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**Abstract:-Modeling the Internet Price Behavior in Kenya-A System Dynamics Approach**

This research aims to establish and model the dynamic relationships between the factors that define the behavior of Internet Pricing in Kenya.

The methodology used is based on the System Dynamics framework which is a discipline that is used to understand and solve complex problems by breaking them into three components - Events, Patterns and Structures (Kirkwood, 2010). System Dynamics holds that addressing complex problems(events) requires one to identify their behavior (pattern) and establish the underlying Structures behind these problems. Long-term solutions that address the root causes of the problem can then be proposed given that behavior is a consequence of the underlying Structures.

Using the ITU (2011) series of Internet Price data, this preliminary research builds and proposes an Internet Price Model that is driven by a goal-seeking Structure - whereby Telecommunication Operators seek to meet specific financial and operational targets within the constraints of competitive and regulatory pressures. The model presented offers Policy makers extra insights and provides policy touch-points - from where they can simulate and view the impact of various policy proposals that address the Internet Price problem.

*Keywords: Decision Support, Internet Policy, Internet Price, System Dynamics*

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# Chapter 1:-Introduction

## ***Context/Rationale/Background***

The cost of Consumer Internet Services remains relatively high in developing countries. This is despite positive developments on the Information Society ICT Indicators of Access, Affordability, Usage and Quality (ITU, 2010). Indeed the recent landing of several submarine cables on the East African Coast in 2009 raised the hopes of consumers, most of whom thought that Internet prices would consequently fall as suppliers moved traffic from the very expensive and unreliable Satellite links to more affordable and high quality Submarine Cables. Whereas the WHOLESALE Internet Prices have registered significant drops of almost 200%, similar drops are yet to be registered at the RETAIL end of Internet Prices. This Research attempts to capture the dynamics and behavior of the various factors that influence Retail Internet Prices over time . It uses the System Dynamics approach to establish a model that depicts the cyclic behavior between these factors over a given period of time.

The following points bring out a summarized background of the problem.

- Cost of Internet Access (Internet Price) remains high despite the landing of the submarine cables which is a much cheaper and better quality Internet medium compared to the old Satellite medium for accessing global Internet.
- Internet Price is “NOT Affordable” based on the fact that monthly Internet rates in Kenya, i.e. the cost of 20hrs of Internet Access per month is 30% of the Average incomes (ITU, 2010)
- The above value compares poorly against Algeria, India, South Africa and Bostwana whose corresponding monthly Internet rates are 2.4%, 3.6%, 4.2% and 5.4% of their respective Average Incomes (ITU, 2010)

## ***Problem Definition***

The eventual price of accessing the Internet is determined by various Stakeholders including but not limited to the Telco Operators (Suppliers), the Market Size (Users), Domestic Infrastructure (Access), the Regulators amongst others ([1]. In most cases, each Stakeholder has a contrary and competing (price) objective to her peers who also make decisions based on the choice the others make ((Wang et al. 2008)). As such, a single intervention by one of the players on the Price relation/equation, generates multiple and often **time-delayed** cascaded reactions (**feedback loops**) from the whole ecosystem.

Many a times, these feedback reactions in the course of time, deliver outcomes that are contrary to what was expected or intended [2]. Systems of such nature are known as complex systems and one of the tools used to uncover and understand their behavior in order to establish the best, long-term intervention is the System Dynamic Approach.

## **Research Aim**

To identify and simulate the dominant feedback reactions(loops) that define the dynamic behavior of Internet Pricing in Kenya.

## **Research Objectives**

1. To identify, describe and estimate the relationships between the factors influencing Internet Retail Price in Kenya
2. To identify the dominant/key feedback loops in the above relationships in order to determine critical points for policy and strategic intervention with respect to Internet Prices.
3. To provide a time-based Model describing the dynamic interplay between the various factors that Influence Internet Pricing in Kenya.
4. To Simulate and Test the Proposed Model (Conceptional Test, Data Test and Validity Test as by ([3]),
5. To automate the Proposed Model in order to provide a "What-If-Analysis" tool for Stakeholders (Policy Shapers, Operators, Regulators, Consumers)

## **Research Questions/Hypothesis**

In pursuing the above Research Aims and Objectives, the following questions shall provide the overarching guidelines:

- What are the dynamic structures behind the prevailing behavior of the Internet Price in Kenya?
- What are the Key Variables i.e. the Stocks(Levels), Flows(Rates), Constants etc that influence Internet Prices in Kenya?
- What are the Key Reinforcing(Positive) Feedback Loops that influence Internet Prices in Kenya?
- What are the Key Balancing(Negative) Feedback Loops that influence Internet Prices in Kenya?
- What are the Key Time-Delays that influence Internet Prices in Kenya?

## **Scope**

The study will be limited to Kenyan Internet Market and will include perspectives from key stakeholders such as the Operators, Regulators, Users, Investors. In addition, the study will focus largely on the dominant mobile data Internet Pricing space - even though the resulting Internet Price model can apply to fixed-line Internet pricing.

## ***Significance***

The Cost of Accessing the Internet is considered to be one of the biggest obstacles that widens the digital divide and denies millions of citizens (particularly in the developing economies) the opportunities to engage and benefit from the Information Economy.

Many interventions have been made including increasing competition (Regulatory Interventions), introducing submarine cables (Infrastructure interventions), reducing tax on ICT equipment (Government Intervention) but the cost of Internet Access remains high. This study will attempt to map out a dynamic model that demonstrates the impact of these and other policy interventions on the Internet Price and how they influence each other in the short and long-term.

Specifically, the expected Internet Price Model would provide stakeholders with insights regarding the dynamic feedback behavior of the factors influencing Internet pricing. This feedback impacts are traditionally uncovered by Policy makers .([4]) Further, the Model would provide a cheaper mechanism for stakeholders to experiment by way of subjecting different parameters and policies to the model and viewing the impact within the safety confines of “lab/virtual” environment

## ***Unique contribution of the Study***

There have been several studies that describe how the various Stakeholders independently treat the Price of Internet Access but very little literature on how these stakeholders holistically and dynamically interact to influence the Price of Internet Access. The typical Supply and Demand approach as a way to influencing and monitoring the Price of a commodity assumes that only one or two variables are changing while the others are held constant. Furthermore, such an approach lacks the ability to capture the impact of time-delays and looping effects between the changing variables. This study attempts to capture the dynamic structure and cyclic behavior of these factors that determine the eventual price that consumers pay for Internet Access/Services. It uses an approach known as the System Dynamics Methodology, designed by Forrester J 1950.

## **Chapter 2: Literature Review**

### ***The Kenyan Internet Price within an Economic Context***

#### **The Demand Side**

Shifting the Demand for a commodity often has the impact of increasing the Price Equilibrium,  $P_e$  (i.e. Increasing the Price). However, for Internet Bandwidth, the higher the demand for bandwidth the lower the Prices will become. The following analysis, summarizes the Kenyan Internet Bandwidth situation using the known (Mudida R, 2010) economic factors of shifting Demand (which should eventually drop prices). The intention is to evaluate the extent to which economic factors could be used to influence Internet Pricing in Kenya.

#### **i) Increase in Disposable Incomes**

In the Kenyan situation, the GDP and subsequently disposable incomes have remained stagnant for several years. Attempting to increase incomes as a way of making Internet Access affordable may not be feasible in the short to immediate term.

#### **ii) Increase in Advertising/Marketing efforts**

This has been the preferred approach by the Providers (Suppliers). There has been, and continues to be aggressive marketing campaigns by all the players in the market. This has increased demand but still failed to significantly lower the Price of Internet Access (target monthly costs should be below 5% average national incomes).

#### **iii) Change in price of Complimentary/Alternative commodity**

In developed economies, alternative sources of Consumer Internet access exist in form of Cable Networks, Public Wireless Hotspot amongst others. In the Kenyan context, mobile access with 4million modem users (CCK, 2011) seems to be the main source of consumer access. Alternative sources e.g. fixed line/wireless through the traditional ISPs tend to be more expensive and a minority form of Internet Access. Alternative forms of access are therefore not a means of providing affordable internet access.

#### **iv) Government Policy (e.g. mandating a certain line of Produce)**

In the Kenyan market, Government Policy has been successfully applied in an effort to increase demand. Specifically, initiatives like Wezesha laptop initiative (offering Laptops at subsidized rates), KENET bandwidth subsidies (offering affordable bandwidth to Universities) and provisioning of the Undersea cable, TEAM have all been successfully used to drive up demand for Internet Bandwidth. This has reduced Internet Prices but only within a select group of Consumers.

#### **v) Credit Provision**

Credit provisioning within the Kenyan Internet market has had little impact on demand since most consumers prefer the PRE-Paid rather than POST-paid charging model. With a large population percentage of un-employed and informal sector, the Credit-provision model is difficult to implement and has had little chance of impacting on the Demand for Internet Bandwidth.

**vi) Change in Consumer Preference (Taste/Fashion).**

The youth have contributed to the over 50% of Kenyans owning mobile phones (CCK, 2011). The Social Network phenomena (Facebook, Blogs, etc) has indeed contributed to the demand for Internet and Suppliers have continued to offer tariffs targeting access from the Mobile Phone.

**The Supply Side**

Increasing the Supply of commodities would usually have the effect of pushing down the Price Equilibrium (lowering prices). The following analysis reviews the Supply side factors with a view to establish the extent to which these could influence the Internet Pricing in Kenya.

**i) Price of other goods (Suppliers divert resources to higher-priced goods)**

If Prices of other complimentary goods went up, Suppliers would often divest from the current production lines as they divert production resources to the more lucrative product lines. For the Internet Bandwidth commodity, this factor may not apply since the Internet as a commodity has no direct alternative.

**ii) Change in factors of Production (Lower costs attract more Suppliers to that line of Produce)**

The major factor of production (of Bandwidth) that has occurred is the move from Satellite to Undersea cable for International Internet Bandwidth. This has led to several players coming into the Internet Gateway market (TEAMS, SEACOM, EASSY etc) - each providing bandwidth through independent undersea cables from Mombasa. This oversupply has indeed caused significant drops in International bandwidth (from 3000USD per 1MB over Satellite platforms to 400USD per 1MB over submarine cable platform). Unfortunately this drop has not been proportionately realized at the retail/consumer end of the market.

**iii) State of Technology (better technologies reduce cost of production)**

The advances in the electronic components of core Internet devices (Routers, Switches, Network Cards, etc) have implied that more capacities of Internet Bandwidth are being provisioned at the same cost. This means suppliers are able to push more quantities of the commodity without increasing the cost or prices - a phenomena that is reflected in the market where ISPs are giving more bandwidth for the same cost. The impact in real terms (drop in price) remains to be seen/realized given that the Price Equilibrium is already quite high and so only a few consumers do actually enjoy the benefits (i.e. only

those who had already been able to afford the high prices do reap the benefits, while the large majority remain excluded)

**iv) Reduced Taxes**

Government has continued to offer subsidies through Zero-rating ICT equipments and Software, Bandwidth subsidies for selected sub-sectors (Education and BPO), amongst others. The impact - increased demand for Bandwidth - has been positive within the Education sector but yet to have an impact in the wider populace.

**v) Improved Weather Conditions**

Weather has no relation and no impact on the Internet Demand.

**vii) Reduced Strikes**

There has been no significant labor unrest in the Internet Market over the recent years. However, what is becoming of concern is the increasing incidents of malicious fiber-cuts. The market seems to be involved in sabotage moves where competitors are suspected to hire vandals and tasking them to damage the competitors cables. The cost of this sabotage for one of the players is in millions of USD per year (TKL, 2010). This could discourage prospective Suppliers from joining this market - thus potentially increasing the Internet Price.

**Price Elasticity of Demand (PED).**

Another economic factor that influences Prices is the Price Elasticity of Demand. This is defined as a measure of the response that a %Price Change has on the Demand.  $PED = \%Change\ in\ Demand / \%Change\ in\ Price$ . Revenue is maximized when the Price is set so that the Price Elasticity of Demand (PED) is 1 - that is Suppliers try to set the price in such a way that a change in Price produces a proportionate amount of Demand.

## The Technical View of Price

### Components of Internet Pricing

In an Internet study for the Asia Pacific region, Denton, Savage et. al. (2000) showed that Internet retail pricing had three major cost components - Infrastructure, Interconnection Agreements and the Local Loop costs as shown below.

I) Cost of Infrastructure (Regional+Backbone Links/Cables)

II) Cost of Internet Interconnection Charges (Access Port)

III) Cost of Local Loop (Access Network)

Proportions of Underlying Cost in the Internet

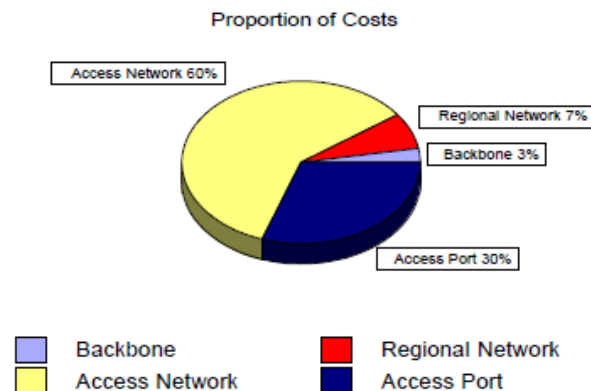


Fig. 1: Proportion of Internet Cost Components

It is significant to note from the Denton Internet Study that **60%** of the Internet Access Costs were found to lie within the Local Loop cost. The local loop, otherwise known as the last mile is the infrastructure necessary to move traffic to and from the customer's premises to the nearest Telecommunication Exchange or mobile Base Station. Perhaps exploring the issues surrounding the cost of the local loop would provide useful parameters that could be used to significantly vary the cost of Internet Access.

([5] found that Operator's or Supplier Pricing is influenced by four Objectives: Network Efficiency, Economic Efficiency, User Utility and Practicability.

i) **The Network Efficiency** is the percentage % of the Capacity Utilized per given time period,

ii) **The Economic Efficiency** is the Return on Investment ROI,

iii) **The Practicability** is the percentage administrative overhead exerted by the particular Charging Model

iv) **User Utility**: The Amount of time User spends on the Network per given time period.

((Li & Wang 2006) further says that this yields the following factors which Operators consider when determining a Charge rate: **Traffic Volume, Distance, Congestion, Application Type** and **User Related** issue (individual based and route based Charging).

([6] also identified several factors that Operators consider when developing their Internet broadband pricing strategies such as:

- i) The competitive structure of the market,
- ii) The degree of regulatory intervention (especially with regard to Local Loop Unbundling or LLU),
- iii) The existing infrastructure of incumbents (including prior investments in ISDN technology),
- iv) The competing technologies (e.g., cable TV) and
- iv) Indirect competitive pressure from neighbouring countries

It is instructive to note that most of these factors map well on the earlier identified economic factors of the Supply and Demand Shift curves particularly; Government and Regulatory Interventions, Price of Complimentary or Alternative forms of Internet Access amongst others.

((Biggs & Kelly 2006) further identify several Pricing Schemes: **Flat-Rate, Time-based and Volume based**. Flat-rate schemes tend to encourages consumption while Volume based schemes moderates or deters consumption. On the other hand, (Biggs & Kelly 2006) observed that Volume based schemes reflected the correct consumer costs while the Flat-rate scheme potentially allowed entry-level-consumers to pay for big-time consumers. Other differentiated pricing was based on whether User access is to Domestic or International destinations.- though this was noted as a rare approach. A more common variation is where Consumers were offered lower prices if they agreed on a longer-term (e.g. 2yr-3yr) contracts.

([7]) established that differentiated, rather than Flat-Rate Internet Pricing was beneficial to both the Users and the Services Providers since it allowed Users to select their needs according to their purchasing power while avoiding congestion. This often leads to better Network Optimization - which is desired by Operators.

([8]) proved that differential Internet Pricing provided for a higher Revenue than Flat rate pricing. In addition, they agreed that it allowed for greater Network Utilization and Optimization. They found that most studies on Internet Pricing were based on two objectives: using Internet Pricing as a mechanism for congestion control and Using Internet Pricing as a way of increasing social welfare.

((Zhang & Liu 2005) further established that the Internet Pricing was a problem of multiple players or Stakeholders, namely:

- i) ISPs/Operators
- ii) Competitors
- iii) Governments,
- iv) Content Providers(CPs),
- v) Users, and vi) The Whole Society.

Operators and Content Providers set Internet Prices that are subject to a Demand that is driven by the Users or Consumer choice to Maximize Value from what they have paid.

((Zhang & Liu 2005) concluded that most costs for ISPs are **Fixed Costs** implying that the incremental cost of sending additional packets on a non-congested network is Zero - thus for ISPs and Operators the Internet Price is a **Fixed Cost Recovery** Issue. This compares well with the Denton 2000 studies with the additional Operational Costs to be included in the Cost equation.

Operators and ISPs face the problem of how to make a Pricing Strategy or Scheme that can maximize profit within a multi-service or a differentiated QoS (Quality of Service) platform. Just like [6], ([8]) reviewed several Pricing Schemes used by Operators as shown below:

- i) **Flat-rate:** Identified as being the most convenient in terms of implementation but weak on ability to allocate resources to different social participants - that is, it does not allow user to select what is best or commensurate for their purchasing power.
- ii) **Paris Metro Pricing (PMP):** is a simplified differential pricing to provide different QoS requirements. Its challenge was implementation in that it required the creation of two logical networks and allows users chose which one to use based on Price.
- iii) **Usage based pricing** is the third option where the Users pay per packet transmitted. Which attempts to avoiding the "tragedy of the commons" phenomena that would arise in Flat-Rate pricing.

([9]) proposed the PMP - Paris Metro Pricing mechanism where the Network is segmented into two logical units allowing for those wishing to pay more to be rewarded by avoiding congestion. Whereas no guarantees are offered, higher-priced networks tended to be less congested. However, (Gibbens et al. 2002) found that the PMP would not survive in a Duo-polistic or more competitive environment since both Suppliers(Operators) tend to derive less profit when deploying a PMP Scheme.

### ***The Techno-Economic View of Price.***

[8] provided a Techno-economic relationship that defined Potential Demand,  $D$ , as the amount of Data Volume download - if the the costs or charges were Zero. Demand was therefore defined as:

$$\text{Demand, } D = P(x) \cdot V$$

where  $P(x)$  is the Probability that a User would within a given time period of 1 month, download Data Volume,  $V$  at Price,  $x$ . Hence Demand,  $D=1$  (maximum), when Price,  $x=0$ ; that is if the Price is set to Zero, then the Demand is expected to be highest and lowest as Price,  $x$  approaches the highest value. This is in line with the economic law of Supply and Demand for the commodity Internet Bandwidth.

(Zhang & Liu 2005) also observed that ISP or Operator Revenues,  $R$  can be represented by:

$$\text{Revenue, } R = x \cdot V$$

where  $x$ , the Price of downloading, Data Volume,  $V$  in a given time period.

This means operators can get their cost-recovery equation resolved even from a single high volume user. Operators would establish the Unit cost of Bandwidth using a Cost Recovery method. In this approach, the User-Demand (Data Volume requested) is charged by way of proportioning that Unit Demand against the overall Volume/Cost structure.

This means that, as an example, if it costs 100,000,000\$ (100million\$) to layout 1,000,000MB (1,000GB) of the Network resource(Bandwidth), then the Unit cost of Internet Bandwidth, 1MB (Internet Price) would be arrived at by the following formulae:

Unit Internet Price = Cost of Provisioning Network/Size of Network Provisioned.

$$1,000,000 \text{ MB} = 10,000,000\$$$

$$1\text{MB} = 10,000,000\$/1,000,000 = 10\$$$

Another techno-economic view from ([10] found that the Operational Cost of an ISP or Operator can be represented by:

$$C(n, k) = C_f + C_m n + C_t v_r(k) \text{ where}$$

**$C_f$** : is the Fixed Cost of provisioning the Network;

**$C_m n$** : is an additional cost that depends on the Number of Users,  $n$ , the subscriber population size and  $C_m$  is the marginal cost, per additional subscriber;

**$C_t v_r(k)$** : the third component depends on the outbound external traffic volume,  $v_r$ . Where,  $v_r$  is a function of the number of Peer 2 Peer (high-bandwidth) users, denoted by  $k$ , and  $C_t$  is the marginal cost per outbound external traffic.

This formulae also maps well with the three cost components identified by Dentol 2000 with [10] adding that the Profit component for the Operator is simply the payments made by the Users minus Operational cost,  $C(n, k)$  identified above. They cautioned that controlling P2P users may cause an Operator/Provider to lose market share but at the same time, avoiding to control them high bandwidth users may cause congestion and increase the Providers operation costs.

Another researcher, ([11]) observed that Operators would wish to have a mechanism that could react to User's willingness to pay, Quality of Service and Congestion. They identified three typical Pricing Scheme pricing schemes namely: Dynamic, Smart-Market and Static as shown below:

**Dynamic Market:** In this approach the Operator addresses the network load increment in terms of real time price adjustments. This scheme estimates the usage price as:

$$P_e = \text{actual\_delay} * \text{delay\_cost} * Q_n \text{ where}$$

$P_e$  is the estimated price,  $\text{actual\_delay}$  is the end-to end delay spent in transmission and  $Q_n$  is the throughput.

**Smart Market;** In this scheme, the Operator tries to internalize congestion as opposed to treating it as an externality. The estimated price,  $P_e$ , for this approach is based on the given equation

$$P_e = MB_p + MC_s$$

where  $MB_p$  is each users marginal benefit and  $MC_s$  represents all users' marginal social cost.

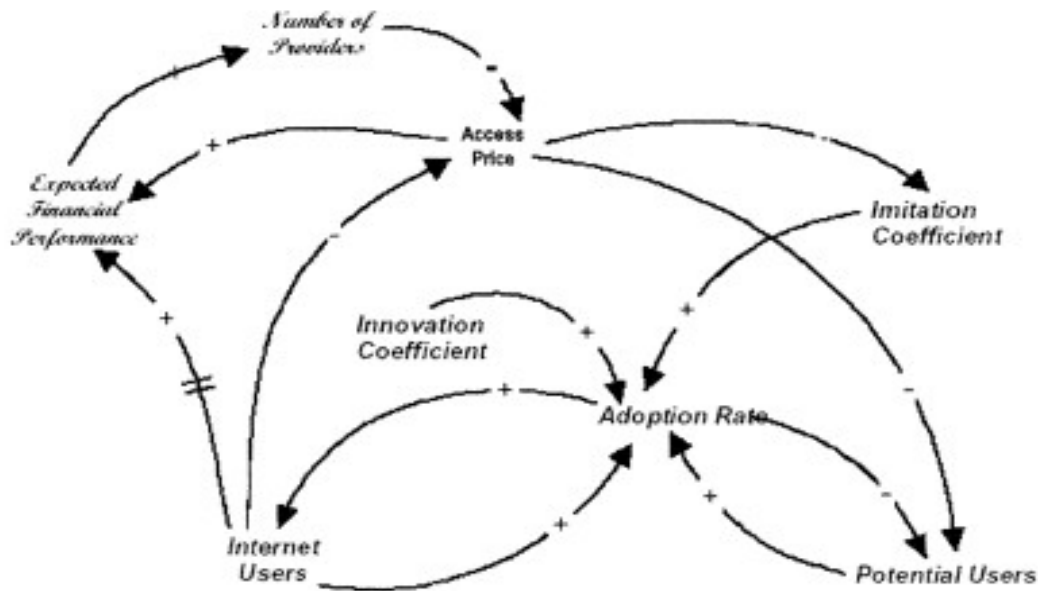
**Static Market;** In this approach the Operator accepts the differences in Users valuation for using the network resources(bandwidth). This approach estimates the usage price per second following the simple formula presented in the equation below:

$$R_e = P_e * Q_n$$

where  $R_e$  represents the total revenue per second,  $P_e$  the estimated Price and  $Q_n$  the throughput. It is possible that most mobile internet providers in the Kenyan market have adopted this Static Market approach.

[11]also defined **price elasticity of demand** as: the percentage change in the network quantity(bandwidth) demanded over the respective percentage change in the price. Another parameter introduced and measured was the "Consumer Surplus" which was defined as the welfare gains or loses imposed by users from the knowledge of the demand curve of the service. Using these two parameters, they simulated a network and attempted to establish which of the above three pricing strategies was most effective in providing QoS on a network - that is using Pricing scheme as a congestion control measure.

The International Telecommunication Union, ITU (2010) found that the Price of ICT service was dictated by Regulation Interventions, Competition, Market Size (no of Users), Operator's(Supplier) costs and Profits. [1] also found that the Price of Internet Access was influenced by No of Operators, No of Users, Cost of Infrastructure and the Anticipated Profit by the Operators. More precisely and from a System Dynamics perspective (Dutta & Roy 2004) described how Internet Access Price affects the Internet Diffusion as shown below.

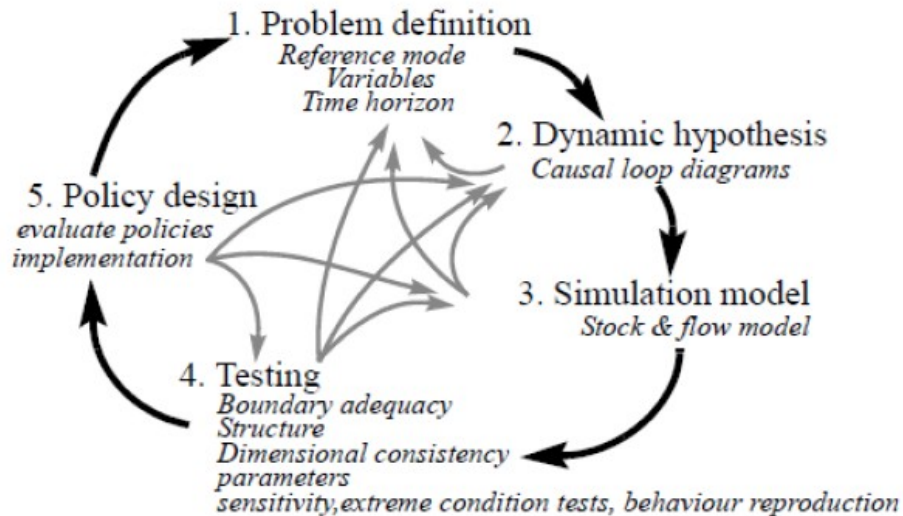


**Fig. 2:** Internet Access Price affecting Internet Diffusion.

## Chapter 3:-Research Methodology

### Research Design

The typical approach for using System Dynamic in investigating a problem area is proposed by ([12]) and is shown below:



**Fig. 3:** System Dynamic Iterative Research Model

1. Using Existing Literature, identify the factors affecting Internet Pricing in general to build an Initial Model based on the System Dynamics Approach.
2. Propose hypothetical Model Structures based on observed behaviour or patterns of Key Variables. Create and enhance Causal Loop Diagrams (CLD) from data collected.
3. Simulate the Model by deriving a Stock and Flow (SFD) that mathematically defines the relationships.
4. Simulate, Test and Validate the model
5. Policy Design: Model the dynamic impacts of various possible Interventions (What if Analysis) on the Internet Price as desired by different Stakeholders (e.g. Policy, Regulatory, Competition, Usage etc)

## ***What is System Dynamics***

System dynamics as defined by the System Dynamics Society(2011) is a computer-aided approach to policy analysis and design. It is often applied to dynamic problems arising in complex social, managerial, economic, or ecological systems -- literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality.

The US Department of Energy(2011) defines System dynamics is a powerful methodology and computer simulation modeling technique for framing, understanding, and discussing complex issues and problems. It was originally developed in the 1950s to help corporate managers improve their understanding of industrial processes but currently system dynamics is being used throughout the public and private sector for policy analysis and design.

## ***Origin of Systems Dynamics***

Founded by Prof. Jay Forrester in 1950s at the Massachusetts Institute of Technology (MIT). Most of System Dynamics principles are grounded in EEE – namely the feedback control systems (servomechanism)

Jay Forrester felt that established engineering disciplines and practices were lacking in social systems and he proposed Systems Dynamics as his attempt to understand social systems through an engineering feedback-control perspective.

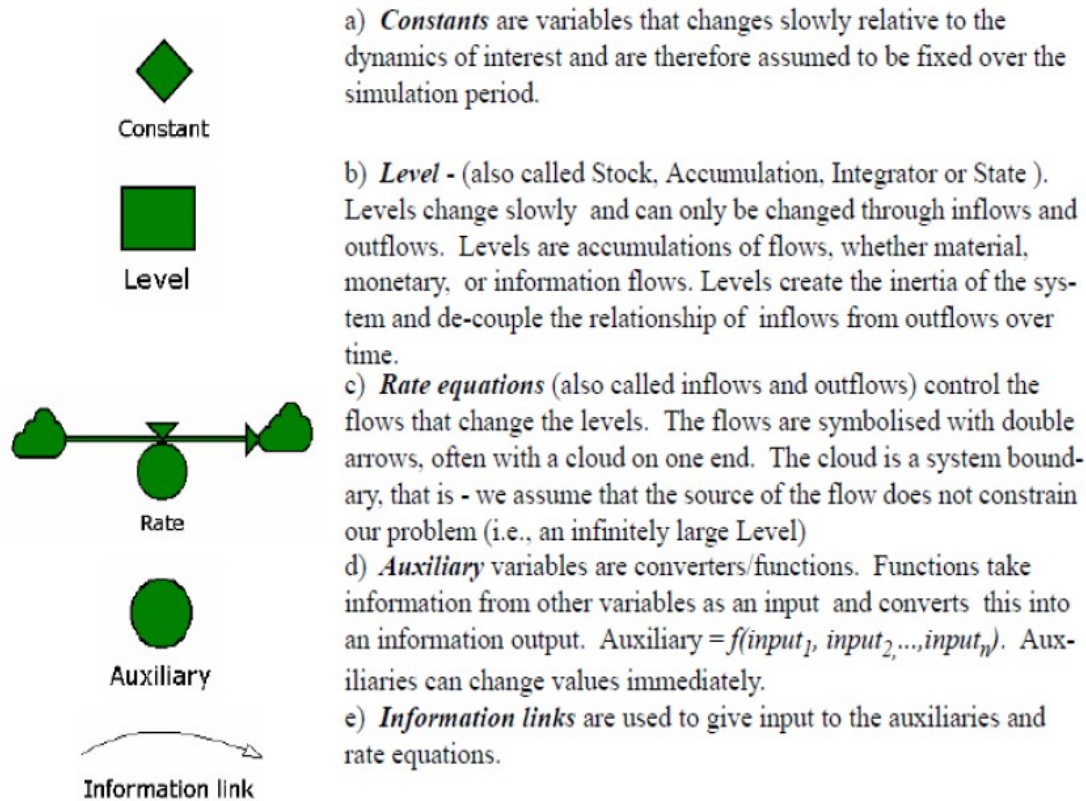
His pioneering work described under his famous book, Urban Dynamics (1969), described how public policy interventions to address the rapid growth, stagnation and eventual decay of American Cities in the 1970s were beneficial in the short-run but highly counterproductive in the long-run.

Through a System Dynamic model describing the dynamic relationships and behavior between the variables "Housing", "Job Creation" and "Populations" in Cities, he traced out the feedback loops that showed that constructing and availing cheap "Housing" in total isolation from "Job Creation" was aggravating rather than solving the problem of Housing deficiencies in the Cities.

The feedback loop simply showed that cheap Housing provided a good but short-term benefit that over time attracted more immigrants (increased population) to the City which in turn took the City back to its original status of housing deficiency (Balancing Feedback effects). He demonstrated that a better and long-lasting solution to the problem of housing deficiencies in the Cities was to increase "Job-Creation" while leaving house construction to be the consequences of the Job creation.

## ***System Dynamic Components***

The building blocks for any System Dynamic model include the Stock, the Rates, the Variables and Information Flows. Their detailed definitions are described below ([12])



**Fig. 4.** Components of System Dynamic Structures

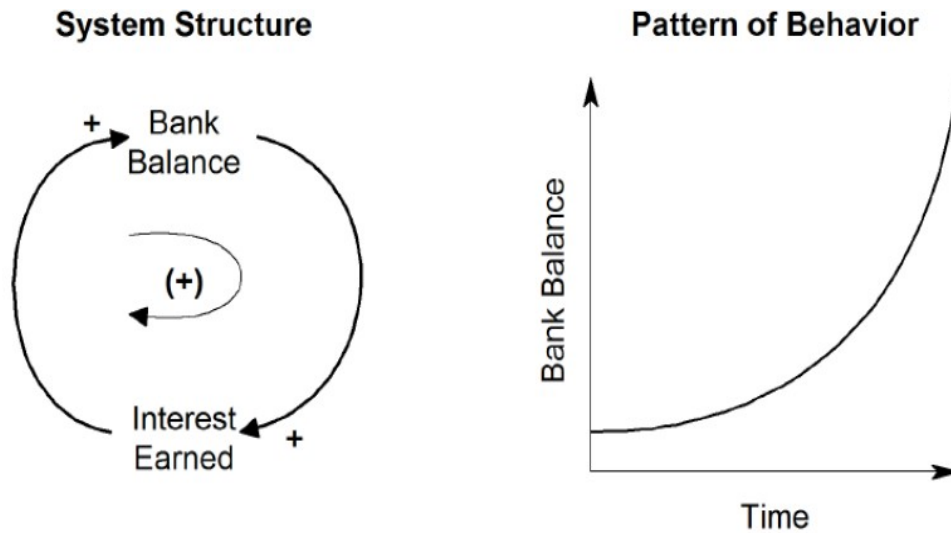
### **Characteristics of Dynamic Systems**

The typical attributes of any dynamic systems have been summarized (Quote) as being the following:

- i) Cause and effect are separated by a lot more time and distance than most Policy makers think. **Time delays** greatly complicate the effort to firmly connect cause with effect - particularly when there are multiple causes and multiple effects.
- ii) The more one tries to improve the system, the stronger the resistance to change. This is the result of "balancing loops" - i.e. inherent forces within the system structures that counteract policy changes as cited in the Urban Dynamic example.
- iii) There are often unintended consequences and indirect effects arising from a given Policy intervention. Sometimes the most obvious solution makes a problem worse.
- iv) Things can get worse before they get better. Reinforcing Loops amplify small changes into big changes.
- v) In System Dynamics there is no single right answer or model [13]. There are often trade-offs that require choices depending on the model intentions.

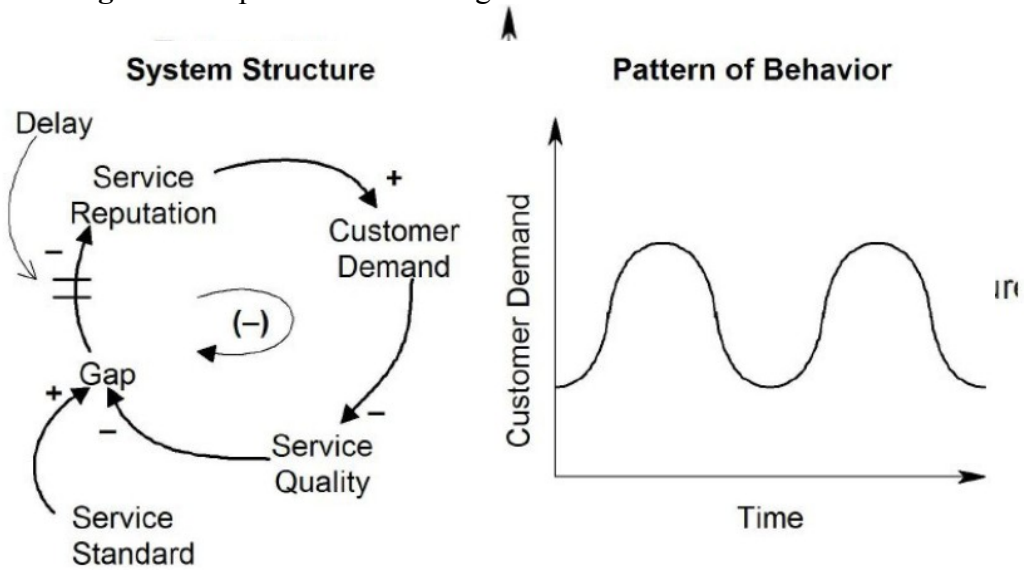
### **Key SD Archetypes/Behavior**

In building a system dynamic model for a particular problem area, one has to establish the dominant behavior of the selected variables or indicators within the System. The behavior or pattern observed often underscores the underlying Structures causing the behavior Kirkwood, C.W, 2010 says that most existing world systems exhibit one or a combination of the following patterns of behavior: Exponential Growth, Goal-Seeking, Oscillating and S-Shaped Growth as shown in the examples below

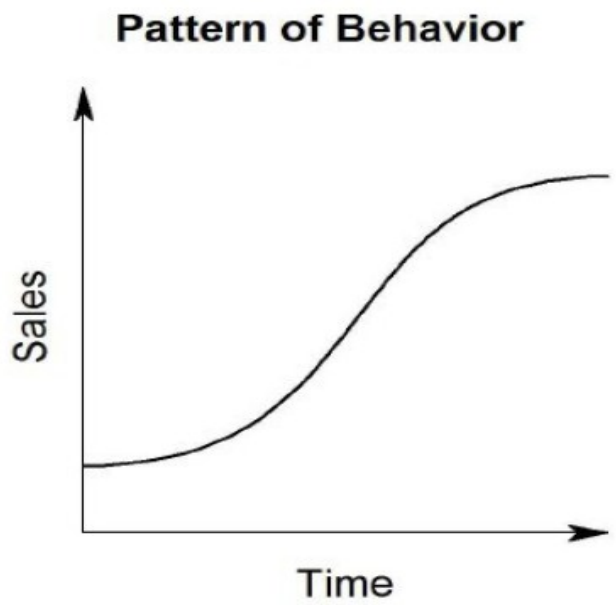
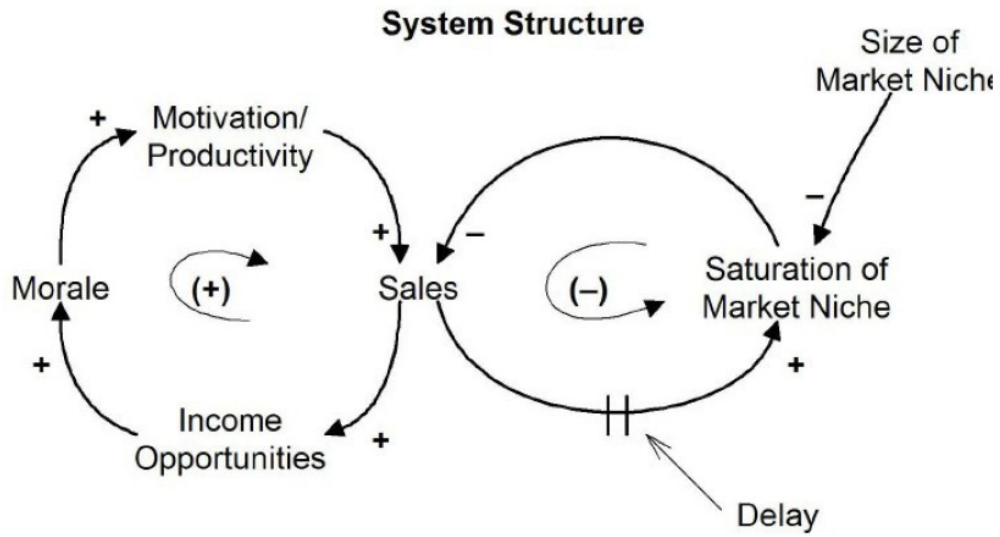


**Fig .5:** Example of Exponential Growth Structure

**Fig. 6:** Example of Goal-seeking structure



**Fig. 7:** Example of Oscillating Structure



**Fig. 8:** Example of S-Shaped Growth

**Fig. 8:** Behaviour pattern for S-Shaped Growth-

***What Archetype suits the Internet Price behavior***

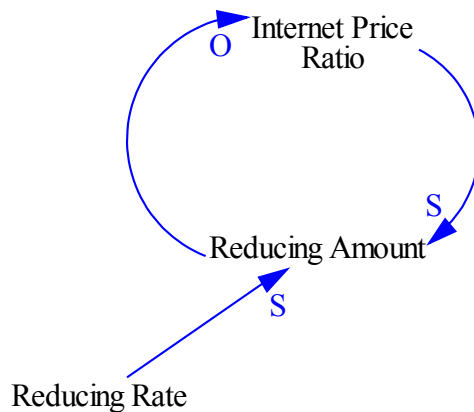
Since the Internet Prices are dropping gradually, they perhaps imply a **Goal-Seeking** behavior and that is what will be adopted to craft the initial structures of the Internet Model. The Internet Price dropping pattern could also signify the reverse **S-Shaped** behavior but this will be explored and added later on as the model is enhanced through during the data collection/case study phase.

## Chapter 4: Developing the Model

### *The proposed Casual Loop Diagrams (Hypothesis)*

Two initial models, Model 1 and Model 2 will be constructed based on [14] Model 1 assumes that the Internet Price is dropping at a fixed Reducing Rate over the given time period (2008-2010). Model 1 is provided as one of the building blocks(Loops) of the subsequently proposed Model 2. The causal loop diagram for Model 1 is given below:

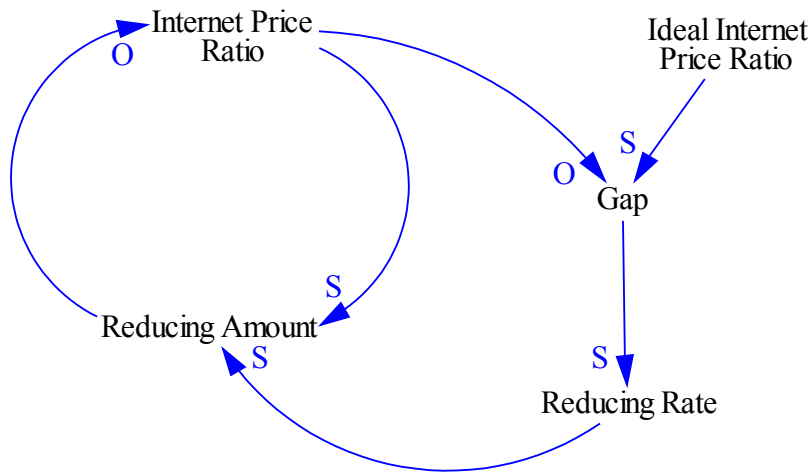
#### Causal Loop Diagram: Model 1



**Fig. 10:** Casual Loop Diagram 1

The Causal Loop Diagram (CLD) suggests the relationship between the three variables: Internet Price Ratio, Reducing Amount and Reducing Rate. It proposes that the Internet Price Ratio (% of Gross National Income, INI) and the Reducing Amount move in the same (S) direction. This means a positive change in the Internet Price Ratio leads to a corresponding positive change in the Reducing Amount. On the other hand, an increase of the Reducing Amount would lead to a decrease the Internet Price Ratio – that is in the Opposite (O) direction. The Reducing Rate is taken as a FIXED% rate by which influences or calculates the Reducing Amount Variable.

**Causal Loop Diagram: Internet Model 2**



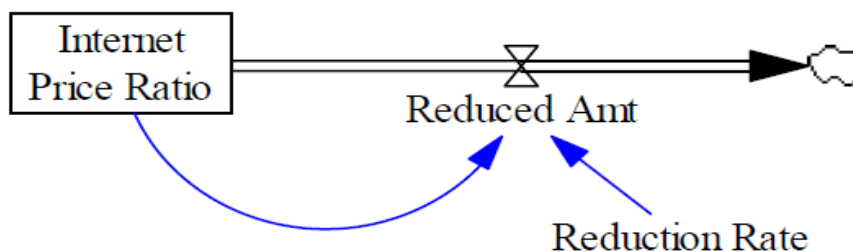
**Fig. 11:** Casual Loop Diagram 2

The second Causal Loop Diagram takes the Model 1 CLD and changes the Reducing Rate variable from being FIXED to being determined by some target (Goal-Seeking behaviour). In this case the Reducing Rate is dictated by how big the Gap is between what the Operator feels is the Ideal (target) Price as compared to the Actual Internet Price Ratio. Basically, the bigger the Price Gap the bigger the Reducing Rate is likely to be and vice-versa (Gap and Reducing Rate move in the same (S) direction).

***The Initial Proposed Stock Flow Diagrams***

In order to dynamically operationalize and generate simulated behavior of the variables from the above Causal Loop Diagram (CLD), a corresponding Stock Flow Diagram (SFD) - the actual mathematical model-is designed and proposed below.

**Internet Model 1- Fixed Reduction Rate**



**Fig. 12:** Stock Flow Diagram for Model 1

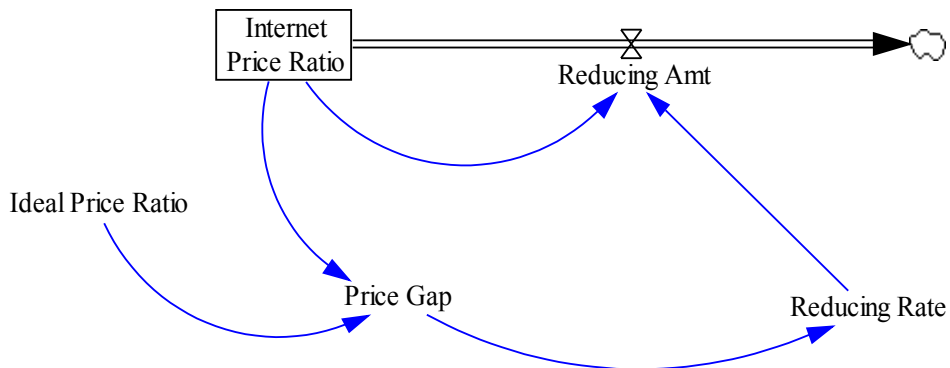
In this Model 1, the Reduced Amount - the absolute value of the reduction is a factor of the Internet Price Ratio and the Reducing Rate i.e.

$$\text{Reducing Amt} = \text{Internet Price Ratio} \times \text{Reducing Rate} \text{ ---Equation 1:}$$

where Internet Price Ratio is the Internet Price as a % of the GNI &

Reducing Rate = A Fixed value, taken as 5.3% per annum which is the observed % drop for Internet Price between 2008 and 2010 (ITU).

**Internet Price Model 2 - Variable Reducing Rate**



**Fig. 12:** Stock Flow Diagram for Model 2

In this Model 2, the Reducing Amount - the absolute value of the reduction is a still a factor of the Internet Price Ratio and the Reducing Rate as defined in Eq1. However, the Reducing Rate is not fixed but is varying according to the Price differentials of the Price Gap which is defined in Equation 2 below:

$$\text{Price Gap} = \text{Ideal Price Ratio} - \text{Actual Price Ratio} \text{ ---Equation 2.}$$

The Price Gap is calculated from what the Operator feels is the Ideal Price less the Actual

Price. The Reducing Rate is therefore a moving value informed by the ever changing Price Gap values. This is the classic goal-seeking structure (exponential growth or decline) that describes the observed Internet Price behavior.

## Relationship between Reducing Rate and Price Gap

Using the ITU (2011) data for Internet Price between 2008 and 2010 as given below:

Year	Actual Price Ratio	Annual Price Change	Reducing Rate	Price Gap
2007	50	*	*	*
2008	49	1	0.02	-8.75
2009	29	20	0.41	11.25
2010	33	-4	-0.14	7.25

**Table 1a:** Reducing Rate and Price Gap Data

The Reducing Rate is derived from the Equation 3:

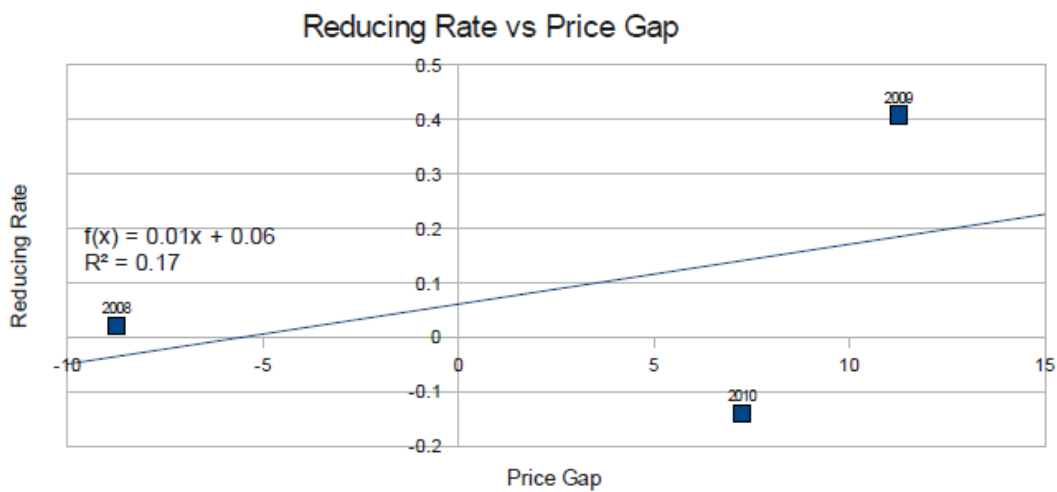
$$\text{Reducing Rate} = (\text{Price Change}/\text{Actual Price}) \text{ ----Equation 3}$$

The values for Price Gap and Reducing Rate over the three years is given below.

Year	Price Gap	Reducing Rate
2008	-8.75	0.02
2009	11.25	0.41
2010	7.25	-0.14

**Table 1b:** Summarized Reducing Rate and Price Gap Data

Applying the Regression analysis for best-fit line between the two variables gives the graph below:



**Graph1:** Best-fit Line for Reducing Rate and Price Gap Data

Which derives the following Equation 4, describing how the Reducing Rate is influenced by the Price Gap

$$\text{Reducing Rate} = 0.01 (\text{Price Gap}) + 0.06 \quad \text{-Equation 4}$$

The value of the Reducing Rate is subsequently used in Model 2 to establish the Reducing Amount for each quarter as earlier defined in Equation 1.

## Chapter 5: Results and Discussions

### *The initial Simulated Runs*

Using the ITU (2011) data to initialize the Price variables as at 2008 and the various equations discussed, the following Table 1 was generated for both Model 1 and Model 2:

Reducing Rate            5.3% p.a                    drop in 3yrs (49-33=16, divide by 3=5.3% per annum)  
 Ideal Internet Price      40.25                         average over the 3yrs

<b>Model1-Fixed Reducing Rate</b>		<b>Year1:2008</b>				<b>Year2:2009</b>				<b>Year3:2010</b>			
<b>Quarter</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>
Beginning Internet Price-1	49.0	49.0	48.4	47.7	47.1	46.5	45.8	45.2	44.6	44.0	43.5	42.9	42.3
Reducing Amt		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Internet Price-1	49.0	48.4	47.7	47.1	46.5	45.8	45.2	44.6	44.0	43.5	42.9	42.3	41.8
<b>Model2-Varying Reducing Rate</b>													
<b>Quarter</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>
Beginning Internet Price	49.0	49.0	48.8	48.5	48.3	48.0	47.8	47.5	47.3	47.1	46.8	46.6	46.4
Gap(Ideal Price-Actual Price)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Reducing Rate		0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Reducing Amt		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Internet Price-2	49.0	48.8	48.5	48.3	48.0	47.8	47.5	47.3	47.1	46.8	46.6	46.4	46.1
<b>Actual ITU Data</b>													
Internet Price -ITU	49.0	49.0	49.0	49.0	49.0	29.0	29.0	29.0	29.0	33.0	33.0	33.0	33.0

**Table 3:** Data for Model 1 and Model2

In Model 1, the Reducing Rate was Fixed at 5.3%, the average observed drop in Internet Price Ratio over the 3years of 2008, 2009 and 2010. The Ideal Internet Price was selected to be 40.25 (%GNI) which is also the observed average Internet Price over the same period. The Reducing Amount is as defined in Equation 1, which is a factor of Internet Price Ratio x the Reducing Rate.

In Model 2, the Price Gap is initially negative (Ideal of 40.25 - Actual of 49.0 =-8.8). This means that the Operators are charging above the Ideal Price - which is taken as the average price observed over the 3year period. When the Price Charged exceeds the Ideal Price, the Operators would prefer NOT to do anything on the Price - other than let the price drop naturally. The best way to model this is to make Price Gap = 0, for Values of Negative Price Gap that is:

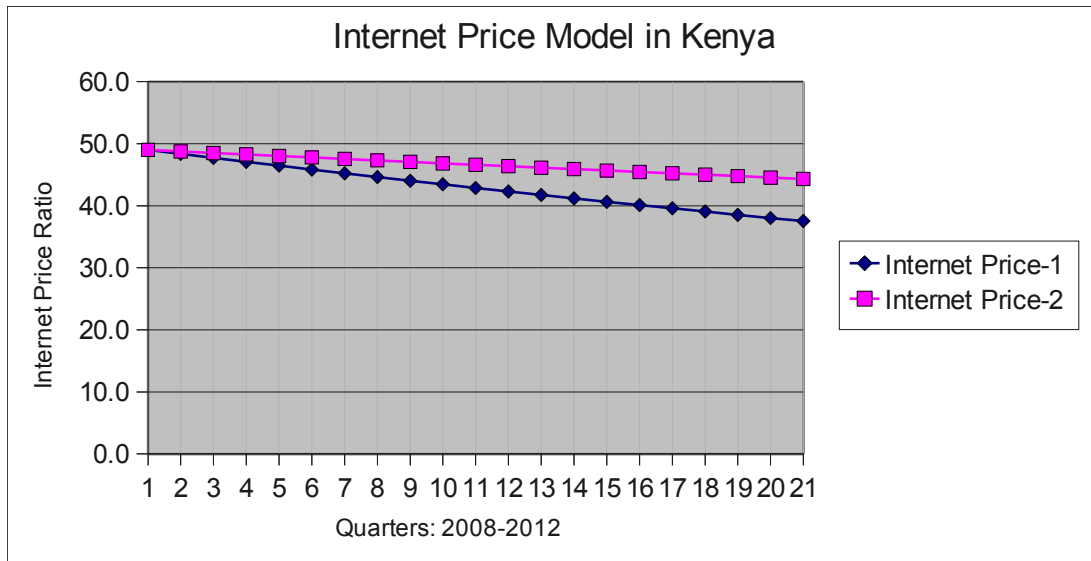
$$\text{IF Price Gap} < 0 \text{ Then Price} = 0, \text{ otherwise Price Gap} = (\text{Ideal Price} - \text{Actual Price}). - \text{Eq.5}$$

Recalling that Equation 4 is as previously defined:

$$\text{Reducing Rate} = 0.01 (\text{Price Gap}) + 0.06 - \text{Equation 4:}$$

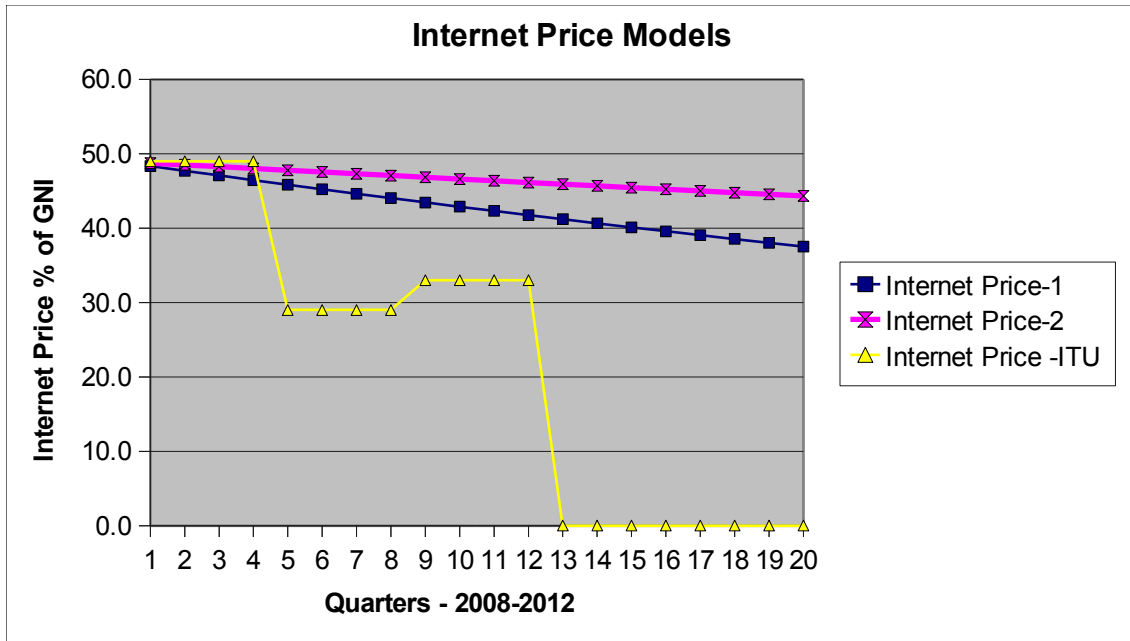
Then, it follows that when Price Gap =0, the Reducing Rate would be 0.06 for all negative values of Price Gap. However, the Reducing Rate would vary accordingly for any positive Values of Price Gap.

Using these equations and data, the simulated model behaviour for Internet Price was as given below - with Price-1 and Price-2 referring to Model 1 and Model 2 respectively.



**Graph 2:** Comparative behaviour pattern for Model 1 and Model 2

In both Models, the Price is seen to be reducing , with Model 1 Price dropping faster than Model 2. The following graph show both Models compared to actual ITU observed Price drops.



**Graph 3:** Comparative behaviour of Model 1, Model 2 & ITU data

The two proposed Models seem to be quite digressed from the ITU trends for 2008-2010. However, it is notable that in the ITU data for 2009 (quarters of 5-8), the Operators significantly dropped Internet Prices but started increasing it in the subsequent 2010 quarters. 2009 is significant in that it is the year that several submarine cables landing in Mombasa and this may have caused instinctive price reductions that may be beginning to reflect an upwards trends as the Operators begin to reflect market dynamics.

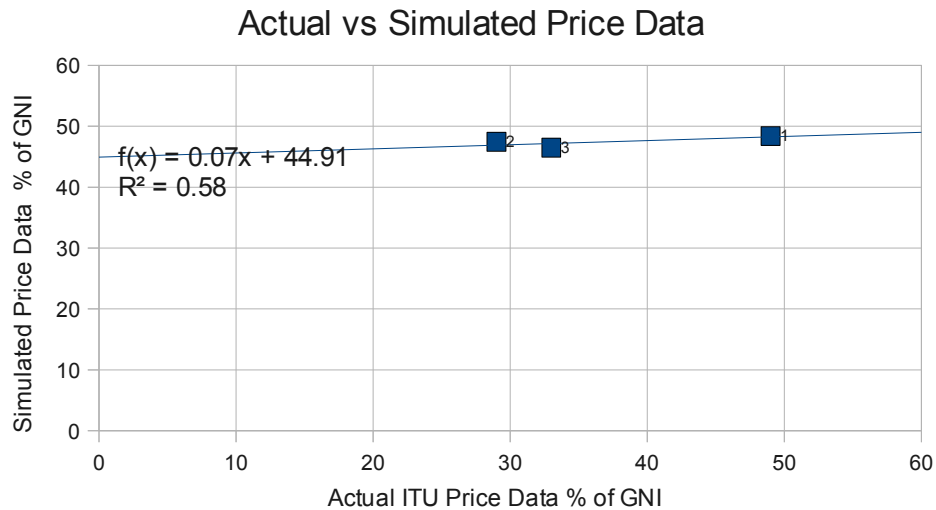
### Testing The Model

A simple test for Model 2 will be to compare to what extent it matches the Observed ITU(2011) data. The comparison data is summarized in the table below.

Testing the Model 2 Price Data		
Year	Actual (ITU)	Model 2
2008	49	48.39
2009	29	47.43
2010	33	46.49

**Table 4: Comparing Actual Price Data against Model Data.**

Which gives a correlation coefficient factor R of 0.58 for the data as shown in the Graph below. This shows that the model is not well matched to the data and it will need some additional work to reflect reality.



**Graph 4: Best fit line for Actual and Model Data**

### ***Conclusions:***

Given that no Field Work has been done at this stage of the study, the equations proposed are not expected to be accurate. They are however presented for purposes of demonstrating the proof of concept that given a particular model, that fairly reflects the real-world, then stakeholders can interact with the system by way of what-if-analysis.

As an example, possible interventions for reducing the Internet Price within the Model 2 include: Manipulating the factors that can reduce the Ideal Price Ratio and/or manipulating factors that can increase the Reducing Rate. Indeed such factors are already known and include, Competition, Regulation, Usage, amongst others. What is not known is the the models that could facilitate this manipulation exercise. This preliminary model acts as the basis for developing and plugging in the other components that impact on the Internet Price.

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Profile:

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Mr. Walubengo holds an MSc in Strategic Business IT (University of Portsmouth, UK) and a BSc in Mathematics & Computing (KU). He has several industry certifications including the CCNA (Cisco Certified Network Associate) and the CISA (Certified Information Systems Auditor) certifications. His area of specialisation is in the designing and deployment of secure Internet based solutions for Local Area Networks and Wide Area Networks.

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