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Factor Exploration and Hierarchical Analysis of Spectrum Pricing: Exploratory Framework

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Abstract

Radio spectrum, a scarce resource, refers to the part of the electromagnetic spectrum that corresponds to radio frequencies. These frequencies of up to 300 GHz are known as radio waves and used for radio communications. Telecom and broadcast services industries along with government agencies utilize this spectrum and create infrastructure that allows the emergence of information-driven societies. This makes radio spectrum a crucial resource for any economy. Given its importance in the development of a nation, it is of critical importance to effectively manage this resource. If spectrum policies are formulated carefully, it would not only lead to sustained growth of information broadcasting and communication technology industries, thereby promoting social welfare, but also maximize the revenues generated for the government. This paper explains about three important effects on the scarce radio frequency spectrum. Spectrum management and the need for a valuation framework are being discussed. We looked at three allocation methods (Auction, Beauty Contest and Administrative Allocation) in greater detail. The aim of this study is to develop a total interpretive structure modelling (TISM) framework for spectrum pricing index. The primary objective of the study is to identify the generic factors influencing Spectrum Pricing and subsequently develop the linkages and hierarchy of factor for Spectrum Pricing by using interpretive structure modelling (ISM) and total interpretive structure modelling (TISM) and also subsequently develops the framework. The exploratory framework for spectrum Pricing is not available for regulators, Policy Planner and Industry. This study fulfils that gap.

Keywords: Grounded Theory, ISM, Spectrum Pricing, TISM

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1. Introduction

Radio spectrum, a scarce resource, refers to the part of the electromagnetic spectrum that corresponds to radio frequencies. These frequencies of up to 300 GHz are known as radio waves and used for radio communications.

Telecom and broadcast services industries along with government agencies utilize this spectrum and create infrastructure that allows the emergence of information driven societies. This makes radio spectrum a crucial resource for any economy. Given its importance in the development of a nation, it is of critical importance to effectively manage this resource.

Radio frequency spectrum is utilized primarily by the telecom and broadcast service industries. Considering the paucity of spectrum, efficient spectrum management is of critical importance. If spectrum policies are formulated carefully, it would not only lead to sustained growth of information broadcasting and communication technology industries thereby promoting social welfare but also maximize the revenues generated for the government.

2. Literature Review

The Indian telecom sector has witnessed exponential growth in the past two decades. The subscriber base in India has increased from 400 million in 2005 to 900 million in 2012. Due to intense competition, the average revenue has declined to such a level that it is now the lowest in the world. The policies of the Indian government are discussed in the following section.

The Indian government has taken after a conventional "order and control" way to deal with deal with the radio spectrum. The initial two 2G licenses in India were auctioned in 1995 after the

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defence sector consented to surrender a certain band of spectrum to the telecom sector. The third license was sold in 2001 and the spectrum access was approved after instalment of the altered permit expense. The fourth permit was likewise approved in 2001 to the state possessed operators and they were required to pay the sum chose in the auction. The administrators were additionally needed to pay an altered rate of their yearly incomes to the government. Extra spectrum was approved to the existing operators if their subscriber base surpassed a discriminating limit. In 2007, Telecom Regulatory Authority of India prescribed that no cap ought to be set on the quantity of administrators in the telecom division.

In the 2G spectrum trading in 2008, small piece of spectrum were allowed to a few new firms which prompted excessive fragmentation in the radio frequency spectrum[24.] In 2010, the 3G spectrum was sold by the Indian government utilizing the technique for "Simultaneous Controlled and Ascending e-auctions". Despite the fact that auctions increase the incomes for the administration, they may prompt overbidding by firms which is adverse to the development of the telecom business all in all and consequently exchanges may not so much advance social welfare. The standard spectrum holding per operator in Indian is well under the global normal and because of the extensive number of operator; the telecom markets are exceedingly focused with HH record of 0.19[15]. The huge challenge and low effectiveness is an essential obstacle to the maintained development of telecom division in India. The massive competition, the strategies of Indian government and the quickly developing Indian telecom business sector has had three imperative consequences for the rare radio frequency range.

2.1 Imperative Consequences

2.1.1 Excessive Fragmentation

The telecom division witnesses expanding come back to proportional. This suggests that among two administrators with the same infrastructure, the one with a more entree to spectrum would have the capacity to give the same services to the same set of subscribers at a decreased expense. Without adequate range of spectrum, the operator needs to work a more number of BTS's and this builds the unit cost.

Due to countless number of operators and the approaches of the Indian government, the radio frequency range has turned out to be too much divided. The normal range per operator in India is 6 MHz though the global average is 21 MHz. This unreasonable discontinuity combined with wasteful utilization of BTS's has prompted a low level of assigning efficiency in the Indian telecom segment[14] which has lessened the rate of development of mobile service industry in India.

2.1.2 High Spectrum Prices

The Indian government has attempted to amplify its income by assigning spectrum through the technique for auctioning. The 3G spectrum in India was assigned through the procedure of concurrent, controlled and expanding e-auctions. French (2009) presume that increasing auction costing neither assure most extreme social welfare nor demonstrates the effectiveness of open arrangement. In situations of high vulnerability, auctioning process may bring about the organizations to overbid which is unfavourable to development of the business as a whole.

2.1.3 Under-utilization of Spectrum

The Indian telecom industry is profoundly aggressive with an expansive number of players in the business. However this has led to under use of spectrum by number of telecom players, particularly the new ones. The new administrators don't have a sufficiently huge subscriber base to use the spectrum proficiently.

2.2 Spectrum Management and the Need for a Valuation Framework

The main aim of the radio spectrum is to boost the net advantages to the general public so that there would be an effective utilization of spectrum. Costs are utilized as a vital intends to guarantee the spectrum assets are utilized proficiently by clients.

Spectrum is an intangible, static, scare and finite resource, which makes it hard, if not impossible to assign a value to it. In India, the auction determined price of spectrum is treated as the market price of spectrum, which is far from reality. Auction prices serve as no more than maximum revenues for the exchequer, and any analysis that uses these as the real value of spectrum is inherently flawed.

Many studies on the subject of spectrum management cite regulatory constraints and prohibitions as the reasons for market failures[2]. However, research into 'common interest tragedies' has helped clarify the costs and benefits of regulation in this sector[9]. A classic paradoxical situation arises when analysing the need for regulatory policies. Traditional allocations in which regulators truncate licensee rights can lead to a tragedy of the anti- commons, whereas allocations of unlicensed spectrum, for which open access rules are imposed by the authority, can lead to a tragedy of the commons[10]. It is not the presence of regulatory control that limits the effective use of spectrum, but rather the absence of a valuation framework that establishes a true market price of spectrum.

However, certain regulatory changes can go a long way in ensuring that spectrum is effectively allocated in an economy. Introduction of secondary spectrum markets and spectrum trading is one such change. To make spectrum markets work for all, an elaborate mechanism is needed that prices spectrum appropriately[20,21].

Effective management of spectrum is predicated on its effective valuation and allocation. Internationally, three allocation methods prevail[23]. Auctioning is a fairly common approach adopted by nations to allocate spectrum. Central regulating authorities such as the Federal Communications Commission (FCC) in the United States of America, and the Department of Telecommunications (DoT) in India conduct these auctions, typically using an ascending bid approach. USA, UK, Netherlands, India and many other nations follow this approach.

A beauty contest approach involves the establishment of certain criteria by the regulating authority, and the award of spectrum rights to operators who fulfil these conditions. Sweden, Portugal and Finland have used this approach for historic as well as the latest 3G auctions[6].

The least common, but the original approach is an administrative allocation of spectrum by regulating authorities at a government determined price. While it may be argued that the auctions approach prices spectrum close to market rates, it is important to note that none of the three uses a real market price for the allocation of spectrum.

The following sections explore these three allocation methods in greater detail.

2.2.1 Auctions

According to economic theory, auctions have two merits. They ensure that spectrum rights are awarded to the most efficient firm, which by the virtues of its profit making ability bids the highest and gets the rights. Auctions also ensure maximum revenues for the exchequer[25.] It is however important to note that uncertain and irrational outlooks, such as over-optimism, at the time of auctions, can lead to problems like 'winners curse'[6].

In 1996, the FCC in USA carried out C-block radio frequency spectrum auctions. Concerns over balancing the budget led Congress to count this amount as a source of income. However, only a few of the winners of the auction made their payments, and many operators including General Wireless, Pocket communications, and Next Wave, declared bankruptcy to avoid paying huge licence fees[18].

The auction approach is often defended by its proponents on the grounds that it not only generates the highest revenues for the government, but since the entry fee is treated as a sunk cost, it does not raise the price of services. This argument however, falls apart when confronted by the fact that high licence fees can raise the lending bank's rate of interest, which in turn not only raises prices, but strains infrastructural investments in the industry.

2.2.2 Beauty Contest

Since common value auctions can often lead to winners curse, an alternative scheme of spectrum allocation, known as a 'Beauty Contest', is sometimes recommended. Under a beauty contest, the government sets specific criteria such as roll-out obligations, the price of service, quality of service, and business strategy, and these have to be met by potential operators. It is important to note that this method rests on the assumption that the government or the regulatory authority has better information on the telecom operators' prospects than the operators themselves[1.]

Flaws inherent in the beauty contest approach are exemplified in the case of India. The first spectrum allocation, held in 1994, saw licences awarded to 8 operators under this approach. At emerging stage, the industry committed to huge licence fees, but it soon became apparent that amongst all licensees, only a few could post revenues higher than the licence fee, and by 1998, most had defaulted on their license fees[11].

2.2.3 Administrative Allocation

This is by far the most unscientific and subjective approach for allocating spectrum. Under this approach, the government decides who is awarded the licence, and how much is charged for these rights. Disclosure on methods used to arrive at a price for this spectrum is usually not part and parcel of the offer by the government. This approach is often criticized on the grounds that favourability and corruption have ample room to grow when using such methods[22.]

Many notable valuation methods have been proposed by the academic fraternity as well as by experts in the field of telecommunication. However, a concise description of all the factors that determine the price of spectrum, that also quantifies their effect, is rarely encountered. It is with this problem statement in mind that this study has been conducted. The next sections describe the methodology adopted in this paper, and set up the stage for an alternative spectrum pricing approach.

3. Scopes and Objectives

The aim of this study is to develop an exploratory framework for spectrum pricing. The problem definition is divided into 3 major Research Objectives (RO).

RO1: Identify the factors influences Spectrum Pricing.

RO2: Develop the linkages and hierarchy of factor for Spectrum Pricing by using interpretive structure modelling (ISM) and total interpretive structure modelling (TISM).

RO3: Develop the framework.

Spectrum pricing framework is not available for regulators, Policy Planner, and Industry. This report fulfils that gap.

3.1 Research Objective 1

Research objective 1 (RO1) aims is to identify the various factors that influence Spectrum Pricing by using Grounded Theory Methodology.

3.1.1 Grounded Theory Methodology

Grounded theory is an inductive methodology. The factors were analysed using the grounded theory methodology which allows factors that affect the study to emerge, rather than approach the problem in a traditional manner where factors are assumed and then put through an analysis[5.] Given the objective of discovering all the factors that influence spectrum price, and not selecting factors based on presumptions, grounded theory is a suitable option[4]. This methodology looks into the actual world and examines the data with no fixed hypothesis[8].

Although Grounded Theory do not explicitly require literature review, it is important to note that failure to do so may lead to incorrect and inadequate analysis of the issue at hand. It is for this reason that a very specific set of participants qualified for the exercise. These experts in the field of telecommunications brought certain credibility to the research, a sort of credibility that would have been absent if the participants this study were randomly selected. Well informed with the current trends, as well as the regulatory policies that govern this industry, these experts afforded the study the seriousness it deserved. One of the most common mistakes in the application of grounded theory is the choice to not review existing research. This can often be traced back to a misreading of the original approach. Just because the approach does not begin within objective in mind, is no reason to ignore prior credible research in the area of study. According to Glaser and Strauss, the fathers of grounded theory, the researcher should have the view point to help identify significant data, and conceptualize logical and appropriate categories from the study of this data.

Generally, there are two ways of grounded theory. One of these advocates the identification and specification of research issues solely from the point of view of the participant[7]. Strauss and Corbin's (1990) method on the other side, permit to the researcher some suppleness to decide the discussion point in advance, in addition to the data collected. The purpose of this paper is a specific research agenda; hence Strauss and Corbin's approach has been followed. The process comprised the following steps:

Step 1: The first step entails open coding, the purpose of which is to break down the results of the discussions and interviews into logical thoughts on the area of study. These thoughts on certain critical issues are then chalked up for further review and analysis.

Step 2: Categories are then constructed from the thought units identified in the previous step[5]. This is achieved through axial coding where idea are rearranged into evolving "categories"[3]. For the purpose of our study, these emergent categories are factors that affect spectrum price.

The factors explored from the grounded theory and literature review are explained as follows:

3.1.1.1 Factor 1 (F1) – Efficiency of Spectrum

Defined as the information carrying capability in a practically deployed network covering a desired population/area. The factors that affected the efficiency of spectrum were identified to be

a. Its propagation characteristics
b. The block size available to an operator
c. The total holding of an operator
d. How contiguous the spectrum is, and
e. The technology supported

3.1.1.2 Factor 2 (F2) – Ecosystem (Network and Devices)

Ecosystem refers to the availability of interconnected or interdependent equipment/devices that are required for the deployment of a technology in a spectrum band. The individual factors that affect the ecosystem are listed below

a. Network Ecosystem
    i. Availability of technology
    ii. Cost of network infrastructure
    iii. Number of countries that have adopted the spectrum band
b. Device Ecosystem
    i. Availability of devices
    ii. Relative price of devices
    iii. Present penetration of devices

3.1.1.3 Factor 3 (F3) – Population Density

Measurement of human population per unit area. Is a function of

a. Population per square kilometre
b. Geographical area distribution – Dense Urban/Urban/Sub Urban/Rural

3.1.1.4 Factor 4 (F4) – Teledensity – Voice

It is the number of mobiles/fixed lines in use, for every hundred individuals living within an area. Affected by

a. Present penetration of telecommunications infrastructure
b. Policy and regulatory objectives

c. Coverage of the operator given the infrastructure at its disposal

3.1.1.5 Factor 5 (F5) – Internet/Broadband Penetration

Refers to number of internet/broadband (fixed of wireless) connections in use for every hundred individuals living within an area. Broadband/internet penetration is influenced by

a. Present broadband penetration
b. Policy and regulatory objectives
c. Coverage of the operator given the infrastructure at its disposal

3.1.1.6 Factor 6 (F6) – Permitted Use

Refers to the technologies that are permitted for use in an allocated spectrum band. It is affected primarily by the regulatory policies of the land

3.1.1.7 Factor 7 (F7) – Sharing

Sharing refers to the following

a. Passive Infrastructure
b. Active Infrastructure
c. Spectrum Sharing

Sharing is affected by the regulatory policies of the land, and whether the above are allowed or not. The cost of sharing spectrum also has a measurable impact.

3.1.1.8 Factor 8 (F8) - Operators' Affordability

Refers to operators' ability to establish a telecom network for provision of services. This affordability is affected by

a. Profitability of operators in the market
b. The nations macroeconomic policies and overall condition
c. Political and regulatory climate

3.1.1.9 Factor 9 (F9) – Customers' Affordability

Refers to the customers ability to consume/avail the prevailing telecom services. This affordability is affected by

a. Present Average Revenues Per User (ARPU)
b. Per Capita Income
c. Types of services and their utility to the consumer

3.1.1.10 Factor 10 (F10) – Spectrum Trading

Defined as the ability to buy and sell access to radio spectrum within the overall terms of the original assignment. Spectrum trading has an obvious effect on the price of spectrum, and this is primarily determined by if and how said trading is implemented in an economy.

3.2 Research Objective 2

Research objective 2 (RO2) aims to develop the linkages and hierarchy of factor (developed through RO1) for Spectrum Pricing by using interpretive structure modelling (ISM) and total interpretive structure modelling (TISM).The diagraph (framework) was developed through Total Interpretive Structural Modelling technique.

3.2.1 TISM (Total Interpretive Structural Modelling) Development

Structural models can be produced to recognize the relationship between the variables of interest which help in comprehension the structure of the framework better. Keeping this at the top of the priority list, the TISM approach has been accepted here. TISM is a novel qualitative technique which is an advancement of the ISM[16]. An ISM interprets the connections in terms of the relevant relationship between every pair of components, and the course of their relationship[17]. There is a need to interpret further as far as causal considering behind the connections which can be accomplished with the assistance of TISM. TISM utilizes the tool of an interpretive matrix[13], which catches the causal thinking of the experts. This helps answer "why" the relationship exists between two components. It is broadly trusted that TISM may have a higher pertinence, in actuality, circumstances, which is the reason it was utilized with the end goal of this study.

The attribute enhancement structure was used for designing the TISM Questionnaire. The steps of TISM is explained in step wise as under[16].

3.2.1.1 Application of TISM

The fundamental procedure of TISM is explained below. The fundamental means of ISM, i.e. reachability matrix alongside its division is accepted as it is from the TISM method.

Step I: Identifying and defining elements: The initial phase in every structural modelling activity is to find out and describe the components whose connections are to be demonstrated.

Our approach: The above step has been completed by using grounded theory as discussed above.

Step II: Defining appropriate relationship between components. To build up the structure representation that relates to the components, it is imperative to first express the relevant connection among the components. This relevant connection relies on upon the kind of structure we are managing, for example, intention, priority, quality improvement, development or mathematical dependence.

Our approach: For the situation of this study, the quality improvement of the structure is suitable since it characterizes the logical connection among the various components as: "Factor 1 (Spectrum proficiency) will influence/enhance Factor 2

(Ecosystem – Device/Network)". The TISM questionnaire is used during the interviews and discussions is incorporated in this report (Appendix A).

Step III: Explaining the essential analysis of appropriate relationships. It is at the initiation of this stage that the study moves forward from the scope of usual ISM. Even though the logical connections are sufficient for understanding the nature of relationships, all alone, they are insufficient for interpreting how that relationship truly functions. So as to move towards TISM, it is prudent to clear up the understanding of the connection.

Our approach: Every combined relationship was further discussed to better comprehend the relationship. Basically, the question deal with - "In what way a particular element influences/enhances another?" Such an understanding is precise to every pair of elements to clearly recognize deep-rooted learning.

Step IV: Appropriative explanation of pair wise evaluation: In ISM, individual components are evaluated to create SSIM (Table 1). The main understanding at this stage identifies with the direction of the relationship. With a specific purpose to update ISM to TISM, interpretive matrices were utilized in order to completely interpret each combined relationship how the directional connections work in the model under thought[16].

Our approach: Each connection in the information base was sorted either as a Yes(Y), or as a No(N). If a relationship was established, it was further studied and translated. With this activity, developed the interpretive logic of the combined relationships.

Step V: Reachability Matrix and transitivity check: The matching comparison in the interpretive logic information base was then changed over to a reachability matrix (Table 2).

Our approach: Reachability matrix was made by making entry 1, if the equivalent entry in knowledge base was "Y", or else was classified as 0 for "N" in the information base. This matrix was verified for the transitivity rule and overhauled till complete transitivity was built up. For every new transitive connection, the information base was likewise overhauled. The "No" section was altered to "Yes" and in the interpretation segment "Transitive" was entered (Table 3).

Table 1. Structural Self-interaction Matrix

	F10	F9	F8	F7	F6	F5	F4	F3	F2	F1
F1	X	X	V	A	X	V	V	0	X	X
F2	V	X	X	X	X	X	X	A	X	
F3	0	V	V	V	0	V	V	X		
F4	V	X	X	X	A	V	X			
F5	X	X	X	X	A	X				
F6	V	X	V	V	X					
F7	X	X	X	X						
F8	X	X	X							
F9	A	X								
F10	X									

Table 2. Reachability Matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	1	1	0	1	1	1	0	1	1	0
F2	1	1	0	1	1	1	1	1	0	1
F3	0	1	1	0	0	0	1	1	1	0
F4	0	1	0	1	0	0	1	1	1	1
F5	0	1	0	0	1	0	1	1	1	1
F6	1	0	0	1	1	1	1	1	1	1
F7	1	1	0	1	1	0	1	1	1	0
F8	0	1	0	1	1	0	1	1	1	1
F9	0	1	0	1	1	1	1	1	1	0
F10	1	0	0	0	1	0	1	1	1	1

Table 3. Reachability Matrix (with Transitivity)

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	1	1	0	1	1	1	0	1	1	1[a]
F2	1	1	0	1	1	1	1	1	1[a]	1
F3	0	1	1	1[a]	1[a]	0	1	1	1	0
F4	0	1	0	1	1[a]	0	1	1	1	1
F5	0	1	0	0	1	0	1	1	1	1
F6	1	1[a]	0	1	1	1	1	1	1	1
F7	1	1	0	1	1	0	1	1	1	1[a]
F8	0	1	0	1	1	0	1	1	1	1
F9	0	1	0	1	1	1	1	1	1	0
F10	1	0	0	0	1	0	1	1	1	1

Note: [a]Transitivity

Step VI: Level separation on reachability matrix: The level separation is like ISM to identify the arrangement of components step-wise[19]. Find out the reachability and antecedent sets for every one of the components. The components in the highest position of the hierarchy won't contact any components over their own level. Thus, the reachability set for a highest position component will comprise of the component itself and the rest of the components inside of the similar position which the component may reach, for example, components of a robustly associated sub-set. The antecedent set for a top level component will comprise of the component itself, components which achieve it from lower levels and any component of strongly joined subset including the top level. As a result, the crossing point of the reachability set and the antecedent set will be the same as the reachability set if the component is in the highest position. The highest rank components fulfilling the above clause ought to be excluded from the component set and the activity is to be repetitive iteratively till every one of the levels is resolved.

Our approach: The process specified above was taken after and six levels were discovered. The level separation of different variables affecting spectrum pricing has been indicated (Table 4).

Step VII: Developing the diagraph: The components are arranged graphically in levels and the directed connections are drawn according to the connections demonstrated in the reachability matrix. An easier edition of the preliminary diagraph is achieved by removing the transitive connections step-by-step by looking at their explanation from the information base. Just those transitive connections may be held whose interpretations are significant.

Our approach: The above mentioned technique was taken after. Diagraph of the components causing spectrum pricing has been demonstrated (Figure 1).

Step VIII: Developing interaction matrix and convert it into interpretive matrix: The final diagraph is interpreted into a binary interaction matrix form and are translated by picking the important interpretation from the knowledge base as interpretive framework.

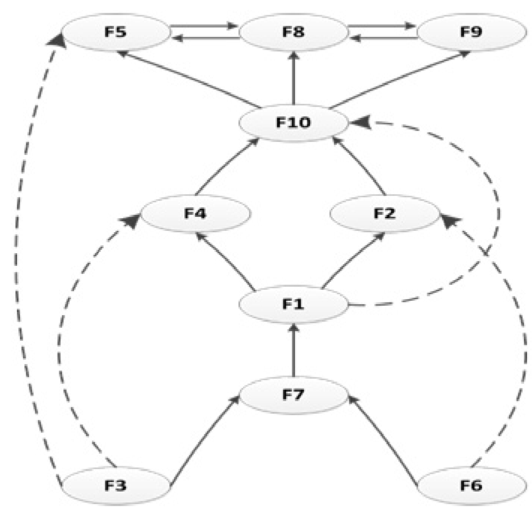

Figure 1. Diagraph with significant transitive links.

Our approach: Binary interaction matrix represents all the interactions by 1 section and others as 0. The cells with 1 entry are interpreted by picking the significant transition from the information base in the form of interpretive matrix and stated (Table 6). Translations for transitive connections are picked only if they are significant, otherwise ignored.

Step IX: Prepare total interpretive structural model: The connective and interpretive data contained in the interpretive direct interaction matrix and diagraph is utilized to obtain the TISM. The nodes in the diagraph are replaced by the interpretation of elements set in boxes. The translation in the cells of interpretive direct interaction matrix is described by the side of the respective connections in the structural model. This prompts to the

Table 4. Partitioning Reachability Matrix into different Levels

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
		Iteration -1		
F1	1,2,4,5,6,8,9,10	1,2,6,7,10	1,2,6,10	
F2	1,2,4,5,6,7,8,10	1,2,3,4,5,6,7,8,9	1,2,4,5,6,7,8,9	
F3	2,3,4,5,7,8,9	3	3	
F4	2,4,5,7,8,9,10	1,2,3,4,6,7,8,9	2,4,7,8,9	
F5	2,5,7,8,9,10	1,2,3,4,5,6,7,8,9,10	2,5,7,8,9,10	I
F6	1,2,4,5,6,7,8,9,10	1,2,6,9	1,2,6.9	
F7	1,2,4,5,7,8,9,10	2,3,4,5,6,7,8,9,10	2,4,5,7,8,9,10	
F8	2,4,5,7,8,9,10	1,2,3,4,5,6,7,8,9,10	2,4,5,7,8,9,10	I
F9	2,4,5,6,7,8,9	1,2,3,4,5,6,7,8,9,10	2,4,5,6,7,8,9	I
F10	1,5,7,8,9,10	1,2,4,5,6,7,8,10	1,5,7,8,10	
		Iteration 2		
F1	1,2,4,6,10	1,2,6,7,10	1,2,6,10	
F2	1,2,4,6,7,10	1,2,3,4,6,7	1,2,4,6,7	
F3	2,3,4,7	3	3	
F4	2,4,7, 10	1,2,3,4,6,7	2,4,7	
F6	1,2,4, 6,7,10	1,2,6	1,2,6	
F7	1,2,4,7, 10	2,3,4,6,7, 10	2,4,7, 10	
F10	1,7,10	1,2,4,6,7,10	1,7,10	II
		Iteration-3		
F1	1,2,4,6	1,2,6,7	1,2,6	
F2	1,2,4,6,7	1,2,3,4,6,7	1,2,4,6,7	III
F3	2,3,4,7	3	3	
F4	2,4,7	1,2,3,4,6,7	2,4,7	III
F6	1,2,4, 6,7	1,2,6	1,2,6	
F7	1,2,4,7	2,3,4,6,7, 10	2,4,7	
		Iteration-4		
F1	1,6	1,6,7	1,6	IV
F3	3,7	3	3	
F6	1,6,7	1,6	1,6	
F7	1,7	3,6,7, 10	7	
		Iteration-5		
F3	3,7	3	3	
F6	6,7	6	6	
F7	7	3,6,7, 10	7	V
		Iteration-6		
F3	3	3	3	VI
F6	6	6	6	VI

Table 5. Level Matrix

Sl. No	Variable Code	Variables	Level in TISM
1	F5	Internet/Broadband penetration	I
2	F8	Operators Affordability	I
3	F9	Customers Affordability	I
4	F10	Spectrum Trading	II
5	F2	Eco-system(Network & Devices)	III
6	F4	Teledensity Voice	III
7	F1	Efficiency of Spectrum	IV
8	F7	Sharing	V
9	F3	Population Density	VI
10	F6	Permitted use	VI

Table 6. Interaction Matrix (Binary Matrix)

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1		**1**	0	**1**	1	1	0	1	1	*1*
F2	1		0	1	1	1	1	1	0	**1**
F3	0	1		*1*	*1*	0	**1**	1	1	0
F4	0	1	0		0	0	1	1	1	**1**
F5	0	1	0	0		0	1	**1**	1	1
F6	1	*1*	0	1	1		**1**	1	1	1
F7	**1**	1	0	1	1	0		1	1	0
F8	0	1	0	1	1	0	1		**1**	1
F9	0	1	0	1	1	1	1	**1**		0
F10	1	0	0	0	**1**	0	1	1	**1**	

Notes: Bold-Direct Link, Italic-Significant Transitivity link

complete understanding of the structural model in terms of the interpretation of its nodes as well as the links.

By seeing a below Figure 2 Level Matrix it is well versed that the said technique was taken after and Total Interpretive Structural Model (TISM) of components influencing has been produced.

3.2.1.2 Interpretations and Findings

The TISM methodology was followed to develop the spectrum pricing framework for telecommunication industry. With the ever rise in mobile devices like smart phones and tablets, wireless data traffic (internet & broadband) has also grown exponentially increasing more and more every year, and is also expected to increase at a rapid pace for atleast the next few years. So as to sustain such large demand, current wireless carriers will not be able to accommodate this surging demand without the use of additional spectrum. Other approaches to expanding the capacity of wireless networks are to improve the spectral efficiency. In short, the projected growth in voice and data traffic can be achieved only by making more spectrum available for wireless use.

Population density and permitted use of spectrum in the allocated band are the base factor that influences the pricing of spectrum. The implications for spectrum managers are that spectrum management policies are evolving towards more flexible and market oriented models to increase opportunities for efficient spectrum use. Spectrum sharing influences the efficiency of spectrum and serves to amplify the effect of the base factor. Spectrum sharing is driven by the population density and as the demand for spectrum rises, frequency bands become more congested. Spectrum sharing typically involves two or more telecom companies sharing spectrum bandwidth for different applications or for different technologies. Teledensity and eco-system influences by the spectrum efficiency. As the number of users in the particular area increases the number of voice and data subscribers also increase thereby requiring a more efficient spectrum bandwidth. Some countries have permitted spectrum trading in the secondary market as an additional means of spectrum distribution. The idea here is not only an efficient spectrum bandwidth but also a cost effective one where the “Customers Affordability”

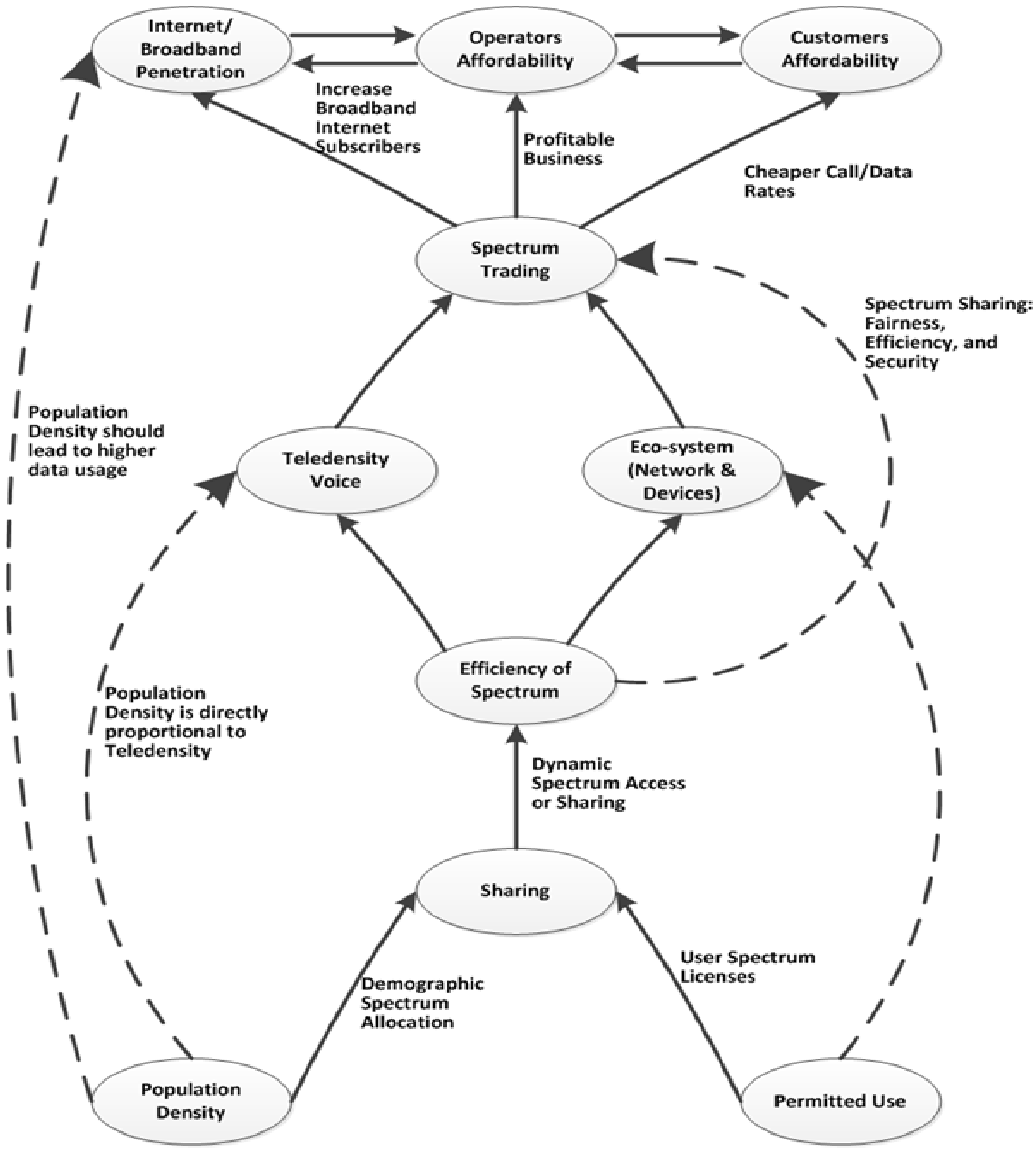

Figure 2. Total Interpretive Structural Modelling of spectrum pricing.

and "Operators Affordability" (in selling the same to its customers) should be kept in mind.

4. Conclusion

Hence, through this work we have understood the different factors affecting the spectrum pricing with respect to the lack of spectrum. A clear hierarchy among the factors and various linkages between them helped us to precisely evaluate and comprehend how these factors interact with each other and finally play a role in affecting the spectrum pricing. The study is the first of its kind as far as analysing the generic factors affecting the pricing of the spectrum is concerned and this has been developed in the context of maximizing the net benefits to society that can be generated from that resource. This framework will have implications for industry associations, academia, telecom service provider, policy planner, government authority and the public in large.

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Author of a paper had no conflict neither financially nor academically

Appendix

A. TISM QUESTIONNAIRE

Please indicate your response to the relationship between pair of factors affecting the spectrum pricing by writing 'yes' or 'No' and also cite reason for the same.

Sl.No.	Element No.	Paired Comparison of factors	Yes/No	In what way a factor will influence/ enhance other factor? Give reason in brief if your answer is YES
F1 – Efficiency of Spectrum				
1	F1-F2	Efficiency of spectrum will influence or enhance the eco-system.		
2	F2-F1	Eco-system of spectrum will influence or enhance the efficiency.		
3	F1-F3	Efficiency of spectrum will influence or enhance the Population density.		
4	F3-F1	Population density will influence or enhance the Efficiency of spectrum.		
5	F1-F4	Efficiency of spectrum will influence or enhance the teledensity - voice.		
6	F4-F1	Teledensity - voice will influence or enhance the Efficiency of spectrum.		
7	F1-F5	Efficiency of spectrum will influence or enhance the Internet/Broadband penetration.		
8	F5-F1	Internet/Broadband penetration will influence or enhance the Efficiency of spectrum.		
9	F1-F6	Efficiency of spectrum will influence or enhance the permitted usage.		
10	F6-F1	Permitted usage will influence or enhance the Efficiency of spectrum		
11	F1-F7	Efficiency of spectrum will influence or enhance the infrastructure sharing.		
12	F7-F1	Infrastructure sharing will influence or enhance the Efficiency of spectrum		
13	F1-F8	Efficiency of spectrum will influence or enhance the operator's affordability.		
14	F8-F1	Operators affordability will influence or enhance the Efficiency of spectrum		
15	F1-F9	Efficiency of spectrum will influence or enhance the customer's affordability.		
16	F9-F1	customer's affordability will influence or enhance the Efficiency of spectrum		
17	F1-F10	Efficiency of spectrum will influence or enhance the spectrum trading.		
18	F10-F1	Spectrum trading will influence or enhance the Efficiency of spectrum		

Sl.No.	Element No.	Paired Comparison of factors	Yes/No	In what way a factor will influence/ enhance other factor? Give reason in brief if your answer is YES
F2 – Ecosystem (Device/Network)				
1	F2-F3	Eco-system of spectrum will influence or enhance the population density.		
2	F3-F2	Population density will influence or enhance the spectrum eco-system.		
3	F2-F4	Eco-system of spectrum will influence or enhance the Teledensity -voice.		
4	F4-F2	Teledensity - voice will influence or enhance the spectrum eco-system.		
5	F2-F5	Eco-system of spectrum will influence or enhance the internet/ broadband penetration.		
6	F5-F2	Internet/broadband penetration will influence or enhance the spectrum eco-system.		
7	F2-F6	Eco-system of spectrum will influence or enhance the permitted usage.		
8	F6-F2	Permitted usage will influence or enhance the spectrum eco-system.		
9	F2-F7	Eco-system of spectrum will influence or enhance the infrastructure sharing.		
10	F7-F2	Infrastructure sharing will influence or enhance the spectrum eco-system.		
11	F2-F8	Eco-system of spectrum will influence or enhance the Operators affordability.		
12	F8-F2	Operator's affordability will influence or enhance the spectrum eco-system.		
13	F2-F9	Eco-system of spectrum will influence or enhance the customer's affordability.		
14	F9-F2	Customer's affordability will influence or enhance the spectrum eco-system.		
15	F2-F10	Eco-system of spectrum will influence or enhance the spectrum trading.		
16	F10-F2	Spectrum trading will influence or enhance the spectrum eco-system.		

Sl.No.	Element No.	Paired Comparison of factors	Yes/No	In what way a factor will influence/ enhance other factor? Give reason in brief if your answer is YES
F3 – Population Density				
1	F3-F4	Population density will influence or enhance the teledensity voice.		
2	F4-F3	Teledensity voice will influence or enhance the population density.		
3	F3-F5	Population density will influence or enhance the internet/broadband penetration.		
4	F5-F3	Internet/broadband penetration will influence or enhance the population density.		
5	F3-F6	Population density will influence or enhance the permitted usage.		
6	F6-F3	Permitted usage will influence or enhance the population density.		
7	F3-F7	Population density will influence or enhance the infrastructure sharing.		
8	F7-F3	Infrastructure sharing will influence or enhance the population density.		
9	F3-F8	Population density will influence or enhance the operator's affordability.		
10	F8-F3	Operator's affordability will influence or enhance the population density.		
11	F3-F9	Population density will influence or enhance the customer's affordability.		
12	F9-F3	Customers' affordability will influence or enhance the population density.		
13	F3-F10	Population density will influence or enhance the spectrum trading.		
14	F10-F3	Spectrum trading will influence or enhance the population density.		

Sl.No.	Element No.	Paired Comparison of factors	Yes/No	In what way a factor will influence/ enhance other factor? Give reason in brief if your answer is YES
F4 – Teledensity – Voice				
1	F4-F5	Teledensity-voice will influence or enhance the internet/ broadband penetration.		
2	F5-F4	Internet/broadband penetration will influence or enhance the teledensity-voice.		
3	F4-F6	Teledensity-voice will influence or enhance the permitted usage.		
4	F6-F4	Permitted usage will influence or enhance the teledensity-voice.		
5	F4-F7	Teledensity-voice will influence or enhance the infrastructure sharing.		
6	F7-F4	Infrastructure sharing will influence or enhance the teledensity-voice.		
7	F4-F8	Teledensity-voice will influence or enhance the operator's affordability.		
8	F8-F4	Operator's affordability will influence or enhance the teledensity-voice.		
9	F4-F9	Teledensity-voice will influence or enhance the customer's affordability.		
10	F9-F4	Customer's affordability will influence or enhance the teledensity-voice.		
11	F4-F10	Teledensity-voice will influence or enhance the spectrum trading.		
12	F10-F4	Spectrum trading will influence or enhance the teledensity-voice.		

Sl.No.	Element No.	Paired Comparison of factors	Yes/No	In what way a factor will influence/ enhance other factor? Give reason in brief if your answer is YES
F5 – Internet/Broadband Penetration				
1	F5-F6	Internet/broadband penetration will influence or enhance the permitted usage.		
2	F6-F5	Permitted usage will influence or enhance the Internet/broadband penetration.		
3	F5-F7	Internet/broadband penetration will influence or enhance the infrastructure sharing.		
4	F7-F5	Infrastructure sharing will influence or enhance the Internet/broadband penetration.		
5	F5-F8	Internet/broadband penetration will influence or enhance the operator's affordability.		
6	F8-F5	Operator's affordability will influence or enhance the Internet/broadband penetration.		
7	F5-F9	Internet/broadband penetration will influence or enhance the customer's affordability.		
8	F9-F5	Customer's affordability will influence or enhance the Internet/broadband penetration.		
9	F5-F10	Internet/broadband penetration will influence or enhance the spectrum sharing.		
10	F10-F5	Spectrum sharing will influence or enhance the Internet/broadband penetration.		

Sl.No.	Element No.	Paired Comparison of factors	Yes/No	In what way a factor will influence/ enhance other factor? Give reason in brief if your answer is YES
F6 – Permitted Usage (Liberalized/Non-Liberalized)				
1	F6-F7	Permitted usage will influence or enhance the infrastructure sharing.		
2	F7-F6	Infrastructure sharing will influence or enhance the permitted usage.		
3	F6-F8	Permitted usage will influence or enhance the operator's affordability.		
4	F8-F6	Operator's affordability will influence or enhance the permitted usage.		
5	F6-F9	Permitted usage will influence or enhance the customer's affordability.		
6	F9-F6	Customer's affordability will influence or enhance the permitted usage.		
7	F6-F10	Permitted usage will influence or enhance the spectrum sharing.		
8	F10-F6	Spectrum sharing will influence or enhance the permitted usage.		

Sl.No.	Element No.	Paired Comparison of factors	Yes/No	In what way a factor will influence/ enhance other factor? Give reason in brief if your answer is YES
F7 – Infrastructure Sharing (Active/Passive/Spectrum)				
1	F7-F8	Infrastructure sharing will influence or enhance the operator's affordability.		
2	F8-F7	Operator's affordability will influence or enhance the infrastructure sharing.		
3	F7-F9	Infrastructure sharing will influence or enhance the customer's affordability.		
4	F9-F7	Customer's affordability will influence or enhance the infrastructure sharing.		
5	F7-F10	Infrastructure sharing will influence or enhance the spectrum sharing.		
6	F10-F7	Spectrum sharing will influence or enhance the infrastructure sharing.		

Sl.No.	Element No.	Paired Comparison of factors	Yes/No	In what way a factor will influence/ enhance other factor? Give reason in brief if your answer is YES
F8 – Operator's Affordability (Active/Passive/Spectrum)				
1	F8-F9	Operator's affordability will influence or enhance the customer's affordability.		
2	F9-F8	Customer's affordability will influence or enhance the Operator's affordability.		
3	F8-F10	Operator's affordability will influence or enhance the spectrum trading.		
4	F10-F8	Spectrum trading will influence or enhance the Operator's affordability.		

Sl.No.	Element No.	Paired Comparison of factors	Yes/No	In what way a factor will influence/ enhance other factor? Give reason in brief if your answer is YES
F10 – Customer's Affordability (Active/Passive/Spectrum)				
1	F9-F10	Customer's affordability will influence or enhance the spectrum trading.		
2	F10-F9	Spectrum trading will influence or enhance the Customer's affordability.		