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ITP4709

Techno-Economic Modeling of Basic Telecommunication Services in India: A System Dynamics Approach

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1. INTRODUCTION

Traditionally, voice communication has been characterized as three distinct types of services: local, national long distance and international long distance. Local telecommunication service (also referred to as Basic Telecom Service) is used to describe the provision of local access networks ("last mile" connection) over relatively short distances. Historically, basic telecom services were considered as "natural monopoly" because of the following reasons: there is huge fixed and sunk cost associated with the investment on the local loop; duplication of local loop is not possible and economically justifiable. In the U.S. basic services were opened up for competition after the landmark Telecommunications Act of 1996 was passed.

In India, basic services were provided by the government owned/controlled monopoly operators. The service areas are designated as circles. The government invited private participation in 1995 for the provision of local and intra-circle long distance calling and envisaged a duopoly structure. During 2001, the government decided to further open up basic services without any restrictions on the number of operators. Currently the new license holders are deploying infrastructure and have already started rolling out services in certain circles. India's tele-density is a little over 3.8 per 100 currently. The New Telecom Policy drafted in 1999 envisages a tele-density of 7 by 2005 and 15 by 2010 (NTP, 1999).

A thorough understanding of the mechanics of growth of the basic telecom services is of interest to policy makers, regulators and the service providers. Especially in developing countries such as India where the basic telecom services is still in its infancy, an understanding of the structure of the erstwhile monopoly market is the first step in this direction. This study can pave way for analyzing the more complicated oligopoly market, which countries such as India will face in the near future.

In this research work, we have used "systems dynamics" methodology to initially model the monopoly basic telecom services. Calibration of the model using data from Indian telecommunications industry indicates that the model indeed validates to the reality. This model will be extended to address 'oligopoly' market structure. Model will be used to predict the growth of basic services – the subscriber base of incumbent and new entrant(s). Rest of the paper has been organized into the following sections: literature survey, modeling, simulation & validation, sensitivity analysis and future research directions.

2. THE TECHNO-ECONOMIC SIMULATION MODELING – A BRIEF LITERATURE SURVEY

Techno-economic simulations can be used to replicate the conditions of the telecommunications technology and its environment so that growth of the services can be investigated and monitored by researchers, planners and managers. Technical parameters such as network bandwidth, quality of service and economic parameters such as sales, subscriber forecasts and revenue projection can be simulated using techno-economic models.

A techno-economic model encapsulates technical, economic, social, political, competition and infrastructural aspects, which are relevant in providing service. Song (2001) highlights the supply side cost parameters of telecom service provisioning such as facility investment, area/non area specific investment and quality related investments etc. Chatterjee (1998) stresses that the demand for services will vary based upon certain socio-economic (household income, profession) and demographic factors (educational level, age, family size, population density, location). Other economic forces that could influence the demand are the price of service (Cocchi, 1992), quality of service (Dutta, 2001A) and competition (Sice, 2000).

The relationship between the demand and supply components of the integrated techno-economic model is illustrated in Figure 1.

3. MODELING MONOPOLY BASIC TELECOM SERVICES USING SYSTEM DYNAMICS METHODOLOGY

The concept of system dynamics was first introduced by Jay W. Forrester at MIT in the 1960s. Basic approach of system dynamics is to identify and to study the influence of the forces operating in a feedback mode in a business, social, managerial or a scientific system. A feedback loop consists of four distinct types of entities- the ***levels***, the ***rates***, the ***constants*** and the ***auxiliary*** variables. Where the level (or state) variables describe the condition of the system at any particular time. The level variables accumulate the flows described by the rate (action) variables.. Auxiliary variables help in defining the rate variables. Constant equations are used to define parameters/decision variables.

The system dynamics approach begins with the identification of the forces that constitute and affect the system under study. This structural hypothesis of the system dynamic study is usually recorded and communicated to others in a "visual-model" called a causal loop diagram and is represented in Figure 2. It shows the existence of all major cause-and-effect links, indicates the "direction" of each linkage relationship, and denotes major feedback loops and their "polarities". A link is positive (or negative) if a change in the causal element produces a change in the same (or opposite) direction for the effect element. A closed sequence of causal links represents a causal loop. An even/odd number of negative polarity links in a loop results in a positive/negative feedback.

System dynamics has been used successfully to study the dynamics and forces in a wide variety of application areas of the telecommunication services. Kim (1997) explores a series of system dynamics models for explaining the fluctuating market shares of on-line services by combining externality effect and congestion effect. Dutta (2001B) emphasizes that contagion effects along with technical development, social factors such as literacy and economic development levels, social norms and regulatory climate have significant effect on the growth of on-line services. Dutta (2001A) integrates customer behavior, network performance and financial consequences in a system dynamics model in order to gain insight in to the business process under lying the network service provisioning.

The causal loop diagram for our techno-economic model is shown in Figure 2. To get an integrated view of the model, we start with the main variable- SUBSCRIBERS which represents the subscribers of the basic telecommunication services in a circle/area. Households subscribe to telecom services. An increase in the number of households in any circle/area leads to increase in the number of subscribers and depletes the potential subscribers. This bi-directional relationship forms a loop with –ive polarity i.e. negative feedback loop. An increase in economic development of an area/circle 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 buildup 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 and subscriber can subscribe 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 monopolist does 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.

4. SIMULATION AND VALIDATION OF THE MODEL

A stock-and-flow simulation model was constructed based on the causal loop diagram shown in Figure 2, using VENSIM (www.vensim.com), a system dynamic simulation package (Educational edition). Data from different sources were collected to build and test the model (Natrajan, 1998; Economic survey, 2001; Thukral 1998; BSNL annual reports).

The basic telecom services monopoly feedback model was simulated for 200 months since Mar'96 for one circle. First 74 months (up to May 2002) details have been used for the validation and calibration of the model with the available data from erstwhile monopoly operator Bharat Sanchar Nigam Limited (BSNL). The results of the simulation are presented in Figure 3. As can be seen, the simulated subscriber base closely follows the actual subscriber base.

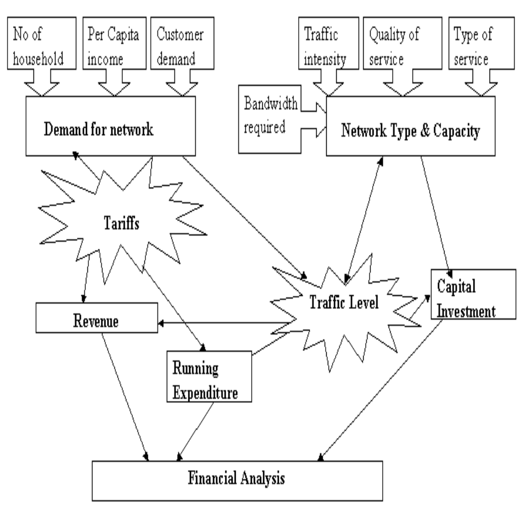

Figure 1: Components of Techno-Economic Model

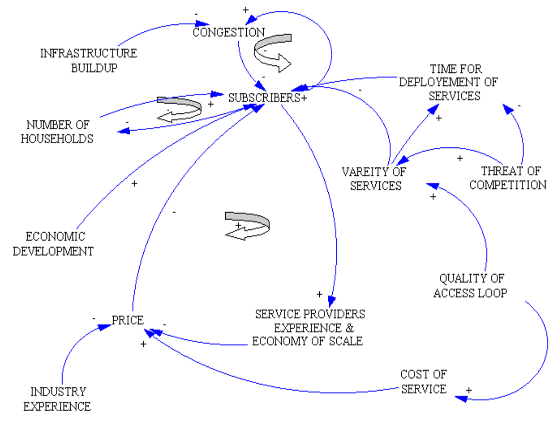

Figure 2: Causal Loop Diagram: Basic Monopoly Model

Literature identifies different ways of assessing prediction quality of these simulation results, all of which involve some averaging of individual error terms. One such measure is the Mean Absolute Deviation Percent Error (Dutta, 2001B) and is defined as follows:

$$\frac{\sum[|\text{Predicted} - \text{Actual}| / \text{Actual}]}{\text{No of Observations}}$$

The MAPE of this model is 6.61% indicating a high predictive quality. Further, regression of both simulated and actual values was carried out and the results are presented in Table 1. The high significance of regression equation indicates that simulated subscribers are close to actual subscribers.

After the calibration using past data, the model was also run to simulate the subscriber base forecast for the next 58 months. It is expected that the subscriber base in the circle under study will be double the present strength (3.36 million against the present subscriber base of 1.74 million), with in a span of five years under prevailing conditions.

5. SENSITIVITY ANALYSIS

The model can be used not only to predict the subscriber base in future, but also study the effect of changes in various variables in the model on the subscriber base. For example, we did sensitivity analysis by increasing infrastructure build-up by the service provider in tune with the boost in the economic development. Figure 4 shows the existing and experimented projections of subscriber base. Under this scenario, the number of subscribers will cross the 5 Million mark with in a span of five years. This can be explained by the dominance of the negative effect on congestion by the infrastructure buildup element and the positive effect on subscriber base by the economic development variable.

6. WORKS UNDER PROGRESS AND FUTURE RESEARCH DIRECTIONS

Indian Telecom industry is witnessing shift from an era of total monopoly to duopoly and even oligopoly. Researchers, academicians, regulators and telecom managers need to understand the complex dynamics of this transition

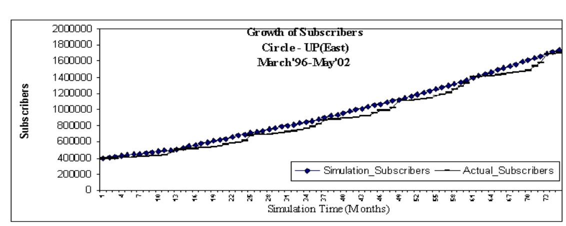

Figure 3: Growth of subscribers (Simulated Vs Actual)

Table 1: Regression Results			
Slope	R^2	F	Significance
1.0173	.994	13143.967	0.000

phase of the Indian telecom industry to make future investment and/or extension of this policy decision. The system dynamics model proposed in this research encapsulates all the relevant techno-economic variables affecting the basic telecommunication industry. The model validates to reality and can be used as a decision support tool to analyze the effect of different variables on the subscriber growth. Further, calibration of the model for more service areas will be done to make it more robust. A model is under development to capture the duopoly structure and competition to decide the relative market share/ leadership.

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