

Spectrum Pricing Index

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Preface:

The fundamental premise of this project was to identify the generic factors influencing the Spectrum Pricing and to subsequently develop the hierarchical linkages of Spectrum Pricing. The main aim of the project develops the spectrum pricing index. This is the index to value the spectrum pricing all over the globe. This report contains all the details.

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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 a crucial resource for any economy. It 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.

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 followed a traditional “command and control” approach to manage the radio spectrum. The first two 2G licenses in India were auctioned in 1995 after the defence sector agreed to give up a certain band of spectrum to the telecommunication industry. The third license was auctioned in 2001 and the spectrum access was granted after payment of the fixed license fee. The fourth license was also granted in 2001 to the state owned operators and they were required to pay the amount decided in the auction. The operators were also required to pay a fixed percentage of their annual revenues to the government. Additional spectrum was granted to the existing operators if their subscriber base exceeded a critical threshold. In 2007, Telecom Regulatory Authority of India recommended that no cap should be placed on the number of operators in the telecom sector.

In the 2G spectrum auctions in 2008, small slices of spectrum were granted to several new firms which led to excessive fragmentation in the radio frequency spectrum. In 2010, the 3G spectrum was auctioned by the Indian government using the method of “Simultaneous Controlled and Ascending e-auctions”. Though auctions maximize the revenues for the government, they may lead to overbidding by firms which is detrimental to the growth of the telecom industry in general and hence auctions may not necessarily promote social welfare. The average spectrum holding per operator in Indian is well below the international average and due to the large number of operators; the telecom markets are highly competitive with HH index of 0.19. The tremendous competition and low efficiency are an important impediment to the sustained growth of telecom sector in India. The immense competition, the

policies of Indian government and the rapidly growing Indian telecom market has had three important effects on the scarce radio frequency spectrum.

1. Excessive Fragmentation

The telecommunications sector witnesses increasing returns to scale. This implies that among two operators with the same infrastructure, the one with a greater access to spectrum would be able to provide the same services to the same set of subscribers at a reduced cost. In the absence of sufficient spectrum, the operator needs to operate a greater number of BTS's and this increases the unit cost.

Due to a large number of operators and the policies of the Indian government, the radio frequency spectrum has become excessively fragmented. The average spectrum per operator in India is 6 MHz whereas the international average is 21 MHz. This excessive fragmentation coupled with inefficient use of BTS's has led to a low level of allocate efficiency in the Indian telecom sector (Prasad and Sridhar, 2009) which has reduced the rate of growth of mobile services industry in India.

2. High spectrum prices

The Indian government has tried to maximize its revenue by allocating spectrum through the method of auctioning. The 3G spectrum in India was allocated through the process of simultaneous, controlled and increasing e-auctions. French (2009) concludes that maximizing auction pricing neither guarantees maximum social welfare nor indicates the efficiency of public policy. In scenarios of high uncertainty, auctioning process may cause the firms to overbid which is detrimental to growth of the industry as a whole.

3. Under-utilization of spectrum

The Indian telecom sector is highly competitive with a large number of players in the industry. However this has lead to under utilization of spectrum by many telecom players, especially the new ones. The new operators do not possess a large enough subscriber base to utilize the spectrum efficiently.

Spectrum management and the need for a valuation framework

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. However, research into 'common interest tragedies' has helped clarify the costs and benefits of regulation in this sector. 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 (Hazlett, 2005). 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.

Effective management of spectrum is predicated on its effective valuation and allocation. Internationally, three allocation methods prevail. 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 (*Datta, 2012*).

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.

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. 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’ (*Datta, 2012*).

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. (*Zheng, 2001*)

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. 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.

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 a nascent 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 (Malik, 2004).

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.

Many notable valuation methods have been proposed by the academic fraternity as well as by experts in the field of telecommunication. However, a succinct 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.

Research Objective and Scope

The aim of this study is to develop a spectrum pricing index (SPI). The study was divided into the following research objectives.

RO1: To identify the factors that plays an important role in spectrum pricing

RO2: To develop a Total Interpretive Structure Model (TISM) for the price of spectrum

RO3: To develop a Spectrum Pricing Index (SPI)

Research Design and Methodology

This study explores the factors that determine the price of spectrum in an economy as well as the relationship between identified factors. A workshop with over 25 experts from telecom, policy, government, and top management was conducted which formed the basis for this study.

Methodology

The contents of the workshop were analyzed using the grounded theory framework which begins with an area of study and then 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 (Corbin & Strauss, 1990). Given the objective of discovering all the factors that influence spectrum price, and not selecting factors based on presumptions, grounded theory seemed an appropriate choice. This theory investigates the real world and analyses the data with no preconceived hypothesis (Glaser & Strauss, 1967).

A common mistake in the application of grounded theory is ignoring prior research (Suddaby, 2006). The workshop conducted as part of this exercise was conducted with peer reviewed research in mind. Participants for the workshop were not randomly selected, but rather chosen because each was a thought leader and an expert in field of telecommunications.

Often criticized for its inability to evaluate the relationship between these factors, this methodology can lead to incorrect results as it involves a great deal of ambiguity and complexity. The very nature of the approach dictates that all the data collected is interpreted in a limited period of time, which can cause biases to be introduced in the analysis. Given this unstructured nature, the researcher has to be ever watchful so as to identify important themes and aspects that would have been encountered if a more systemic approach was adopted (Mehmetoglu & Altinay, 2006).

RO1- Identify the factors that affect the price of spectrum

Even though the use of Grounded Theory does 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 with an 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 must have a perspective to help her/him identify relevant data, and conceptualize logical and appropriate categories from the study of this data.

Broadly, there are two approaches to grounded theory. One of these advocates the identification and specification of research issues solely from the point of view of the participant (Glaser, 1992). Strauss and Corbin's (1990) approach on the other hand, allows the researcher some flexibility to choose the focus of the interviews around an area in advance, as well as the data that is gathered. 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. These are higher in level and more abstract than the concepts they represent (*Corbin & Strauss, 1990*). This is done through axial coding where thought units are regrouped into emergent “categories” (*Baskerville & Pries-Heje, 1999*). For the purpose of our study, these emergent categories are factors that affect spectrum price.

RO2 - Develop a Total Interpretive Structure Model (TISM) for the price of spectrum

This step of achieving the second research objective involves the use of Total Interpretive Structure Model (TISM). The relationship between the identified factors that affect the price of spectrum in an economy was established using the interpretive structure model (ISM). This will help us quantify the effect a factor has on another for use in the design of a spectrum price index, discussed in the next section.

RO3 – Develop a Spectrum Price Index (SPI)

The final objective of this study culminates in the design of a Spectrum pricing model, and its application for determining best practices for the industry, the technology provider, the policy planner, and the telecom service provider.

$SPI = F1X1 + F2X2 + \dots + F10X10$, where

F1 -> Factor that affects the price of Spectrum

X1 -> Weightage of that factor

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

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

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

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

Factor 5 (F5) – Internet/Broadband penetration – Refers to number of internet/broadband (fixed or 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

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

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.

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

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

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.

TISM: Total interpretive structural modelling

Interpretive structural modelling has a proven track record in mapping complex relationships between factors in complex situations (Warfield, 1976). ISM takes this study one step closer

to its prime objective – to develop a spectrum price index based on qualitative inputs. ISM takes into consideration multiple points of view which were quite prevalent during the round table discussions and interviews, and interprets as well as incorporates subjectivity in its analysis (Sage, 1977). We adopted a modified version of ISM called the TISM (Sushil, 2012) (Nasim, 2011). Years of investigation and close study on the subject has led to an evolution of sorts. The TISM avatar takes its predecessor to the next level by incorporating the interpretation of each observed relationship. The new approach improves upon the interpretive aspects of ISM by building a knowledge base of logical interpretations of each observable relationship. This repository of knowledge serves to bolster the interpretive aspects of ISM, and makes the logic that drives the model more transparent and less likely to being interpreted incorrectly. Essentially, TISM is a modern day innovation over Warfield's ISM methodology, and designed for use in cases where a greater understanding of the relationship between emerging factors is warranted (Prasad & Suri, 2011). It is widely believed that TISM may have a higher applicability in real life situations, which is why it was used for the purpose of this study.

The attribute enhancement structure was used for designing the TISM Questionnaire (Appendix B). The basic process of TISM is presented in a step-by-step manner as under (Sushil, 2012) and Nasim (2011).

Application of TISM

The steps of the basic process of TISM are briefly outlined as follows. The central tool of ISM, i.e. reachability matrix along with its partitions is adopted as it is from the TISM process.

Step I: identify and define elements: The first step in any structural modelling exercise is to identify and define the elements whose relationships are to be modelled.

Our approach: This has been done by using grounded theory (Research method 1) as discussed earlier.

Step II: defining the contextual relationship between elements. To develop the model of the structure that relates the elements, it is crucial to first state the contextual relationship between the elements. This contextual relationship depends on the type of structure we are dealing with, such as intent, priority, attribute enhancement, process or mathematical dependence.

Our approach: In the case of this study, the attribute enhancement structure is appropriate since it defines the contextual relationship between different factors as: "Factor 1 (Spectrum efficiency) will influence/enhance Factor 2 (Ecosystem – Device/Network)". The TISM questionnaire used during the interviews and discussions is included in Appendix A.

Step III: defining basic interpretation of contextual relationships. It is at the commencement of this step that the study moves forward from the scope of traditional ISM. Although contextual relationships are adequate for interpreting the nature of relationships, on their own, they are inadequate for interpreting how that relationship really works. In order to move towards TISM, it is advisable to clarify the interpretation of the relationship.

Our approach: Each paired relationship was further analysed to better understand the relationship. Essentially, the question addressed is - “In what way a specific factor influences/enhances another?” Such an interpretation is specific to each pair of factors so as to explicitly identify deep rooted knowledge.

Step IV: interpretive logic of pair-wise comparison: In ISM, individual elements are compared to develop SSIM. The only interpretation at this stage relates to the direction of the relationship. In order to upgrade ISM to TISM, interpretive matrices were used so as to fully interpret each paired comparison in terms of how that directional relationship operates in the system under consideration. (*Sushil, 2012*).

Our approach: Each link in the knowledge base was categorized either as a Yes(Y), or as a No(N). In the event that a relationship was confirmed, it was further analysed and interpreted. With this exercise, emerged the interpretive logic of the paired relationships

Step V: reachability matrix and transitivity check: The paired comparisons in the interpretive logic – knowledge base were then converted to a reachability matrix (Appendix B(ii))

Our approach: Reachability matrix was made by making entry 1, if the corresponding entry in knowledge base was “Y”, or else was catalogued as 0 for “N” in the knowledge base.

This matrix was checked for the transitivity rule and updated till full transitivity was established.

For each new transitive link, the knowledge base was also updated. The “No” entry was changed to “Yes” and in the interpretation column “Transitive” was entered. See Appendix B(iii) for a binary interaction matrix

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's 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.		
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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.		

I - 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									

II - Reachability Matrix

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

III - 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	1a	1	1	1
F3	0	1		1	1	0	1	1	1	0
F4	0	1	0		1	0b	1	1	1	1
F5	0	1	0	0		0b	1	1a	1a	1
F6	1	1	0	1	1		1	1	1	1
F7	1	1a	0	1	1	0		1	1	1
F8	0b	1	0	1	1a	0b	1		1a	1
F9	0b	1	0	1	1a	1	1	1		0b
F10	1	0b	0	0b	1	0b	1	1	1	

Note: ^a Direct Link, ^b Significant Transitive

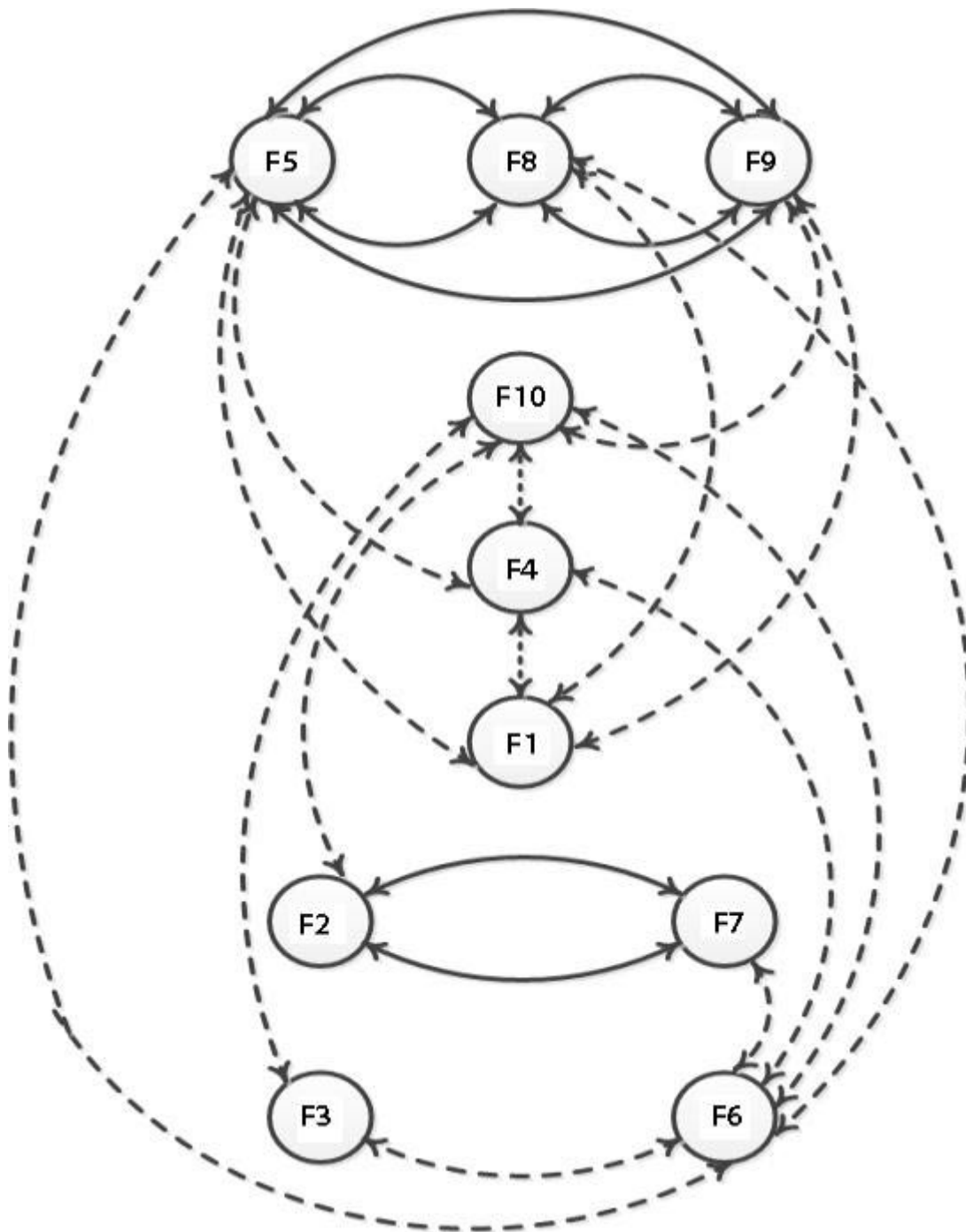
IV - Partitioning the Reachability matrix into different levels (Iteration-1)

Variables	Reachability set	Antecedent Set	Intersection Set	Level
F1	1,2,6,7,10	1,2,6,7,9,10	1,6,7,9,10	
F2	1,2,4,5,6,7,8,9,10	2,3,4,5,6,7,8,9	2,4,5,6,7,8,9	
F3	2,3,4,5,7,8,9	1,3	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	

V - Partitioning the Reachability matrix into different levels(Iteration 1-6)

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

VI – Total Interpretive Structural Modelling



Budget:

The total budget of this project was 5 Lakh rupees. The total expenditure is 1.20 Lakh rupees only and that too was only on the project assistant for 6 months. The rest of the money has been transferred to TCOE.

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Appendix A – Workshop Details

Spectrum Pricing Index (Project RP02132) as per IRD MI 00971.

The project was considered relevant as title “Development of Spectrum Pricing Index”. Globally Spectrum Pricing Index is not available for regulators, Policy Planner, and Industry. This project fulfils that gap and fundamentals. Research Objective is as follows:

- RO1. To identify the factors that plays an important role in spectrum pricing
- RO2. To develop a Total interpretive structure model (TISM) for consumer awareness.
- RO3. To develop Spectrum Pricing Index (SPI).

Till now we have completed Research Objective 1 & 2. For conducting Research Objective 1 literature was conducted coupled with application of government theory as mentioned in brief summary report. Research Objective 2 was completed by developing ISM. After this questionnaire development, which was based on factors identifying RO1. Subsequently a testing of questionnaire and coding of TISM was done by conducting Spectrum Pricing Index workshop. In this workshop nearly 30 senior level experts from various telecom operators/industry associations/dot/Government/Academia participated. The workshop was inaugurated by Ms Vijaylaxmi Gupta, Member TRAI. She lauded the efforts of developing Spectrum Pricing Index as generic tool. The work done in this regard is also mentioned in the report. The workshop visuals are also part of this note. The data gathered during workshop is analysed and subsequently TISM is being developed.

As mentioned earlier Spectrum Pricing Index concept is very well appreciated by TRAI/DOT in various industry association and we are able to generate funding for the project from various agencies like DOT, TRAI. Spectrum Pricing is the cardinal point of any telecom policy.

Appendix B – Workshop Brochure

SPECTRUM PRICING INDEX

EXPERT WORKSHOP FACTOR EXPLORATION

ABOUT IIT DELHI

The Indian Institutes of Technology Delhi (IIT-D) is known as the Centre of Excellence for higher education, training, research and development in Science, Engineering, Technology and Management in India. The Institute emphasizes on research based educational and academic deliverables which have high industrial and societal impact.

ABOUT THE PROGRAM

This workshop is an expert's workshop for identifying the factors/determinants of spectrum pricing. This workshop is based on the fundamental premise of developing spectrum pricing index (SPI). To develop SPI, grounded theory and Interpretive Structure Modelling (ISM) will be used. This workshop is mainly to identify and explore factors for SPI.

This expert workshop attempts to develop a SPI. The participants will be from Industry Regulatory Bodies, Government, and Academic Researchers. Industry association will also be responsible. This is an expert workshop and is based on the protocol of grounded theory. The experts will identify explore key factors which are important for spectrum pricing. The aim of this entire exercise is to identify the possible mutually exclusive quantifiable factors.

SESSION PLAN:

6th September 2013 (Friday)

Time	Session Details	Resource Person
10.00-10.05	Introduction	Dr. Mahim Sagar, IIT Delhi
10.05-10.10	Overview of Bharti School of Telecommunication Technology & Management (BSTTM)	Prof. Ranjan Bose, Co-ordinator BSTTM
10.10-10.15	Overview of Department of Management studies	Prof. Kanika T Bhal, Head DMS
10.15-10.30	Spectrum Pricing: Emerging Scenario	Dr. Vijaya Lakhshamy Gupta (Honorable member TRAI)
10.30-10.45	Brief introduction of workshop	Mr Ravi Gandhi (Researcher, IIT Delhi)
10.45 – 12.30	Discussion of Factors	Experts
12.30 – 12.45	ISM Questionnaire	Experts
12.45 – 13.00	High Tea	

IMPORTANT DETAILS:

Date: 6th September 2013

Venue: IIT DELHI

Dr. Mahim Sagar

Program Coordinator

5th Floor, Room No.: 506, Department of Management Studies, Vishwakarma Bhawan, Indian Institute of Technology Delhi, Hauz Khas, New Delhi – 110016.

Appendix C – Significance of the Factor

Workshop on Spectrum Pricing Index at IIT Delhi Factor Exploration & Validation

Factor 1:

How do you rate the importance of this factor on the scale of 1 to 5?

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Components if any corresponding to the factor:

Sub Component 1:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 2:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 3:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Any Other Comments:

Factor 2:

How do you rate the importance of this factor on the scale of 1 to 5?

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Components if any corresponding to the factor:

Sub Component 1:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 2:

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Sub Component 3:

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Any Other Comments:

Factor 3:

How do you rate the importance of this factor on the scale of 1 to 5?

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Sub Components if any corresponding to the factor:

Sub Component 1:

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Sub Component 2:

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Sub Component 3:

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Any Other Comments:

Factor 4:

How do you rate the importance of this factor on the scale of 1 to 5?

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Components if any corresponding to the factor:

Sub Component 1:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 2:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 3:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Any Other Comments:

Factor 5:

How do you rate the importance of this factor on the scale of 1 to 5?

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Components if any corresponding to the factor:

Sub Component 1:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 2:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 3:

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Any Other Comments:

Factor 6:

How do you rate the importance of this factor on the scale of 1 to 5?

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Sub Components if any corresponding to the factor:

Sub Component 1:

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Sub Component 2:

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Sub Component 3:

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Any Other Comments:

Factor 7:

How do you rate the importance of this factor on the scale of 1 to 5?

1	2	3	4	5
Unimportant	Slightly Important	Important	Very Important	Critical

Sub Components if any corresponding to the factor:

Sub Component 1:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 2:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 3:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Any Other Comments:

Factor 8:

How do you rate the importance of this factor on the scale of 1 to 5?

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Components if any corresponding to the factor:

Sub Component 1:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 2:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 3:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Any Other Comments:

Factor 9:

How do you rate the importance of this factor on the scale of 1 to 5?

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Components if any corresponding to the factor:

Sub Component 1:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 2:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 3:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Any Other Comments:

Factor 10:

How do you rate the importance of this factor on the scale of 1 to 5?

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Components if any corresponding to the factor:

Sub Component 1:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Sub Component 2:

1

2

3

4

5

Unimportant

Slightly Important

Important

Very Important

Critical

Sub Component 3:

1

Unimportant

2

Slightly Important

3

Important

4

Very Important

5

Critical

Any Other Comments:

Appendix D – Workshop Photograph



