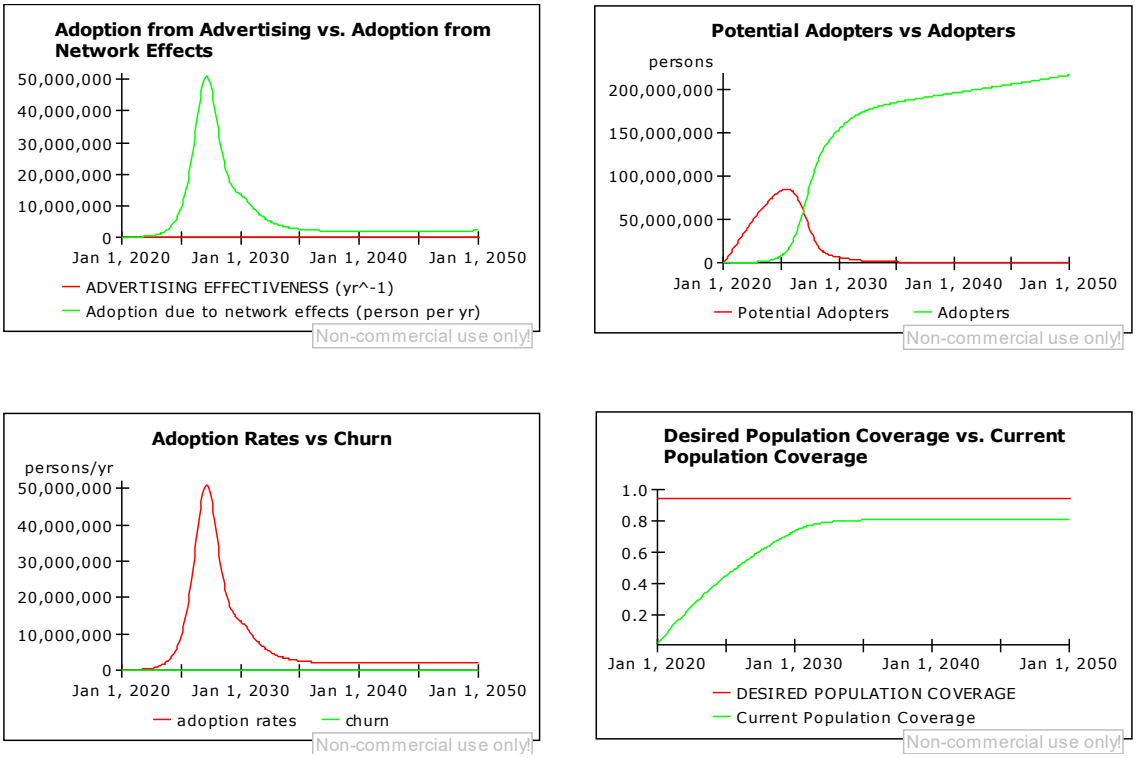

Figure 7: Behaviour over time graphs of model behaviour.

Policy Analysis and Implementation

- The Supply and Demand gaps that exist can't be covered by market forces alone.
- Government Intervention and policy regulation is required for the stagnation to be addressed.
- So far, there have been eroding goals, as seen by the population coverage goals as originally intended, and the coverage that currently exists.
- SD would contribute immensely to broadband in terms of finding equilibrium points, where supply matches demand perfectly, and the points above which *Adoption Critical Mass* is attained, and intervention is not necessarily required.

Data Collection and Analysis procedure

- The main source of information requires subjective judgement from experts and as such, results are acquired using the **Delphi method**.
- **Panelists** (for the Delphi method) are drawn from constituent members of the committee of the **NNBP** which is composed of industry stakeholders, representatives of key government agencies, non-governmental and civil society organizations and development partners.
- Data sources include ***Literature review***, the Nigeria National broadband policy plan of 2013-2018, the Nigeria National broadband policy plan of 2020-2025, and the Policy document on the implementation of the Digital economy, Federal Ministry of Communication, Nigeria Communications Commission, GSMI and Telcos.
- A **Causal Loop diagram**, **Stock and Flow Diagram**, and a Model would be developed.
- A **simulation and policy analysis** would then be done, and the findings documented.

Implications of the study

The contributions of this work would be three-fold:

Implications to practice: Research can be rigorous and relevant by being made consumable. This work would be done and reported in a way and format that is easy for practitioners and policy makers to directly apply it to everyday life situations, with only minimal modifications.

Theoretical implications: This research work intends to conjecture a dynamic theory of the problem of the poor demand for broadband networks and services, an even possibly, a theory of the solution!

Methodological contributions, especially in the IS field, where most of the research is done from the process and variance perspective. This work employs the systems perspective

Conclusion

Ultimately, this work is a **Simulation-based IS research**, using the Systems Dynamics paradigm, to provide theoretical insight from the systems perspective, which is based primarily on temporal and reciprocal rather than just a static, one-way time-invariant perspective as found in the variance or process perspectives. (Burton-Jones, 2014; Yulin Fang, Kai H. Lin, Ying Qian, & Bo Feng, 2018). An artifact by way of a simulation model, which would serve as a kind of management flight simulator, would be among the project deliverables.

I hope to couple my research findings with public policy and a regulation recommendation as is relevant for the promulgation, and implementation of better policies to facilitate effective demand and supply of broadband network and services.

Future Research

Work would be devoted to the development of a comprehensive system dynamics model of the broadband ecosystem, to identify the key leverage points for broadband *deployment, coverage, adoption, and effective use for benefits realization* in developing countries.

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