DOMESTIC INITIATIVES IN TELECOMMUNICATION SWITCHING SYSTEM:

- *FROM ITI TO C-DOT*

DISSERTATION SUBMITTED TO
THE JAWAHARLAL NEHRU UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
MASTER OF PHILOSOPHY

SANJAY KUMAR

Centre for Studies in Science Policy
School of Social Sciences
Jawaharlal Nehru University
New Delhi -110067
India

JULY 2003

Centre for Studies in Science Policy
School of Social Sciences
Jawaharlal Nehru University
New Delhi – 110067

Date: July 31, 2003

Certificate

This is to certify that the dissertation entitled **"Domestic Initiatives in Telecommunication Switching Systems; From ITI to C-DOT"** submitted by **Sanjay Kumar** in partial fulfilment of the requirements for the award of the degree of **Master of Philosophy** of this University is an original work according to the best of our knowledge and may be placed before the examiners for evaluation.

Prof. V.V. Krishna	**Prof. A. Parthasarathi**	**Prof. Nasir Tyabji**
(Chairperson)	(Co-Supervisor)	(Supervisor)

CHAIRPERSON
Centre for Studies in Science Policy
School of Social Sciences-I
Jawaharlal Nehru University
New Delhi 110067

Prof. Ashok Parthasarathi
Centre For Studies Inscience Policy
School of Social Sciences-I
JNU, New Delhi.

Dedicated to

My Parents

ACKNOWLEDGEMENT

The very conception of taking up a topic like domestic initiatives in switching system, owes its origin to the discussion with my Supervisor, who inspired me a lot to pick it up. In linking up this topic to the field of telecom policy and giving it a concrete shape I acknowledge my indebtness to my Supervisor, Prof. Nasir Tyabji. I'm tremendously obliged to him for all his kind help in supervising me and his patience in bearing up with the entire process of writing the dissertation.

I would also like to thank the other professors of the centre, Prof. V.V.Krishna, Dr K.J.Joseph, Dr.Desai and Prof.Parthasarathi for their kind support and guidance during the process of writing the dissertation.

I'm thankful to all my friends, Kalim, Manish, Sangeeta, Arpita, Seetha, Rini, Chandan, Ravinder, Vikrant, Abhishek, Manik, and Jean Luc, for their support and encouragement. Special thanks are due to Vinod Kosthi for his help in typing the document.

Thanks are also due to Mrs. Shyamala Krishnamurthy for her help, and to the centre staff, Tawarji, Khannaji, Meenaji, and Murugesan of their assistance.

It really matters a lot to have friends when you feel frustrated and depressed, therefore I will not thank Mahesh, Nimesh, Pritpal, Amiya and Savita because thanking them would be an offence, as they were always with me whenever I needed.

Finally, I would like to thank my grand parents, parents, uncles, and brothers for their moral encouragement to complete this dissertation.

Sanjay Kumar

LIST OF CONTENTS

1.0	**Introduction**	
1.1	Preamble	8
1.2	Basics of Telecommunication	8
1.3	Conception of Telecommunication	9
1.4	Relevance of Telecommunication	11
1.5	Telecommunication in India– An Overview	12
1.6	India's Telecommunication – Hardware Initiatives	13
1.7	Scope and Objectives of the Study	13
1.8	Research Methodology	14
1.9	Chapter Scheme	14
2.0	**Evolution Of Telecommunication- An Overview**	
2.1	Introduction	16
2.2	Telegraph System- Introduction and Growth	16
2.3	Telecommunication system	18
2.4	History of Telecom in India	23
2.5	Conclusion	38
3.0	**Technology Transfer: Theories And Policies**	
3.1	Technology in India's Developmental Journey	43
3.2	Conclusion	50

4.0	**Technological Choices in Switching System**	
4.1	Introduction	51
4.2	An Overview of Switching System	52
4.3	First Wave of Imports: The Strowger Switching System	57
4.4	The Second Wave: Crossbar Switching System	66
4.5	Third Wave: Electronic Switching System	84
4.6	The Genesis of C-DOT	91
4.7	Achievements of C-DOT	101
4.8	Conclusion	105
5.0	**Conclusions and a perspective for the future**	106
	Appendix	109
	Reference	110

LIST OF TABLES

Table No.	Title	Page No.
2.1	Development of Switching System	22
2.2	Telegraph Network of India: Early Years of Independent India	26
2.3	Telephone System in the Early Years of Independent India	31
2.4	Telephone Lines and Exchanges (1950 and 1951)	32
2.5	Telephone Densities of World Cities	33
2.6	Investments Over Various Five Year Plans and Annuals Plans	34
2.7	Distribution of Telephones between Urban and Rural Areas-1984	35

2.8	Evolution of Indian Telecommunication Sector 1980s- Till Date	35-36
3.1	Repetitive Collaboration of Products and Process	47
4.1	Price paid to M/s ATE for Strowger Technology	61
4.2	Progress of Implementation of the Recommendations of Strowger-Improvement Committee	65
4.3	Royalty Paid Till 1971	69
4.4	Money Paid By ITI to BTM	70
4.5	Schedule of Ordering and Delivery of machinery	72
4.6	Production of Cross-Bar Switching System (1968-69 to 1971-72)	75
4.7	Crossbar equipment of Bangalore:	82
4.8	Capacity utilization in the Crossbar Equipment	83
4.9	Various Competing Electronic Switching Systems	87
4.10	Salient Features of the Collaboration Agreement between ITI and Alcatel-CIT	88
4.11	Price (Contracted) for the ESS	89
4.12	Extent of Cost Overrun at the Large Local ESS Plant (Rs in Crores)	91

LIST OF FIGURES

Name	Page No.
1.1: Schematic Representation of Telecommunication Process	9
4.1: Switching System Categorisation	53

Chapter 1
Introduction

1.1 Preamble

Communication over long distances has always fascinated mankind. Different methods of communication evolved over different periods in history involving, men, birds, and animals. The open-ended nature of long distance communication lead to the conception and implementation, of a series of initiatives aimed at maintaining a semblance of secrecy and privacy. Science and technology played a major role in the above objective. From the days of Morse code based telegraph, to operator-assisted telephone calls over copper wire, to multimedia, voice enabled messaging services; through wireless the science of communication has come a long way. The impact of technology, has never been, as distinct and deep rooted, in any form of human interaction, as it is with respect to communication. The sociological, economic and political impact of such new and varied forms of communication, rich and diverse on one hand, forceful and directionary on the other, is too exciting a field of enquiry. However it is not the focus of the current dissertation. The nature, form and direction of development of telecommunication vary with the developmental trajectories of the countries of the world. From the first world countries, where the telephone density, which is continuous, even, diverse and technologically sophisticated to that of the third world, whose technological and resource poverty is captured by the pity statement "Half the world's population has never made a phone call"; the telecommunication system is varied in different countries in terms of technological advancement, geographical reach, growth trajectories, and future directions.

1.2 Basics of Telecommunication

With the world going through a process of communication revolution, telecommunication has come to occupy a place of extreme importance as a link connecting a whole range of communication channel like television, computers and satellites. "Telecommunication is electronic highway of economic opportunity in the emerging ' information economy ' as much did the railways in the earlier periods of proformed structural change in the industrial economy" (Goddard and Gillespie, 1986).

The concept of communicating at a distance has been shown in the figure 1.1 (it has been illustrated by the essential components. Though this may seem simplified, the process of sending and receiving information in an orderly and successful manner can be extremely complex for today's modern communication system). An information transfer between sending and receiving parties or devices as a connection of facilities the basic components involved are encoder, transmitter, communication medium, receiver, decoder and information (Bryan, 1984).

Figure 1.1: Schematic Representation of Telecommunication Process

Basic components of communication system involve:

- Nature of information
- Format of information
- Transmission speed
- Transmission medium
- Modulation technique
- Error Control

1.3 Conception of Telecommunication

Literally, telecommunication (tele-from the Greek meaning 'far-off') means communication at a distance. Communication is generally understood to be the act of importing or exchanging information, knowledge, and ideas. Originally, it required people to come to speak to each other; subsequently, with the invention of writing, messages were carried from place to place so that communication could take place at a distance but only as far as and as fast as a person could travel. Improvements in transportation resulted in improvements in speed and distances at which communication occurred making the organization of, States enterprises and communities of ideas, possible (Bryan, 1984). The invention of the telephone by Alexander Graham Bell in 1876 led to the growth of the telephone system which further extended our ability to communicate "at a distance" (Hioki, W 1998). With the introduction of telegraph and the telephone, limitations of both distance and time were removed and instantaneous communication over any distance is now available to most of the world's population. Moreover, the same technology which resulted in electronic communication has given rise to computers which are programmed to exchange data with other machine in other locations and provide information through the mediation of terminals.

Television and radio broadcasts spanning the globe via satellite communication added the steady growth of an industry: the telecommunication industry, one of the largest and fastest growing industries in our history. Thus, telecommunication has come to be regarded as long distance communications via a conglomeration of information sharing network all tied together. These include Public Switched Telephone Network (PSTN) data communication network, radio and television networks and most important the fibre that is destined to link virtually all communication systems together: the Internet and World Wide Web (Hioki, 1998). Telecommunication services represent a subset of the contents and functions of the medium tailored to satisfy a particular need. It follows that, to provide a specific service, it requires a medium whose contents and functions are at least equal to those that will be required to handle the types of messages and to provide the degrees of interaction needed to deliver the services.

Nowadays telecommunication services are dictated by the digital data communication system. While in the past telecommunication systems transmitted voice information in analog signal form. An analog signal is one that is a continuous range of values as a function of time. The PSTN, for example, was designed to accommodate voice transmission in analog form. Due to enormous capabilities of the computer, however, the trend in telecommunication has been that of a gradual conversion from analog to digital transmission. In a digital transmission system signals transmitted are in digital form. The digital signal has discrete sets of values as a function of time, such as binary 1 or 0, that means digital pulse stream is comprised of two discrete voltage levels: one for a logic high and zero for a logic low. Digital data communication which is essential for modern communication system involves the transmission and reception of digital signals from one location to another. The digital signals typically represent information that is alphabetical, numerical or symbolical in nature. The organization of this information is referred to as data. Virtually every human thought process can be represented as data and therefore can be transmitted by the data communication system (Hioki, 1998).

Thus, one could safely argue that telecommunication has assumed the proportions of a complex technological system, with its own, production, transmission, and consumption sub-systems. The telecommunication industry from its very inception has been dependent on the foreign technological imports and in most of the cases the indigenous effort to absorb that particular technology was not successful. This industry is basically characterised by an oligopolistic market with a concentration of firms dominating across the industry spectrum in most of the countries.

1.4 Relevance of Telecommunication

The socio-economic development of a nation is closely linked with the growth of telecommunication. Any new development in the field of telecommunication is bound to have its impact in the overall socio-economic sphere. We live in an era that is often referred to as information age. An age in which the furore of internet and the emergence of www (world wide web), the most interactive and fastest growing segment of the internet, has spawned enormous growth in technology standards and products beyond anyone's imagination. Internet addresses have become as common as telephone numbers appearing on everything from business cards and magazines to automobile, buses, and television shows. Among a variety of infrastructural goods, telecommunications is special in one respect: the application of modern telecommunications technology is an extremely important ingredient in the rapid growth of India's economy. In this sense, telecom should be viewed as an essential "factor of production" which is part of the process of transforming the efficiency of utilisation of India's labour and capital (Mohanasundaram, 2002). This idea has three facets:

1. Business Process Re-engineering using Telecom,
2. Telecom as Window to the World, and
3. Telecom as a Response to Poor Transportation.

It is proved theoretically as well as empirically that telecommunication has a decisive role to play in the economic growth of a country. The production function estimates have shown that infrastructure, labour, technological progress has positive and significant contribution to the output of economic growth. When the stocks of infrastructure are taken in a segregated manner, transport, electricity, gas and water supply, communication have a significant positive effect on economic growth with increasing returns to scale (Sahoo and Saxena, 1999- 00).

1.5 Telecommunication in India– An Overview

Earlier in India as well as in any other countries in Europe and Asia, telecommunication services were operated by government department. The expansion of network was very slow and was used and managed primarily by the government. This continued until the early 1990s by the time the concept of natural monopoly was increasingly challenged. India's telecommunication sector had been mostly state run despite a decade long process of reforms that ended the state monopoly and allowed private entry, introducing independent regulation. The result has been inefficiency and under investment - India and China had similar numbers of telephone lines in 1990 (6 million) but a decade later India had 28 million lines while China had 120 million (Dossani, 2003). The process of telecom reform in India began in 1980 when "mission better communication" was launched by the government. During this period private manufacturing of customer premise equipment was allowed (in 1984) and the Centre for Development of Telematics (C-DOT) was established (in 1984) for the development of the indigenous technologies and proliferation of Public Call Offices (PCOs) for local and long distance services were undertaken on a large scale across the country through private individual franchisees.

After liberalisation of the economy in the early 1990s and announcement of the New Industrial Policy (NIP, 1991), the telecom equipment manufacturing was de-licensed in 1992. Licenses were issued to the private sector in value-added services in 1992 and for radio paging, cellular mobile and basic telephony services thereafter. During this phase a National Telecom Policy was announced in 1994 and its emphasis was being on universal services and qualities improvement in services. In 1999 New Telecom Policy (NTP 99) was announced which may be termed as third generation of telecom reforms. Its theme was to usher in full competition through unrestricted private entry in almost all service sectors unless restricted by spectrum availability with the full protection of strong regulation, NTP 1999 allowed existing private service providers to migrate from earlier fixed license revenue while duopoly rights were discontinued in order to allow for unlimited competition. The year 2001 saw the arrival of CDMA based limited mobile telephony services, and currently the state is contemplating the process of providing unified licences for telecommunication services.

1.6 India's Telecommunication – Hardware Initiatives

In line with the prevailing ethos of self-reliance, India in the 1950s embarked upon an ambitious programme of indigenous manufacture of telecommunication equipments, which was fully reserved for the public sector. Like every other S&T intensive sector, even here the state had to depend on foreign technology for establishing manufacturing facilities. The Indian Telephone Industries (ITI) with its multiple production units was the pioneer in the production of all the equipment needed for the Department of Telecom and was partially successful in indigenous manufacturing but turned out far from satisfactory performance when it comes to effective indigenisation of technology (See Mani 1992 for more details). This was followed by C-DOT which was a commercial success in terms of locally producing telecommunication equipment. The liberalization process embarked upon in 1990s has paid to the indigenous ambitions especially in the public sector.

1.7 Scope and Objectives of the Study

In the context of the shift in the priorities of the State with respect to telecommunication, with the assumption of a telephone being a luxury in the 50s to telephone being a necessity in the 90s the nature, scope and direction of the State with respect to telecommunication also evolved and changed. Situated in a democratic society, the telecommunication sector was fully controlled by the State and is thus subject to the pulls and pressures of the statecraft. Hence the conception of the sector, its role in national well being, and the degree of importance attached to the impact of the sector on the overall economic scenario determines the degree and direction of State intervention subject to the overall political priorities. Amongst the technological sub-systems constituting the telecommunication sector, one area where, India has consistently attempted to build domestic technological capabilities is the switching systems. Using the case of switching systems in the telecommunication sector, the study attempts to analyse two important dimensions of Indian journey for technological self-reliance:

a) The first objective of this study within limited scope is to trace the technology choices made by the firms in the industry and the role of state in such choices, and their effectiveness, in terms of the stated objectives of self-reliance.

b) To evaluate the success of the later day establishment of C-DOT, vis-à-vis the failure of the indigenous initiatives of pervious ITI, based on the theoretical perspectives on technology transfer, and draw upon certain conclusions.

1.8 Research Methodology

Since the research is primarily exploratory, the descriptive analysis has been used. The thurst of the study is based on primary data sources including different committee reports like Committee on Public Undertakings reports (COPU), Estimates committee reports, Standing Committee reports of Government of India (GOI) and Annual reports of ITI, Department of Telecommunication (DOT), Department of Electronics (DOE), and C-DOT and other GOI publications. The information was collected mainly from IIPA, NISTADS, IIT and JNU libraries as also from the internet. Views and opinions from different experts have added value to this study. This has been supplemented with foucussed unstructured interviews with key policy makers, industry executives and civil society players interested in telecommunication industry.

1.9 Chapter Scheme

Following the introduction, we provide an overview of the telecommunication sector in the next chapter. Here we focus on historical roots of the sector internationally and provide a brief overview of Indian telecommunication scenario. The third chapter discusses the development of the conception of technology transfer, situates the same in the overall context of the idea of development. Briefly reviewing the literature on technology transfer over the years, this chapter also provides an overview of India's technology journey in broad terms. In Chapter four, we present an exhaustive overview of technological choices in the switching system industry, and discuss the process of selection, integration and assimilation of the technologies by the Indian public sector corporations, and success and failures of attempts at indigenous efforts in switching systems. In the last chapter we discuss the policy implications of the domestic technology initiatives, and draw conclusions.

Chapter 2
Evolution of Telecommunication- An Overview

2.1 Introduction

The need and desire to communicate quickly over longer distances with secrecy and speed as the most important factors, led to the first attempts to utilize principles of science and technology for better communication during the late 18^{th} century. From the early days of telegraph to current integrated communication systems with, always-on connectivity aided by GPRS (General Packet Radio System), MMS (Multimedia Messaging System)[1] and so on, the evolution of telecommunication has been a fascinating journey. But relative importance of alternative communication media varies at different stages of economic development as Solomon (1994) puts it "the typewriter co-existing with Internet."

This chapter is a modest attempt to trace the evolution of the telecommunication system, as one understands it today. Following the introduction, the second section discusses the telegraph system, its origin and growth internationally. The next section provides a perspective on international telecommunication system. Both these sections are generic and the attempt is to provide only a broad overview. The fourth section discusses the introduction and growth of Indian telecommunication system over the last two centuries or so. In the last section conclusions are drawn.

2.2 Telegraph System- Introduction and Growth

The history of telecommunication starts with the successful initiation of telegraph cables. The first tentative steps towards modern communication were fostered by the French revolution. A French engineer, Claude Chappe (1763-1805), developed a system of "optical telegraphy" in 1791 with which he displayed the coded messages on the towers. Paris and Lille were connected by such a system in 1794. An English bishop, George Murray, established in 1795 a semaphore[2] consisting of six independent shutters for admiralty in

[1] Multimedia Messaging System not only sends text message but also sends voice and picture messages
[2] Semaphore is a counter used to provide access to a shared data object for multiple processes.

London to link it to Portsmouth. In this system operating the shutters differently could send different combination of signals. Ingnace Chappe (Brother of Claude Chappe) was the first to use the word "telegraph" in April 1793. The word signified the "ultimate" in speed in French. However, full advantage of telegraphy was realised only in association with electricity. In 1809 Prof. Alessandra Volta recorded the production of electricity by chemical means. In 1819 Prof. Hans Christian Oersted (1777-1851), a Danish scientist, discovered by chance that a current created magnetic effects. Thereafter, emerged electromagnets, that encouraged the pioneers of electrical telegraphy, to try out new ideas. George Lesage in Geneva built one of the first electric telegraph systems in 1774. He used a single wire for each letter. A Russian, Baron Paul Schilling (1768-1837), experimented in 1832 with deflecting compass needles under current flow and developed an electromagnetic telegraph (Garratt, 1958).

The railroads encouraged the use of telegraphy to prevent accidents. By 1837, Prof. Charles Wheatstone and Cooke developed a working telegraph, which had five needles to spell out 20 letters, known as Wheatstone working (Rajan, 2001). Samuel Finley Breeze Morse (1791-1872) designed a code for letters of the alphabet on the basis of the deflection of the pen to mark a strip of paper under the influence of an electric current through an electromagnet thereby giving birth to the famous Morse telegraphy in 1845. On first January 1845 the first words were transmitted over the lines between Washington and Baltimore. Since then the message transmitted "what hath God wrought?" has become historic (Gupta, 2000). The dots and dashes of the Morse code could be operated only with strong current. Converting the code into plain language was also a problem. A key development in the evolution of telecommunication came about when information was converted into coded electrical signals, which were then transmitted over a distance using wires. The first such instance of electrical communication was provided with the invention of telegraph in1837 by Morse and Wheatstone, both working independently. The successful initiation of first submarine telegraphs cable linking Britain and France occurred in 1851. Different technology initiatives in telegraph greatly increased the rate of transmission, notably the initiative by Charles Wheatstone (1858) was one of the steps in this direction. (Williams, 1982) A common feature of telegraph service is that messages are converted into dot-dash Morse code, transmitted and decoded at the other end. Operators sent the message in the early days by coding them, and de-pressing a key at the other end, heard the "clicks" on Morse sounder and decoded them. This process was slow and prone to error. It took several decades of effort to mechanise the process of encoding and decoding messages for electrical transmission (Biswas, 1964). David solved the difficulty to some extent with the invention of plain language telegraphy in 1855. E. Hughes (1831-1900), a British, was the one who won a patent for the same. Known as Hughes-type printing telegraph, it had a rotating wheel with letters of the alphabet, which stopped when the wanted letter appeared on paper. Hughes machine could transmit 40 words a minute as against 25 in Morse telegraph. The next advance came in 1875 when an officer of the French telegraph service, Emile Baudot (1845-1903) introduced a five-unit code to represent each letter of alphabet. Five impulses were sent over the lines to actuate a set of five magnets. Through this coding system 60 words in a minute could be transmitted. Baudot telegraph was used in England and in his honour the speed of transmission is now called "Baud" (Mcneil, 1990).

2.3 Telecommunication system

Unlike the telegraph system the telecommunication system, grew rapidly within a span of six seven decades in the current century, from a system which transfers voice from point to point, to an integrated and complex system transferring voice, data, and graphics, in unimaginably large quantum at tremendous speeds.

2.3.1 The Initial Years- The Telephone System

Though Alexander Graham Bell patented the first effective telephone in USA, which was subsequently followed by Elisha Gray in Britain in 1876, the telegraph system has been firmly established and was a heavy source of revenue. In many countries the telephone system was being regarded as an extension of telegraph services, which was totally under the state monopoly. Though some countries such as Germany initiated telephone services under state monopoly (1877), but licenses were issued to private operators as long as the (government revenue) role of telephone was uncertain. But in twentieth century these licenses expired and state absorbed these systems and telecommunication came under state monopoly (William, 1982).

Initially in the Bell telephone technology, the transmitter and receiver were identical. The telephone consisted of an electromagnet attached to a large paper diaphragm, which moved by the pressure of sound waves, and caused a varying signal to be transmitted through the wire. Detected by similar equipment on the other side, this signal was converted back into sound. The first long distance telephone call took place over a two-mile distance in the Bell neighborhood in late1876, using the standard wire. From 3000 connections in November 1877, the number of telephones in use shot upto 1, 33, 000 in 1880, a phenomenal growth within a few years. While old technology remained with respect to the pattern for the receiver, Edison developed an improved form of transmitter in 1878, which was widely used even in 1950s (Gupta; 2000). The expansion of telephone services, particularly cheap long-distance calls came in to existence in 1930 after a new technique was developed for radio; this new technique facilitated multiple conversations simultaneously through a single coaxial cable (Williams, 1982)

2.3.1.1 Telephone Exchanges

In early days, the telephone was used to make point-to-point[3] or point-to-multipoint link[4], without switching systems. The idea of connecting telephone lines through exchange arose from the nature of the demand for connections, as connecting direct one telephone line to every other telephone line was found uneconomical, Thus, Bells famous invention encouraged many attempts to set up small exchanges. The first commercial telephone exchange was opened on 28 January1878, at New Haven, Connecticut, providing services to 21 subscribers with 8 lines. Within a decade, the US had 140000 subscribers with 800 exchanges (Jon Clark, 1988, see also Williams, 1982).

Several switchboards were required and two operators were involved in most calls. By 1879, subscribers were called by numbers rather than by names. In 1880, signaling current from a common battery in the exchange, individual telephone sets was introduced for the first time. This was done by JJ Carty (1861-1932), an American electrical engineer at Boston. Use of a common battery for both speaking and signaling came into commercial service in 1893. After Strowger exchanges[5] in 1889 another development happened in 1896 when the

[3] Point-to-Point link connects subscribers directly to one another without switching system.
[4] Point-to-Multipoint link connects one subscriber to many subscriber without switching system
[5] Strowger exchanges are dealt in detail in the next section on switching systems.

rotatory dial was introduced. The first commercial automatic exchange was working by 1897. In the United States competition among private telephone companies marked the development of service. In the UK the post office gained control of the telephone service by getting a court order that it was a 'telegraph' within the meaning of the telegraph Act of 1868 (Rajan, 2001).

The first automatic telephone exchange in the UK was opened in 1912. Strowger (step by step) system was the first electromechanical exchange, which removed the role of telephone operator. With the fast growth of telephone traffic, the limitations of the step-by-step system were increasingly felt. The direct controls, which the exchanges exercised due to the dialing process in the Strowger's system made people, think of an indirect way of control. Some indirect control features were introduced in the 1920s. One of them was a penal system started at Newark, New Jersey, in 1915 as a semi automatic switch. It was the first attempt to remove direct control from the dial and placed it in a separate mechanical unit. There was provision to register the digits dialed, which in turn converted them into suitable control pulses and set up a link. More innovation followed and in 1913, Reynolds presented a new type of switch. It was a rectangular array of contacts arranged in rows and columns so that contacts could be operated in any intersections. Betulander and Palmgren of Sweden developed this into the well-known crossbar switch in 1919. The first crossbar exchange was in service in Sweden in 1926. The next step was coupling of common control with crossbar switch in 1938 in Brooklyn New York. Another element in the common control system, know as the marker was introduced. Together with the registers for registering the digits and translators for coding them, the marker came to perform the task of testing and selecting the path through switching network. Thus, the second generation of switching system was still electromechanical but used the experience of the first generation equipment to develop common control devices. The relay played a major role in telephone exchanges of electromechanical nature like the strowger and the crossbar, where control is done by contacts (relays), which are opened or closed by electromagnets, physically moving them through a mechanical link. Relays are electromechanical devices that are used to open and close electric circuits. They change electric signals into mechanical action. A crossbar exchange is an all-relay exchange, since all connections are set up by the operation of relays. Only the number identifies the destination dialed. Neither the routing nor the number of stages of selection corresponds to each of the digits dialed. The common circuits that are used to set up the call do not remain engaged during the entire duration of the call.

2.3.2 Evolution of Switching Technology

The first operator-manned switchboard was created in 1877 for doctors in Connecticut to communicate with drug stores. The operator, on receiving a call from the caller using a hand crank, connected the call to the other side using a patch cord device[6]. The first automated switching system called strowger switching system was invented in 1897 by a Missouri undertaker, Almon Strowger. This electromechanical system allowed the calling party to automatically select and connect the number. The need was to do away with manual operation of the system by the operator[7]. Concurrently in 1896 the first dial phone limited to 99 numbers was designed. Even in 1978, Strowger switches served over 23 million Americans users (Vishwanathan, 2001).

Another electromechanical switching system was the crossbar system with hardware control subsystems. It used a bewildering array of relays and latches, which made enormous noise. A large switching office used to take up many floors of a building and contained millions of different moving parts and miles of wires, all of which had to be manually maintained.

In the 1950s, the advent of electronic devices like silicon transistors and integrated circuits made it possible to develop the first electronic switching system. This allowed for reduction in size and weight, greater reliability (less maintenance), faster switching of calls, easier, faster and more cost-efficient production, and greater potential for new features.

2.3.2.1 Electronic Switching

The electronic switching systems employed processors (or computers) for performing the control functions. Hence, these were called 'stored program controlled' (SPC) systems, whereby new facilities could be added by changing the control program. The first SPC

[6] Patch chord device has a plug or a pair of clips on one end, used to connect two pieces of sound equipment such as phonograph and tape-recorder or an amplifier.

[7] There is an interesting story behind the invention of Strowger switching system. Strowger, an undertaker had to communicate through an operator, who happened to be the wife of another undertaker. He realized that he was losing business when he found that the operator was making use of the information and passing it on to his rival in the profession-probably the earliest known example of telecom fraud. This made him think of a device which would automatically select and connect the desired destination number.

exchange - an analog one with electromechanical switching - was introduced by Bell Systems, USA in 1965. The switching scheme used by electronic switching systems can be either 'space division switching'[8] or 'time division switching'.[9]

A time division digital switching may also be designed by using a combination of space and time switching techniques. A large electronic switch may be a combination of time division and space division units and would be called time-space-time switch[10]. Between the late 1970s and 1980s, a widespread introduction of digital time division switching was witnessed in central office and toll networks.

The first digital electronic local exchange E10A, was developed jointly by Centre National d'Etudes des Telecommunications "CNET', (National Telecommunications Research Centre) and the Societe Lannionnaise d'Electronique 'SLE', a subsidiary of CIT-Alcatel. It was commissioned in a public telephone network in France in 1970. Subsequently, digital exchanges from various other manufacturers like Northern Telecom (Canada), GTE (USA), LM Ericsson (Sweden), Fujitsu (Japan), arrived in the market (Roche, 1980).The table (2.1) shows the different manufacturers, who were involved in the development and manufacturing of switching systems

Table 2.1 Development of Switching System

Technological Era	Period	Product	Major World Manufacturers
A. Manual System	1880s	-	Ericsson and others
B. Electro-mechanical First automatic direct/indirect C. Crossbar	1920s 1940s	500-switch (Ericsson) Strowger (Siemens) Rotary (ITT) Panel System (Bell) Cross-bar (Ericsson) Pentaconta (ITT)	Siemens ITT Ericsson.
D. Electronic Stored Program control Digital Signal processing	1970s	AXE (Ericsson) Metaconta (ITT) Systems 12 (ITT) ESS-I (Bell-ATT) System X (Plessey) DMS (Northern)	Ericsson ITT (Metaconta) Northern (AT&T) CIT-Alcatel

Source: Grindstone and Sjolander (1990: 41)
Note: The companies in brackets have developed the product.

[8] Space division switching provides a dedicated path between calling and called subscriber for entire duration of call
[9] In time division switching , speech signals are transferred at fixed intervals
[10] Time-space-switch is the combination of time division and space division switching

The above table shows the technological changes in the switching system during the last hundred years. There were three main pioneers in export markets for the telephone switches based on SPC (Stored Program Control): CIT-Alcatel (France), Ericsson (Sweden) and Northern Telecom (Canada). The marketing effort of these companies got worldwide recognition. During a short period in the 1970 the buyers of telephone exchanges shifted their preference from old crossbar technology to new SPC technology. A similar phased diffusion happened in the transition from analogue to digital telephone switching. (Granstrand and Sjolander, 1990)

2.4 History Of Telecom In India

2.4.1 Telegraph system

Since its very inception, Indian telegraph had been the exclusive monopoly of the Government until the late 1980s. It arrived in India at about the same time as in the rest of the world. As early as 1839, W. B. O. Shaughnessy, a Calcutta based doctor of medicine, was conducting experiments with electric telegraphy. He set up the first experimental electric telegraph line in India in 1839 for the East India Company. This line was spread over a distance of 33 km from Calcutta towards Diamond Harbor between Calcutta and Chinsurah. One half of this line was underground and the other half aerial. The lines, from Calcutta to Diamond Harbour (30 miles), Bishtapore to Mayapore (11 miles) and Kukrahata to Kedgeree (25 miles) were constructed in quick succession (Shridharani, 1953).The first telegraph line in India was opened for traffic in 1851 primarily for official use. The same year also saw the beginning of large-scale construction of telegraph lines. By March 1854, telegraph messages could be sent from Agra to Calcutta over a distance of about 1200 km. The telegraph system in India was then the exclusive monopoly of Government and telegraph department had the distinction of being the first government owned public utility department in India and perhaps in the whole world (Vaidya K, 1979).

During the second half of the 19^{th} century the representatives of the East India Company were still occupied with the task of consolidating British hold on India. The focus of all their activities was military. Lines of communications and transport, which they developed, represented the topography of the military mind. They employed Indians only in menial positions. Yet at the birth of telegraph, in India, the British attitude towards Indian participation in constructive work had not irrevocably hardened. The idea that all the crucial positions even in post, telegraph and railway department should be reserved primarily for the Englishmen had not struck roots yet. In February 1855, the telegraph service was opened to public. At the end of 1856, on the eve of the First war of Indian Independence there were 4,250 miles of Electric Telegraph in India and 46 receiving offices and in 1857, telegraph played a major role when the large scale revolt broke-out, as there were series of telegrams exchanged between provincial government and supreme council during 16-29 May 1857, which led to the accomplishment of a huge troop movement with in a very short time (Kumar, 1995).

In the ongoing diffusion of telegraph system, the electric telegraphy was exclusively imperial innovation to serve the military purpose. The technology transfer under colonial relations offered very little scope for Indians to learn about the technology of telegraph, as almost all machinery came packed from outside most of time along with the technicians to handle it. The British policy was not to encourage technological development, but to increase the productive resources of the country through the agency of imported technology. Whatever information Indians gathered regarding the technology was therefore, a result of their quest for it (Sangwan, 1991). An Indo-European telegraph line was built during 1867-1870 by a German firm, connecting London and Calcutta. A London-Bombay telegraphs service over a sub-marine cable was also inaugurated in 1870. Mumbai and Calcutta were also linked by a telegraph system that allowed simultaneous transmission in both directions (Shridharani, 1953).

Even though most of the development in telegraphy was primarily executed to meet the administrative machinery of the British Empire in India and helped colonial government to rule India and the neighbouring countries, it did provide the general public some services too. The amenities and facilities for the public grew gradually as the science and technology of telegraphy made progress. New features were introduced as soon as they were invented in Europe or America or in the Calcutta workshops. The main hurdles pertained to India's limited purse and to the absence of skilled workers and trained managerial personnel. This limitation was keenly felt especially in the beginning.

In 1883 a new process called the 'combined office system', was introduced, it was this very process by which telegraphy became an administrative annexe of the postal department. The principal object of the scheme whereby the Post Office assisted in the operations of the Telegraph Office was to utilise a less costly method to open offices at many small places where the traffic was not sufficient to justify a separate Telegraph Office. At the end of 1884-85 and as a consequence of the combined office system, there were 267 offices managed by the Post Office for the Telegraph Department against 55 at the end of the previous year. To connect these offices to the main system of the country, 1,216 miles of line and wire, and 636 miles of new wire on existing supports had been added between the inception of the scheme in December 1883 and 31st March 1885. By the beginning of 20th century the Telegraph Department operated 52,909 miles of line, 170,766 miles of wire and 283 miles of cable. Of the wire, 57,423 miles were used by railway 2,650 by canals and 110,693 by the Telegraph Department, while of the cables; 13 miles were used by railways and the rest by the Department. The total number of Telegraph Offices were 4,949, including canal and railway offices. There was a considerable increase in the use of services both nationally and internationally.

During the decade, 1910-11 to 1920-21, there had been marked variations in foreign telegraph traffic. The total number of telegrams increased from 1,417,094 to 2,756,264 and the revenue from Rs 25,01,601 to 57,67,456. Telegraphic money order service between India and Mesopotamia and the Persian Gulf started from the 1st September. Money orders between India and the United Kingdom started on the same basis from 1st November 1917. The year 1938 marked a significant event. This year witnessed the introduction of uniform telegraph rate between the countries of the Empire. This was the result of a Conference of Heads of Postal Administrations of the empire which was held in London during December 1937 (Rajan, 2001). As on March 1925, there were 1960 Railway and Canal administrative Telegraph offices of which 1,671 were maintained by the department and rest were maintained by other parties. This could mean a modest degree of private participation in telegraph system, but the degree of participation is not known. The same year modern multiplex system of Baudot, Murray and Morkrum, replaced entirely the Wheatstone Automatic system (*Annual Report*, Post and Telegraph, 1924-25, pp.7-10). As on the March 31st 1950, the number of telegraph offices in India was 7,772 of which 89 (including 10 temporary) were departmental telegraph offices 3,321 were combined Post and Telegraph offices and 4,362 Railway and Canal licensed Telegraph offices (Annual Report, Post and Telegraph, 1949-50)

Table 2.2 Telegraph Network of India: Early Years of Independent India

Number open for paid traffic on 31st March	**1950**	**1949**
Department telegraph offices	89*	77
Combined Post and Telegraph offices	3,321	3,284
Railway	4,243	4,227
Canal	119	199
Total	7,772	7,781
Postal Receiving offices	7,415	7,474
Telegraph offices for administrative need of Railway and Canal administration	1,314	1,553

Source: P&T Annual report 1949-50, p. 62.

2.4.2 Telephone System

2.4.2.1 The Early Years of Provincial Telephone Systems

The first private telephone line in the country was set up in 1875, between the P O Esteem Navigation Company at the Mazgaon dockyard and the Fort area office in Mumbai. The instrument was operated through letters of the alphabet instead of numerals. The early development was especially slow. There was an initial, and perhaps unavoidable, handicap; most of the instruments were magneto-telephones.[11] The pull of the commercial community was decisive in the character that the telephone system assumed in India. In November 1880, the Government of India informed the Bombay Chamber of Commerce that they were

[11] Magneto Phones can be connected together by a pair of wires and use Carbon Microphones which require energizing from a battery and moving coil ear pieces.

considering the question of introducing the telephone into India as part of the machinery of the Telegraph Department, thus making telephone also a Government-run public utility, and asked for an expression of the views of the Chamber. The Chamber of Commerce naturally replied that it was in favour of leaving telephone to private enterprise since those who had set their eyes on the industry were also members of the Chamber. In accordance with this view, the Government of India granted permission to the Oriental Telephone Company, a British firm, in 1881 'to place telephone wires throughout the city, and latter to establish exchanges at Calcutta, Madras, Bombay and Rangoon. The Crossley Company was granted license for Calcutta. The license granted to the latter Company lapsed but the Oriental Telephone commenced operation at once and established exchanges in those large cities. The first telephone exchange was commissioned at Bombay on January 30th 1882. That year saw exchanges being commissioned in all these cities with 244 subscribers- Bombay, Calcutta, Madras, Rangoon and Karachi had 90, 102, 24, 17 and 11 subscriber respectively. By 1899, there were about 50 telephone exchanges with 3300 lines owned by private companies and the government (Rajan, 2001). The Bombay Telephone System operated on Law's Call Wire Equipment, which was subsequently replaced by Magneto Equipment using a single wire with an earth return from 1883 onwards. The company had only 90 subscribers on its role when it opened on 28th January 1882. During its first year it collected revenue of Rs 25,194. One hundred and two subscribers to the credit of the Calcutta Telephone System made it the largest unit on the list of the Oriental Telephone Company. The India Government may have bowed down to the wishes of the Chambers of Commerce so far as the large cities were concerned, but it did not forget the smaller towns. It insisted on running its own telephone system for its offices even in those cities like Calcutta and Bombay where private companies had been given a virtual monopoly. Moreover the Government kept under its control the provision of trunk lines.

Private enterprise, however, in such a large-scale industry did not have a smooth sailing. The Oriental Telephone Company did not last long; and in 1882 the Bombay Telephone Company, established with limited liability under the India Company's Act, was formed with a nominal capital of 9.6 lakhs of rupees to acquire from the Oriental Telephone Company all the telephone exchanges and lines in Bombay and Karachi, together with the licences and rights granted to them by the Government of India. But by 1883 the license passed into the hands of the Bengal Telephone Company, which, around 1922, was rechristened as 'Bengal Telephone Corporation'. In 1890 the number of exchange and private lines in Calcutta totaled 437 and by 1900 it had risen to 821. The early exchanges were Magneto type and this system was maintained till 1920. Of course technical improvements were introduced as the service expanded; underground cables, for instance, were laid as early as 1903. The Central Battery Exchanges were inaugurated on 21st April 1921[12]. The reign of 'Bengal Telephone Corporation lasted until 1943 when the Indian Posts and Telegraphs Department took over the ownership and management.

Around 1906 the Central Exchange, by then very large, came into existence using Magneto Lamp Signalling Equipment. Other smaller exchanges round about gradually closed down, and all the subscribers in the Bombay Island, some 1,600, were concentrated on the Central Exchange. Two more exchanges at Bandra and Ghatkopar were opened in 1910-11. By 1921 the Bombay Telephone Company was serving 6,000 subscribers and it was found necessary to resort to Central Battery working. A total of 11,000 lines of equipment began to work on a five-digit number scheme. The first automatic exchange was commissioned at Shimla in 1913, with the capacity 700 lines and 400 working connections. As early as 1923 the Department had designed circuits, which provided inter-dialling facilities between subscribers of both the exchanges. Lyallpur subscribers, who were about 90 miles away form Lahore, could be directly dialled by the Lahore Trunk Exchange. The first trunk telephone circuit in Burma was established between Rangoon and Pegu by a superimposition on telegraph wires. The circuit was opened to public by December 1923 and earned revenue of Rs 571 on 761 calls. (P& T annual report 1924-25 page 22)

Experimental research on Telephone Repeaters[13] and composite working carried on in departmental workshops produced several results in the same year. As a consequence of

[12] In Central Battery Exchanges, battery is located at central place, which energises the microphone of subscriber.

[13] Telephone repeaters are used to amplify the weak signals

these experiments, Telephone Repeaters were installed in Lahore and Delhi to furnish inter-provincial trunking facilities between telephone exchanges in the Punjab on the one side, and those in the United Provinces of Agra and Oudh on the other. On the March 1925 the number of exchanges owned and maintained by Govt. were 252 with13031 straight line connection and 1754 extension telephones of which 158 exchanges with 1459 straight line connections and 386 extensions were not operated by the department. There were also 290 independent, non-exchange systems with 930 telephones. The number of exchanges owned by the licensed telephone companies was 14, with 26,455 connections (P&T *Annual Report*, 1925, pp.26-33). In 1926 Delhi Telephone system was converted from manual to automatic. The Automatic plant consists of two Strowger type exchanges manufactured by Peel Corner Telephone Company, the one in New Delhi was equipped with 1350 direct lines and other at Lothian road for 1500 lines. There were automatic telephone exchanges at Lahore Cantonment and Lyallpur. This equipment at the Cantonment worked in conjunction with Lahore Auto-Exchange (Strowger Plant). The conversion of the Delhi Telephone System from the Manual to the Automatic was completed during 1926. There were now in Delhi three Automatic Exchanges. One was at the Secretariat equipped for 2,000 lines; the second with 1,500 lines was at Lothian Road; and the third, a relay Automatic Board of 300 lines, at Delhi Cantonment.

A bulk expansion took place during 1947-48 of about 4,000 lines. In 1951, the capacity was raised to 7,000 lines making it the largest exchange in the Capital. To meet the increasing needs of the city, a 600 line Central Battery Multiple Board was installed at the Lothian Exchange in 1946 to be operated in conjunction with the Automatic Exchange. A 200-line extension of the Auto Equipment was secured during the same year. In 1949-50, 300 lines of Auto Equipment were added, thereby raising its capacity to 2,600 lines (2,000 Auto plus 600 Manual). The replacement of the Lothian Exchange, which has been in service for over 27 years, by a 4,000 line Exchange, was completed during this year. The 2,000 line Exchange at the Secretariat was dismantled early in 1949 and all its connections were transferred to Connaught Place Exchange. The Manual Exchange at Avenue, opened in 1941-42, was meant primarily to cater to the requirements of the Defense Force. It had a capacity for 960 lines. The 300-line Relay Automatic Telephone Equipment installed at Cantonment in 1925 was replaced by a 200-line C B Board in 1936-37. This was again converted to Automatic in 1950-51.

The economic depression of 1931-32 affected the Madras Telephone System also considerably but after 1932 there was a trend toward expansion, slow but steady. The 1,500 lines of 1927 increased to 3,300 in 1943. With the change over to the Automatic System, a scheme of laying underground cable was put into motion. In 1941 the Government offered to purchase the Madras Telephone Company, but according to the terms of the license, they had to secure the consent of 75 per cent of the subscribers, which was not forthcoming. In 1944 a small satellite exchange of 100 lines was opened at St. Thomas Mount and 300 lines were added to the Mount Road Exchange. By 1947 the Mount Road Exchange was extended by 1,500 lines at a cost of Rs 478,000. By 1950-51 there were 2,456 miles of telephone lines and 35,349 miles of cables in the Madras Telephone District.

During the war years of 1940-46, vast expansion took place in the telephone system of India. To provide improved communication facilities to the administrative and fighting services, the Government of India constituted in 1942 the Telecommunication Development Board whose main function was to co-ordinate the requirements of different fighting services and of the Telegraph Department and to draw up schemes for the expansion of the telephone networks of the country. A scheme costing over Rs 16 Crores was drawn up and work was started almost immediately. These war years saw the installation of type T-43 Trunk Exchanges the design of which was in many ways completely different from the older type of Trunk Exchanges (T-32), in about 110 places. Defense Trunk Exchange of a similar design in about 76 stations and Combined Defense and Post and Telegraph Civil Trunk Exchanges were installed in 45 places (Shridharani, 1953).

The expansion continued at a vigorous speed and it was decided by the Department to convert the Calcutta System to automatic working; in 1945-46, the Telephone Manufacturers of India Ltd. (a British firm) was given a contract for the preparation of a master plan for the complete conversion of the present antiquated manual system by an automatic one. The plan was completed by 1945-46, and a new branch under an Engineer-in-Chief, Calcutta Automatisation, was opened, augmented with the services of some British Post Office engineers for detailed planning and supervision. A great calamity struck in 1948. Fire broke out in the Calcutta Exchange, the largest of the exchanges catering to nearly 20 percent of Calcutta's telephone users. From the embers of the burnt-out exchange, new plans rose like the proverbial phoenix. Schemes for the future envisaged 22 new exchanges, providing 56,000 subscribers' lines. The exchange formally came to be known as 'Central'. On May 30, 1953, they were renamed, economically, as '24' as it started with 24 subscribers in 1882.

The Carrier network expanded rapidly and by 31st March 1946 about 80 three-channel telephone systems were completed and work of installation on 14 was in progress. Voice Frequency Telegraph systems expanded to about 45. A 12-channel carrier system was installed between Calcutta and Patna to cope with the increasing demand of trunk traffic. The system was started on 16th June 1951. The installation to such systems between Calcutta-Delhi, Delhi-Amritsar, Bombay-Ahmedabad, and Bombay-Poona, where there has been always been heavy traffic congestion, were in the offing.

Table 2.3 Telephone System in the Early Years of Independent India

Year	Scheme	Initial Deposit by Subscriber	Duration of Telephone Connection in Years	Collection in Rs	Number of Applicants
1949	'OYT' Bombay, Calcutta	2500	20	30985500*	13310
	'OYT', Kanpur, Delhi, Madras, Ahmedabad	2000	20		

* "OYT": Own Your Telephone

** Rs 5 million of "OYT" earnings were expended for telephone expansion in 1950

The 'Own Your Telephone' Scheme was inaugurated in December 1949. The India public was clamoring for more telephones, but due to financial stringency the Department was unable to go ahead with its schemes. Communication Minister introduced a scheme the details of which can be seen in Table 2.3.

Two other schemes were inaugurated. One was 'Own Your Own Telephone Exchange' Scheme whereby any place, mohalla, or mandi, or a small town could have its exchange (50 lines) if at least 25 prospective subscribers were willing to pay Rs 2,000 each. The conditions attached to this scheme were the same as under 'Own Your Telephone' Scheme. The other one was the 'Telephone Loan Scheme' whereby bodies like Chamber of Commerce advanced a lump sum of at least Rs 50,000 to the Government for 20 years at 2¾ per cent, interest, the Department taking the responsibility of providing them with a small Telephone Exchange.

The infrastructure in the initial years just after independence can be seen in Table 2.4

Table 2.4 Telephone Lines and Exchanges (1950 and 1951)

Date	Departmental Telephone Exchange	Direct Lines	No of Extensions	Private Exchanges	No. of Telephones	Non-exchange Systems*	No. of Telephones
March 31, 1950	354	81593	14204	192	5211	1091	6267
March 31, 1950	540	102156	18902	117	2875	1122	8779

* Non-exchanges: These are telephone Connections without exchanges
Note: There were 33908 connections from 3033 private branch exchanges linked by junction lines.

There were 147 small licensed systems with 2699 telephones (P&T annual report 1949-50 page48) and in 1951, there were 167 small licensed systems with 2,748 telephones

In 1951, the total revenue due to telephone rentals, call fees, trunk call fees, and recovery from guarantors and royalties from Companies amounted to Rs 88,958,000. The total number of trunk calls was 7,135,434. The following table shows how poor our large cities are as compared to certain cities in other countries in terms of telephone connectivity.

Table 2.5 Telephone Densities of World Cities

City	Population in thousands	Number of Telephone on 31st March 1951	Telephones per 100 population
Bombay	3,700	44,550	1.2
Calcutta	5,700	33,829	0.5
New Delhi	1,194	11,844	1.0
Buenos Aires	4,955	502,251	10.1
Melbourne	1,328	284,801	18.7
Sydney	1,591	187,123	18.0
London	8,417	1,632,900	19.4
Paris	2,795	635,714	22.7
Honolulu	230	78,654	34.2
Stockholm	746	356,999	47.9
New York	7,927	3,137,405	39.6
Washington DC	805	487,472	60.6
Cape Town	530	60,068	11.3

Source: Shridharani K, Story of the Indian Telegraph: A Century of Progress, Post and Telegraph Department

The situation in the 1950s thus was bleak with respect to telecommunications even for the urban areas. The overall scenario too was far from satisfactory. In 1951, there were approximately 74.8 million telephones in the entire world. Out of these, India had only about 160,000. As India's population was about one-fifth of the population of the world in 1951, the number of telephones should proportionately have been about 15 million. Ten-countries viz., United States, United Kingdom, Canada, Germany, France, Japan, Sweden, USSR, Italy and Australia have more than one million telephones each and there are six countries, which have more than 15 telephones for every 100 of their populations.

With an objective to improve the abysmal level of telephone densities, the country embarked upon a massive investment programme in establishing telecommunication capabilities. The following table provides an overview of investment in the telecom sector.

Table 2.6 Investments Over Various Five Year Plans and Annuals Plans

Plan	Period	Total outlay (Rs Billion)	Telecom outlay value (Rs Billion)	Percent
First	1951-56	20	0.47	2.40
Second	1956-61	47	0.66	1.41
Third	1961-66	86	1.64	1.91
Annual	1966-69	66	1.59	2.40
Fourth	1969-74	158	4.15	2.63
Fifth	1974-78	287	7.81	2.73
Annual	1978-80	230	5.19	2.26
Sixth	1980-85	1097	27.22	2.47
Seventh	1985-90	2250	81.47	3.65
Annual	1990-92	823	61.0	7.40
Eighth	1992-97	3420	406.0	11.90
Ninth	1997-98	918.39	**124.34**	13.54
	1998-99	1051.87	**137.72**	13.09
	1999-2000	1035.21	**197.88**	19.11

Source: India Infrastructure Report, 2001

During the formative years of the Indian economy, unfortunately, telecommunications was not perceived as one of the key infrastructure for rapid economic development. The persistent low level of investment and low priority given to telecommunication adversely affected the sector in terms of quantity, quality and range of services provided. But over the years the plan outlay on telecom sector has increased indicating the importance of this sector. In absolute terms it has increased form Rs. 0.47 billion during First Five Year Plan to Rs. 460 billion during the first three years of Ninth Plan (Table 2.5). The corresponding increase in terms of percentage was from 2.4 to 19.1 in other words, before 1990s the investments made were meagre and only during the last decade the Government substantially increased the outlay for this sector. Thus after more than three decades of development the Indian telecom sector, was fully regulated, yet the services were of substandard levels, penetration abysmally low, backlogs were of a very high order and the system was incapable of being a driver of national economic growth. The following table explains the lopsided growth of the telecom sector till that time.

Table 2.7 Distribution of Telephones between Urban and Rural Areas-1984

	Population in Crores	Percentage of Population	No. of Telephones (in thousands)	Percentage of telephones	Telephones per 100 population
Urban					
4 Metro City Districts	3.20	4.36	895	33.95	2.80
5 Major City Districts	1.28	1.75	245	9.19	1.91
22 Minor City Districts	1.77	2.42	315	11.81	1.78
184 Other Cities	4.43	6.04	486	18.21	1.10
3029 Towns	7.23	9.87	448	16.80	0.62
Total Urban	17.91	24.44	2389	89.56	1.33
Rural					
Rural	55.39	75.56	278	10.44	0.05
All India	73.30	100.00	2667	100.00	0.264

Source: Ministry of Communications, DOT Release

In terms of quality, the telecom services are noisy and unreliable. And in the context of price it is stated that the prices charged for local, long distance and international communications are extremely high compared with world standards.

Table 2.8 Evolution of Indian Telecommunication Sector 1980s- Till Date

1984	Manufacturing of subscriber terminal equipment opened to private sector
1985	Telecom was constituted into a separate department with a separate board
1986	MTNL and VSNL created as corporations
1988	Government introduces in-dialing scheme, PABX services only within a building, or in adjoining building
1988	Telecom Commission formed
1991	Telecom equipment manufacturing opened to private sector. Major international players like Alcatel, AT&T, Ericsson, Fujitsu and Siemens entered equipment manufacturing market
1992	VAS sector opened for private competition
1992	Private networks allowed in industrial areas
1993	Licenses for radio paging (27 cities) issued

Cont...

May 1994	New Telecom Policy announced
September 1994	Broad guidelines for private operator entry into basic services announced
November 1994	Licenses for cellular mobiles for four metros issued
December 1994	Tenders floated for second operator in basis services on a circle basis
July 1995	Cellular tender bid opened
August 1995	Basic service tender bid opened; bids caused lot of controversy. A majority of bids were considered low
December 1995	LOIs issued to some operators for cellular mobile operations in circles
January 1996	Rebidding takes place for basic services in thirteen circles. Poor response the Telecom Regulatory Authority of India (TRAI) formed by ordnance
October 1996	The LOIs being issued for basic services
March 1997	The TRAI Act passed in parliament
June 1998	Several VASs available through private operators. The first private basis services becomes operational
March 1999	Announcement of the TRAI Act
January 2000	Amendment of the TRAI Act
August 2000	Announcement of Domestic Long Distance Competition Policy
October 2000	Planned Corporatization of DoT
2001	Formation of BSNL
2002	Disinvestments in VSNL start
2003	Proposed Unified Licenses

The Indian telecom sector was wholly under Government ownership until 1984, and was characterized by under investment, outdated equipment, and growth well below the potential of the market. By realizing the fact that a responsive, business-oriented, and technologically advanced telecom sector plays an important role in the growth of the economy, the process of introduction of new organizational forms and structures and appropriate policy mix was started from 1984 onwards (see Table 2.8). Past experience of reform across many countries suggests that the fundamental issue that must be addressed in telecom reform is effective separation of the basic functions of policy-making, operational management and regulation. The second level of consideration is access to capital and human resources. The third level of concern is the introduction of competition for efficiency (Rekha Jain, 2000).

Thus with the advent of privatization and after the formation of Telecom Regulatory Authority of India the telecom scenario has witnessed turbulent changes with new issues and problems. Instead of solving the issues, whenever they arose, they were complicated due to the wars between the Department of Telecommunications (DOT) and the Telecom Regulatory Authority of India (TRAI). The setting up of the TRAI may have been the result of increasing pressures from private operators and was perhaps not part of a well thought-out strategy of reform. (Mohanasundaram, 2002) The TRAI was certainly a positive step, but inadequate legislative reform in other areas of the telecom sector had made the TRAI's task harder. Despite concern from the industry and users at the outdated legislation governing the DOT, the Government had not responded and there had been no formal review of the various acts to determine whether they needed to be reviewed or implemented *de novo*. Meanwhile, several technological changes made it imperative that the government view IT, telecom and broadcasting legislation in a coherent and convergent manner. This led to the draft of the Information, Communications and Entertainment (ICE) Bill, which was recently discussed in Parliament (*The Hindu,* August 31, 2001).

2.4.2.2 Network Development

The number of telephone lines increased from 5 million in 1990-91 to 17.8 million by 1998. More than 80 per cent of the telephones were in urban areas serving nearly 26 per cent of the population. About 30 per cent of these were concentrated in the four metros of Calcutta, Chennai, Mumbai and New Delhi. The telephone network had been expanding at the rate of 22 percent, direct exchange lines (DELs) added since 1993-94 and accounted 178 lakhs lines at the end of 1997-98 which swelled to 213 lakh lines at the end of 1999.

2.4.2.3 Private Participation

In 1992, service provision was opened for the private sector. However, major changes took place after the announcement of the National Telecom Policy announced in May 1994. It boldly specified as its major objectives telephone on demand, achievement of Universal Sector Obligation (USO), assurance of world class service, so as to cover all 6,00,000 villages in the country and provide a PCO for every 500 persons in urban areas by the year 1997. This policy also, paved the way for private sector participation in telecom services.

Telecom services were categorized into domestic basic (which included basic telephony, telex and fax), domestic Value Added Services (VAS) which covered all other services such as paging, cellular and data services. New technologies, rapid growth, and world-wide trends ushering in competition exposed the limitations of NTP 94. In 1999, NTP 99 was announced to replace NTP 94. Since then, opening up National Long-Distance Services (NLDS) has been another landmark policy. Since 1994, private participation in basic, cellular and VAS has been to consider vehicle for rapid telecom development. The Rakesh Mohan Committee report hoped that the private sector would invest in telecom Rs. 425 billion and Rs. 581 billion between 1996 and 2001 and between 2002 and 2006 respectively.

Though private entry was facilitating, the poor design of auctions and the licensing conditions resulted in delays. Subsequent litigation further delayed services. Consequently, until 1997, provision of basic services by the private sector did not fructify. In effect there was little competition, due to the stipulated duopoly in both cellular and basic operations. The inter-circle STD services were to be the monopoly of DOT and the international services were to remain with Videsh Sanchar Nigam Limited (VSNL). While cellular services were a private duopoly, for basic services the DoT and an additional operator were licensed. NTP 99 provided guidelines for managing contentious issues such as license fee, interconnections, constraints on services provision (Provision of PCOs through cellular operations) and opening up of satellite services to foreign companies.

2.5 Conclusion

In this chapter we have attempted to provide an overview of the telecommunication industry both form the national and international perspective. As we have seen, the Indian telecommunication industry is at cross roads. On one hand with increased private sector participation the nature, form and content of the services have grown and diversified beyond recognition. On the other hand, the disparity between the rural and the urban, the rich and the poor customers is growing larger. The nascent Indian manufacturing capabilities are increasingly under strain, the growth of the industry still does not warrant domestic manufacturing capabilities in many segments of the industry

Chapter 3

Technology Transfer: Theories and Policies

A major factor which drives the economic strength, material well-being, military might and political standing of the developed countries is technology to be precise and narrow, or innovation system to be less specific and inclusive, or the capability to generate and apply knowledge to be more inclusive and generic. Understanding the role of technology in particular and innovation in general has been an abiding concern from the mid –20th century. Initiated by the work of Solow (1957) and Arrow (1962) in the neoclassical tradition, the idea was further refined by Nelson (various years), Pavit (various years) Dosi (various years), Romer (1986), and Lucas (1988), amongst others. Thus technology has assumed an important role in explaining economic growth and development by late 20th century.

But through out the later part of the 20th century especially from the post second world war era, conception of technology transfer assumed a larger interest. Ahmed & Wilkie (1979) conclude that the Marshall Plan, executed after the Second World War in aid of the war ravaged European countries, is the 'most massive technology transfer in history'. Interestingly, while rest of the trade in commodities, goods and services were termed in terms of imports, or aid or even assistance, it was only with respect to technology that the term transfer was used. As UNCTAD (1969) would argue, the term technology transfer communicated an element of altruism which meant that the developed countries which were the custodians of useful knowledge, gained the same due to historical, anthropological, sociological, economical and political factors, and hence were duty bound to help and assist the less privileged nations to develop themselves. But the political goals of the nation which provided such assistance did also play a major part in the transfer of such technology. (Galdi, 1988, Hogan, 1987).

Dominated by the Rostow's stages of growth theory, development in the 1950s was punctuated with the following premises. A) Development of the third world was synonymous with the creation of replicas, of the values, attitudes and institutions of the west. B) The existence of the first world, meant the availability of a host of technologies off the shelf, and last but not the least, C) the belief that S&T constituted some sort of an autonomous variable, which when the poor third world countries waved like a magic wand, transformed their feudal, tribal societies into first world countries in a generation (Parathasarthi, 1980). As an observer noted "Common to all Western explanations of different patterns of development was the assumption that modernization is essentially a European phenomenon and that the Asian development must be analyzed with reference to the European experience" (Baark, Elzinga & Bortgstrom,1980). This period saw the dominance of a technocratic development discourse, with its own set of powerful structures like IMF, World Bank, and to a lesser extent UNCTAD which were set up to promote it. Assumptions and images of modernity and progress are exported from the industrialized west, which have been uncritically accepted by the leaders of many recipient countries. The Keynesian assertion of the primacy of the state, led the development planners to conceptualize the State as the central character, and development as primarily nation specific, and this period also the saw the focus of self reliance, and consequently import substituting industrialization. Self reliance meant, the will at the national level, to build up capacity for autonomous decision-making and implementation, on all aspects of, the development process including science and technology. And it meant, 'walking on many legs', the rural and the urban, the small scale and the large scale, labour intensive and capital intensive, technically sophisticated and unsophisticated, in the Science and Technology realm (Parthasarathi, 1977).

But bounded as they were with the technocratic notion that development meant western model of development, most of the developing countries ended up following the heavy industry led development process and flow from both the sides of the ideological divide meant transfer of technology–hardware, industrial processes, knowledge and skills (Spencer, 1970, pp. xii- xiii). As Rosenberg (1970) commented, ".....During that era we exaggerated form the outset what could be accomplished by making western technologies available". But the Rostowian stages became recalcitrant, when applied to particular countries, and the social, cultural, and religious beliefs proved more recalcitrant than what the planners anticipated. The irony was summed up by Hirschman (1978) when he wrote "In that eminently exciting era, development economics did much better than the object of its study, the development of the poorer regions of the world".

By 1970s while on one hand, a set of nations especially in Africa and Asia, got disillusioned with the pace, direction and level of growth achieved by a heavy technology led developmental process, another set of nations, Korea, Brazil, India, and few others steadfastly embarked on the process of technology led development. As McIntyre and Papp (1986, p.13) comments "International technology transfer has emerged as a separate field of enquiry in the 1970s as a consequence of the accelerating awareness of economic interdependence of nations and of the central role of technology in international relations". This period was also marked by the heightened tensions arising out of the cold war, and while technology at one level kept flowing between nations holding allegiance to certain ideological premises, efforts were on also to prevent technology flows to countries which were not on the right side of the ideological spectrum (Seshagiri, 1975, Foote, 1982, Hayden, 1976, Gustafson, 1981 among others). This period also saw the emergence of the club of Rome, which questioned the unprecedented attempts to exploit resources and the warned of the limits to growth.

The next major school which emerged was the Dependency School and following Schumacher (1973) of the "Small is Beautiful" fame the phase moved towards appropriate technology. It was first born out of the Neoclassical discussion on the "choice of technique", where many economists criticized the developing countries for choosing "overly capital-intensive" technologies in their import substitution industrialization (ISI) strategy and called for them to choose more labour-intensive technologies. But both these schools argued that not only the technologies imported from the advanced countries were "inappropriate" for the factor endowments of the developing countries but also they were also "inappropriate" for meeting the "real" consumption needs of their population.[14] During this era, by conceptualizing technology as intermediate, these schools, attempted to reduce technology to a static non changing instrument of production.

[14] See Stweart, 1974, and Emmanuel, 1981, for critical assessments of this debate.

The 1980s and 1990s also the saw the arrival of conception of techno nationalism which was elucidated by Rosenberg and Nelson (1993), when they noted "There clearly is a new spirit of what might be called 'techno nationalism' in the air, combining a strong belief that the technological capabilities of firms in an economy forms a key source of their competitive prowess, with a belief that these capabilities are in a sense national, and can be built by national action". Such a phenomenon was accelerated by the tremendous success of Japan, and the newly industrialized countries like South Korea, Taiwan amongst others. The Japanese success in automobiles, electronic goods, semiconductors, consumer electronics, steel industry and certain process industries (Nelson, 1990; Kenny & Florida, 1993) led to a renewed vigour in achieving technological competencies by the west, especially by the United States. The controls established during the cold war times in terms of defence related technologies now extended even to commercial technologies, technology transfer as a conception was abandoned and the national technology competence building came into the fore (See, Dickson, 1984, Frye, 1985, Matkin, 1990, Enos and Park, 1988, Freeman, 1987, Johnson, 1992 amongst others).

The 1990s moved away from the passive[15] conception of technology transfer, to the active conception of technological innovation, which is much more inclusive in terms of learning, institution, government polices and state intervention. This led to a spate of studies on the conception of technological competence and technical change especially within the national boundaries (Lundvall, 1992, Nelson et al, 1993, Rosenberg, 1994, amongst others). On the other hand a growing band of literature which focuses on the technological change in the era of globalization argues that in an era of ever expanding degree of interaction between countries, and the continued rise of transnational corporations, national technology and thus national control on technological innovation has lost its meaning (Giddens 1991, Bartlett and Ghoshal, 1990, Dunning, 1992, Ohame, 1999) among others.

By early 1990s in the developing countries the development debate has been a little skewed towards market and subdued in its tone and tenor due to the twin processes of globalization

[15] By passive we mean a process where in no attempt at modification or improvement of the technology was made by the receipt country

and liberalization. The dominance of globalization, the balkanization of Soviet Union, and the general failure of the communist experience, and the relentless pursuit of globalization aided by the new technologies like Internet, led to a lull in the developmental debate, where market was considered the panacea to all developmental ills. Science and Technology in this era was still a powerful ally of development, but only to be deployed by the market. The later part of the decade, however, saw a renewed attempt at examining the ills of unbridled globalization thanks to the collapses of the East Asian bubble, the persistently widening gap between rich and poor; the role of the State again came under renewed focus and development debates got entrenched in terms of human development with its own indexes (HDI). Technology again took pride of place but now with the understanding that most of the benefits actually flow from and to the capitals of the world, to the wealthier enclaves, families, and that majority of the population was not part of the map of development (Hewitt, 2001). Increasingly nations are realizing the fact that, growth is one means of national development, and technology one, albeit a major means of achieving growth. (Solomon 1994).

3.1 Technology in India's Developmental Journey

Science and Technology has been one of the prime drivers identified by independent India in its quest for achieving economic, social and military growth. The Scientific Policy Resolution (SPR) (1958) clearly states that

> *"The key to national prosperity......lies in an effective combination of three factors, technology, raw materials and capital, of which the first is perhaps the most important since the creation of and adoption of new scientific techniques can , in fact make up for a deficiency in others......"*

But unfortunately the SPR then went on to state that technology can only grow out the study of science and its applications. This linear view of innovation, advocated primarily by Bush (1945) and others led to India focusing on building up of a science and technology infrastructure far removed from the needs of poor, technologically underdeveloped nation (Sharma,1992). Thus it was noted that while we achieved tremendous strides in science led industries like defence, space and atomic energy (Gopal raj, (various years), Meemmasi, (2000), Raja Menon (Various years), Chidambaram (1999), in the industrial sector, Indian performance was far from satisfactory. In the following sections we trace the evolution of Indian technology interventions in the industrial sector in three time periods.

3.1.1 The Phase of Attempted Self–Reliance: 1947- 1971

When India became independent the world was fresh from the ravages of the Second World War and most of the nations were busy in their own reconstruction barring US and the Soviet Union. While the farmer was unaffected by the war, later though was critically affected due to ideological compulsion needed to provide assistance to others along with its own development. As Shapiro (1990) contended that an export led growth was inconceivable for third world politicians who had witnessed the collapse of 1930s, and trade expansion looked bleak with most of Europe on a reconstruction spree, thus many countries shifted their attention to the domestic market.

Based on the above premises, reinforced by the strong nationalistic sentiments of the time, India too embarked upon a journey of development with technology as its able ally. The strong belief in the capability of Science and Technology to improve productivity substantially and provide employment in sufficiently large numbers so as to overcome the disadvantage of lack of ownership of means of production by majority of the population thus led to the industrial policy finally favouring a rapid heavy industry led industrialization strategy. The IPR (1948) thus explicitly states that, "meagre redistribution of existing wealth would make no difference, and a dynamic policy must therefore be directed to continuous increase in production". Thus rapid industrialization was ensconced in the policy, and since the Indian capitalist class, was primarily of trading vintage[16] the state assumed role of the prime mover of industrialization, with the IPR (1948) reserving major sectors of the industry exclusively for the state, and reserving the right "to intervene whenever the progress of the private sector is unsatisfactory". The import substitution industrialization strategy, which finally emerged, focused on building large industrial assets, and the strategists believed that, such a big push strategy would compress within a short period the kind of changes that had taken over two centuries to unfold in the developed world, and it was expected that it would

[16] Most of the Indian Industrial groups like Tatas, Birlas, and the Goenkas where traditionally traders who later moved on to become manufacturers. For a detailed discussion see (Desai (1992) "Then came the Marwadi".

bring in prosperity without violently affecting any of the existing power structures. (Swami, 1995).

The technological underpinning of an import substitution strategy (ISI) adopted by a technology starved third world country was two–pronged. While dependence on imported technology and capital was accepted, the policy made it clear that, ownership and control as a rule would lie in the Indian hands, there by effectively gaining control, on the technology and its dynamics Nehru (1949). By restricting the entry of foreign capital, the foreign players were forced to sell technology outright or enter into collaborative arrangement with Indian players, there by leading to diffusion of technology. The outcome of such a technology strategy could be examined at the large industrial or capital goods sector, dominated by the public sector and the batch processing industries sector. Based on the sectoral studies by Dhar (1984) on fertilizer, D'Mello (1985) on steel, Khanna (1994) on petrochemicals, Tyabji (2000) concludes that though the public sectors achieved a certain degree of innovational capacity, they are severely constrained by inconsistent degrees of State support and consequently subjected to political vagaries, while as Swamy (1995) would argue that though public sector achieved production capabilities comparable to the developed countries, they were dependent substantially on foreign technological assistance, a view partly shared by Mani (2003) with respect to telecom and Menon (1982) in case of the fertilizer industry.

In case of batch processing sector the phased manufacturing programme was the tool, which the State wielded to assimilate technology. The phased manufacturing programme was the key component of the ISI strategy, This as the name suggests was a programme, where in both the foreign firm, and the Indian collaborator, undertake to reduce the import content of products or systems progressively and over a period of time achieve a certain degree of indigenous manufacture. At the level of production capability, the programme was a success, and India, by mid 1960s achieved a level so as to manufacture a large range of industrial and consumer goods. But as Bagchi (1975) emphasized that the high cost of adaptations in the context of slow growing potential markets and the prevailing xenophobia among bureaucrats, politicians and scientists, inhibited innovations and local adaptation of imported technology. Such stagnation led to high production cost of goods, and in a dynamic market, these firms and their technologies would have been outpaced be new and nimble competitors with improved technologies, and consequently, new products. Using their clout, as Hazari (1967) and Dutt (1969) point out, the industrialists of the day obtained pre-emptive licenses to prevent entry of future competitors. Thus, while the licensing system restricted the private capital onerously in abstract, it was in practice, the linchpin of a profitable, anti-Schumpeterian bargain. With their hoarded licenses, the capitalist of the day, could rest assured that capacity restrictions would prevent Schumpeter's gale of creation destruction from threatening the lucrative rental heaven that the custodial state has bestowed upon them (Evans, 1992). While the Scientific policy resolution, dutifully acknowledges that' an early development of S&T in the country could greatly reduce the drain on capital during the early and critical stages of industrialization' by reducing the dependency of foreign capital" since no attempt is made in the industrial policy to incorporate achieving technological competence as a critical success factor, the import content of new investment continued to be more than 60 percent even during the 3rd plan period (Hazari, 1967) a point reinforced by (Nayar, 1983).

While the technology competence of the majority of Indian industry to use Tyabji's (2000) words, showed impressive post independence advances in sheer range of products indigenously produced, they have not been able to generate the same enthusiasm for innovation in design, manufacture, quality and reliability and cost reduction. In other world, they learned to industrialize but not to innovate. The failure of Indian technology policy and the dichotomy between Indian Science and Indian technology policy becomes distinct in this era. To achieve economic growth, nations need to invest in both science and technology. But the proportion of investment and the outcomes of such an investment are subject to debate. Parthasarathi (1966) opines that, as for as the technical component of economic progress is concerned, it is obliviously not the expenditure on science that is crucial, but rather, the input of know-how in terms of new and relevant technologies. He goes on to criticize the science focus of science and technology policy, and according to him, technological policies have to take into consideration, the balance between, high low and intermediate technology and arrive at an optimum ideal for a developing country like India.

The industrialization route which India under took with its heavy tilt towards heavy industries meant that there was substantial dependence on foreign technologies. This coupled with the absence of meaningful domestic R&D efforts led to a scenario where in substantial amount of technology was imported that too repetitively.

Table 3.1: Repetitive Collaboration of Products and Process

Frequency Range	No of Products and Process	No of Collaboration	% of Collaboration (2)	% of Collaboration (3)
1	2	3	4	5
2 to 5 times	285	802	77.6	50.7
6 to 10 times	60	431	16.5	27.2
11 to 15 times	14	185	3.9	11.7
16 and above	7	165	2.0	10.4
Total	363	1583	100	100

Source: A. Rahman S&T in India p-137

This failure on the part of the Indian industries in their capability to indigenize or even adopt foreign technologies led to a scenario, where in the state was forced to open up the domestic industries to varied degree of foreign controls at different points of time.

3.1.2 The era of unsure liberalization 1971- 1991

This era saw three major resolutions, the IPR (1970), IPR (1973) and the IPR (1978). The IPR (1970) was issued with an objective to give teeth to the socio-economic and technological advancement objectives enunciated in the earlier polices. But by 1973, with the excitement over restriction of concentration of wealth waning, and a looming recession in the economy, and the seemingly intractable economic mess, compounded by the Oil shock, the Government of India (GOI) made the first attempts at loosening of the resolve to be more firm on the industrial licensing regime. The Monopolistic and Restrictive Trade Practices (MRTP) Act was loosened; the IPR (1973) Government decisions were the first explicit attempt at inviting foreign participation. The statement invited foreign players to participate in industries, where production is predominantly for exports, an uncontrolled openness criticized by Subramanian (1978). Thus a formulation that technology improvement also requires a phased process, which Tyabji (1997) opines, was beyond the understanding of the State, and hence the Indian policy establishment doomed the Indian manufacturing sector willy-nilly to perpetual foreign dependence. This is a view advocated by Joseph (1997) while studying Indian electronics he opines that "in a perverse sense the Indian policy willy-nilly made the domestic firms in the private sector the trading agents of foreign firms". This was reflected in the three major phases of import liberalizations, which India undertook, 1975 to 79, 1980- 84, and 1885- 89, and the fourth and the final phase it entered into in 1991. As the state, was buffeted by political, economic and external crisis like oil shock on one hand, and political crisis's on the other hand culminating in emergency, the economic policy was subjected to violent mood swings from socialism to guarded capitalism to rural development within a span of one decade, and they definitely influenced technology indigenization too.

With the introduction of, the Industrial Policy Statement (IPS) 1980, which was the first Industrial policy statement which explicitly focused on Research and Development and transfer of technology domestically, and the Technology Policy Statement TPS (1983) whose highlight is that it for the first time focuses on the basics of acquisition of technologies, one would have expected the same policy to provide an analysis of the current status of technologies in the country, and a road map for developing domestic Research and

Development capabilities. BM (1987) after critically examining past performance of the Indian industrialization experience in terms of foreign capital and technology concluded, liberalization of economy and the strategy of import based industrialization would lead the industrial enterprise in the country, to function and develop as appendages to foreign suppliers of technology, a view echoed by Mohan (1989) when he states the promotion of modern technology has become a tool of neo-colonialism.

3.1.3 The era of liberalization, privatization and globalization (1991- to present)

In terms of conception of technology this era has been far reaching. The premise of this era was that the hope on self reliance in the past has resulted in foreign capital and multinationals passing India in favour of other countries and they have consequently grown and modernized themselves. Therefore to achieve growth India too needs to integrate itself with the world economy, while the stated objectives of foreign collaboration even with equity participation is the continuous improvement of technology, the policy lays down that foreign equity proposals need not be accompanied by foreign technology agreements (Pranjepae, 1991).

The concern for the dwindling technological competences, and the increasing isolation of research from reality led to the demand for reorienting Indian science establishment and its priorities. Arunachalam and Sunder (1996) in Economic Times made an impassioned plea for enlarging Indian, atomic energy departments brief to include all energy sources, de-bureaucratise Indian establishment, cease building new laboratories for the next ten year and rebuilt university research capabilities. Chandrasheker (1995) in a well researched article argues for comprehensively redrafting the Indian Science and Technology priorities a fact also reinforced by Parthasarathi (2001) Chidambaram (2000) Srinivasan (2000) amongst others. The IEEE Spectrum (1994) after paying obsience to India's world renowned commitment to use Science and Technology for overall development of its people and its technological superiority in strategic sectors castigates India for its poor performance in all development metrics. The article summarizes in short, over the last four decades, while most of East Asia was making great strides towards western standards and comforts, India was left far behind. With respect to manufacturing the article is scathing. Quoting a researcher of

TIFR the report says "Industry says the risk of investing in unproven, Indian developed technology is much greater than licensing existing technology-even if they are obsolete from the multinationals".

3.2 Conclusions

Thus India's technological journey is at cross roads. The nation has achieved tremendous strides in technological competence in certain sectors, and has been an abject failure in most other sectors. The question which is before the state is which direction it needs to intervene if the failures need to be corrected. To be successful State intervention has to be focused strategic, and well targeted and coordinated. Sometimes laws have to be changed, institutions have to be created, and bureaucratic involvement has to be modified. Some other time markets have to be promoted, restrictions on monopolistic and other practices to be applied, competition policies enacted and arbitration procedures set up. Interventions by their very nature have an impact. It could be positive or negative based on the intentions behind it Sengupta (1998).

In the next section using the case of telecommunication switching system industry we examine the technological journey which a State controlled industry has undertaken over a period of nearly five decades, four of which were when the industry was under total State control. Herein we attempt to trace the trajectory of the technological choices, the efficacy or other wise of the technology transfers undertaken, the attempts at adoption of the imported technologies to domestic conditions and an critical assessment of indigenous attempts at technology development.

Chapter 4
Technological Choices in Switching System

4.1 Introduction

The switching systems act as the backbone of the telecommunication system and hence independent India turned its attention towards the same at the earliest opportunity. The systems were initially imported since there was neither intellectual resources like engineering and technological skills nor the physical resources like manufacturing facilities, locally available. In order to manufacture and develop these devices domestically, Indian Telephone Industries Ltd. (ITI), the first public sector undertaking in India was established in 1948 in Bangalore. During the last five decades, ITI had manufactured three major types of switching systems namely, Strowger, Cross bar and Electronic switching systems (ESS). All three technologies have been manufactured with active foreign assistance. The indigenization efforts of ITI, moved from total import dependency in case of Strowger to fully indigenous development of digital electronic switching systems (ESS), with the help of TRC (Telecom Research Centre). The emergence of Centre for Development of Telematics (C-DOT) in 1984, further established the fact that India was capable of manufacturing indigenous switching systems especially making its mark in developing digital switching systems. This chapter is an attempt to examine the process of technological change in the switching system industry.

Following the introduction, the second section provides an overview of the technological dimensions of switching systems. The next three sections examine in detail the three major technologies indigenized by ITI, namely Strowger, Cross-bar, and ESS. In these three sections, with respect to each one of these technologies, we examine the details of the process of technology transfer, in terms of process of selection of technology, the salient features and shortcomings in the transfer agreement and their consequent impact, the attempts at domestic manufacturing, and the difficulties encountered in the process, and general overview of performance of all the technologies. The sixth section focuses on the evolution and developmental efforts of C-DOT in manufacturing the switching systems. The last section drawing upon the previous sections identifies the learning from each technology transfer individually, and draws implications and future directions for polices.

4.2 An Overview of Switching Systems

The primary function of a switching system is to establish an electrical path between a given inlet-outlet pair[17].The primary function of a switching system is to establish an electrical path between a given inlet-outlet pair. The hardware used for establishing such a connection is called the switching matrix or the switching network, which is one of the important components of switching system. If number of inlets and outlets are equal then such switching network is called symmetric network. All the switching systems are treated as common resource and the required resources are allocated to a conversation as long as it lasts. The quantum of common resources is determined based on the estimated busy hour traffic when the traffic exceeds the limit to which the switching system is designed, a subscriber experiences blocking. A good design generally ensures a low blocking probability. In the switching system while the switching network provides the switching paths, it is the control subsystem of the switching system that actually establishes the path. The switching network does not distinguish inlets/outlets that are connected to the subscribers, it is the job of the control subsystem to distinguish between these lines and interpret correctly the signalling information received on these lines. It senses the end of information transfer and releases connections. A connection is established based on the signalling information received on the inlet lines. The control subsystem sends out signalling information to the subscribers and other exchanges connected to the outgoing trunks. In addition, signalling is also involved between different subsystems within an exchange. The signalling formats and requirements for the subscriber the trunks and subsystems differ significantly.

A switching system is composed of elements that perform switching, control and signalling functions. Switching systems are used to interconnect any pair of subscribers in the Public Telephone system (Sinnema, 1982). The subscriber lines are terminated at the subscriber line interface circuits and trunks at the trunk interface circuits. There are some service lines

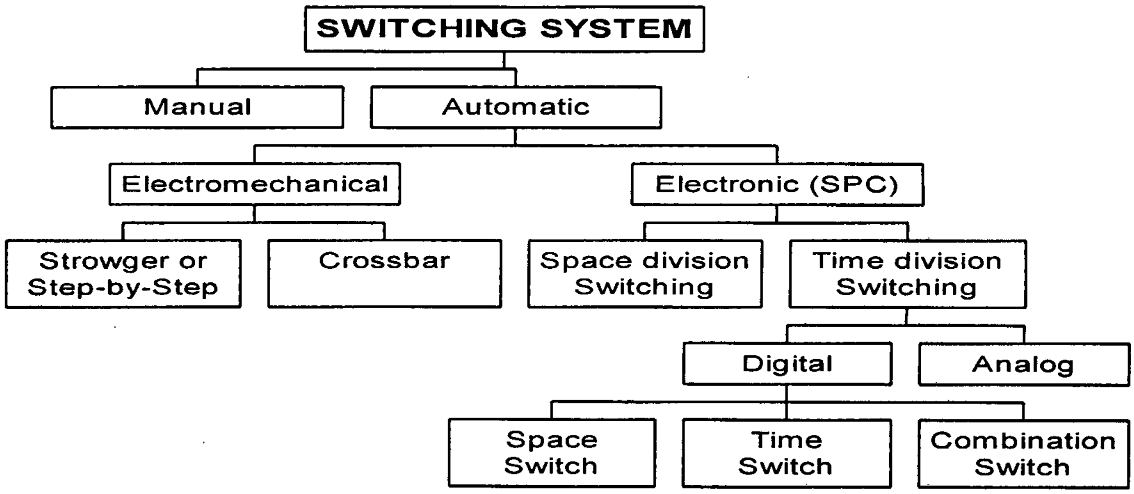
---

[17] Inlet → [Central Exchange] → Outlet

used for maintenance and testing purpose. Junction circuits imply a folded connection for the local subscribers and the service circuits. It is possible that some switching systems provide an internal mechanism for local connections without using the junction circuits. Line scanning units sense and obtain signalling information from the respective lines. Distributor units send out signalling information on the respective line. Operator console permits interaction with the switching system for maintenance and administrative purposes. In some switching system the control subsystem may be integral part of the switching network itself. Such systems are known as direct control switching systems. Those switching system in which the control subsystem is outside the switching network are known as common control switching system.

Switching system may be categorized as follows (figure 3.1)

Figure 4.1: Switching System Categorisation



4.2.1 Strowger Switching System

In the Strowger System there are two types of selector which form the building block for the Switching system:

- Uniselector
- Two motion selector

A uniselector is one which has a single rotatory switch while two motion selector has two rotatory switches. Two motion selector is capable of horizontal as well as vertical stepping movement. These rotatory-switches are very important in construction of selectors and are electromechanical in nature. Whenever the electromagnet is energised the armature is attracted to it and the pawl falls one position below the present tooth position. The ratchet wheel however, does not move and is held in position by detent[18]. When the electromagnet is de-energised the armature is released and returns to its rest position due to the restoring action of the spring. During this reverse motion of armature the pawl moves the ratchet wheel one position up where it is held in position by detent. The clearance between the armature and the electromagnet is such that during the forward movement of the armature the pawl slips over the ratchet exactly by one position. As the ratchet wheel rotates up by one position, the wiper moves across one contact position in the direction indicated. Thus if electromagnet is energised and de-energised five times by applying five pulses the wiper moves by the five contacts (Viswanathan, , 1992).

4.2.2 Step-by-Step or Strowger Switching

A step-by-step switching system may be constructed using uniselector, two motion selectors or a combination of both step-by-step switching systems that contains three major parts. The first part is line equipment part, which consists of selector hunter or line finders and other two parts consist of selector, one of which is group selector stage or switching network part and other is final selector or connector part, which connects to the called subscriber. The selectors hunters and line finders represent two fundamental ways in which a subscribers gains access to common switching resources. A selector hunter searches and seizes a selector from the switching matrix part, and there is one selector hunter for each subscriber. Usually 24-outlet uniselector are used as selector hunters. Line finder is associated with the first set of selectors in the switching matrix part and there is one line finder for each selector in the set. A line finder searches and finds the line of subscribers to be connected to the first selector associated with it. Line finders are built using uniselector or two motion selectors. The line equipment part is also known as preselector stage. The selector hunters and line finders are generically referred to as preselectors. In a selector hunter based approach, when a subscriber lifts the hand set, the interrupter mechanism in his selector hunter gets activated and the status of the first group selector, free or busy, is known by a signal in one of the bank contacts of the selector hunter If a free first selector is sensed, the interrupter is

[18] detent is an instrument used in strowger switching system

disabled and the first selector is marked 'busy'. Now, the first selector sends out a dial tone to the subscriber via the selector hunter which simply provides an electrical path. The first selector is now ready to receive the dialling pulses from the subscriber.

4.2.3 The Working of the System Based on the Strowger Technology

The Strowger exchange consists of a number of stages of two motion (usually vertical and rotatory) selectors, each of which has its own individual control equipment for taking the digits and selecting the path. Control of exchanges is decentralized among its numerous selectors. One switching stage is required for every digit. In a six-digit exchange there are five stages of selection, the last one taking two digits. For instance on dialling 385748, the first three digits will send out pulses that will step up to 8, and so on until at the fifth stage, after going up to four levels it will also select 8. Each of the ten levels (corresponding to the 10digits) will have 20 outlets, arranged in two rows of 10 each, one below the other, to be seized, if free. The selector will hunt for a free outlet by the time the next digit selected is intimated. Every subscriber will have access to limited numbers of selectors. In a 10000 line exchange, for example, about 1500 selectors might be provided, depending on traffic intensity. Each subscriber will have access to 24 motion selectors through uniselectors, which are individually provided to each and every subscriber.

4.2.4 Cross-bar Switching System

With the fast growth of telephone traffic, the limitations of the step by step system were increasingly felt. The direct control of exchange was exercised by the dial in the Strowger's system. The disadvantage of this system was its dependence on moving parts and contacts that are subject to wear and tear was the main reason to select an indirect way of control. One of the indirect systems was a penal system, which was the first attempt to remove direct control from the dial and place it in a separate mechanical unit. There was provision to register the digits dialled, which in turn converted them into suitable control pulses and set up a link. In crossbar switching system rectangular array of contacts are arranged in a rows and columns so that contacts are operated in any intersections. The next step was coupling of common control with crossbar switch in 1938 in Brooklyn New York. Another element in the common control system known as the marker was introduced. Together with the registers for registering the digits and translators for coding them, the marker came to perform the task of testing and selecting the path through switching network. Thus, the second generation of switching system was still electromechanical but used the experience of first generation equipment to develop common control devices. The relay played major role in telephone exchanges of electromechanical nature like the Strowger and the crossbar, where control is cone by contacts (relays) which are open or closed by electromagnets, physically moving them through a mechanical link. Relays are simply electromechanical devices used to open and close electric circuits. They change electric signals into mechanical action. A crossbar exchange is an all-relay exchange, since all connections are set up by the operation of relays.

4.2.5 Electronic Switching System:

Till 1950s the switching as well as the transmission system in long distance communications, were analog using FDM (Frequency division multiplex) links, and space - division switches like strowger and cross bar. Even during the early 50s, only analog time division switching was being experimented with. France and UK started developing digital switching system in 1960s and installed experimental systems from 1968-71. The Bell system USA developed a large switching system, called No.4 ESS and this became operative in 1976. Various other nations also then attempted to develop the electronic switching system.

4.2.6 Principles of digital switching system

A digital switching system uses speed signal in a digital form and switches the digital signal to the destination either by space division or time division switch. The different switching techniques used currently are time division switching, space division switching and multiplexing of both. Switching arrangements for the ESS was made up of sealed dry reed switches that are activated or de-activated by a 300 macro second pulse. The magnetic material within the reed relay is a ferrite. No power is consumed by the switch while it is its quiescent state of either opened or closed. The current pulse determines the remnant state of the switch. Two types of memories are used for ESS namely1) Twister memory and ferrite sheet memory. Twister memory is super permanent memory that stores the control program and any data that are not likely to change. Memory is thus read only memory (ROM) and therefore non -volatile. Power failures and reed errors cannot alter the clues for memory contents. Only an operator can change its contents by manually extracting the card and reprogramming its contents with a special device. The twister memory card is made of aluminium sheets. Each sheet contains rows of magnetic spots that are either magnetised or de-magnetised prior to installation. The magnetic state of each spot represents one bit of stored data. Each card stores 64 words that are 24 bits in length. The state of each bit is determined by sending a pulse down an interrogating loop of wire. Perm alloy magnetic tape is spirally wound around copper sensing wires placed over the magnetic spots. The interrogating loop intersects the magnetic spot and sensing wire at right angles. If the spot has not been magnetised the interrogating pulse will cause the perm alloy magnetic tape to become magnetised for the duration of the interrogating pulse. This result in a small current that is sensed by amplifiers, when the spot is already magnetised no current is produced.

Ferrite sheets are used for temporary storage of data (read-write memory) related to the processing and administration of a call. The ferrite sheets consists of 256 perforated holes on a 1 inch square board and ferrite material surrounds each hole. Three lines are threaded through each hole to allow reading and writing to each hole in a manner similar to core memory. Each hole acts as core and stores 1 bit of information. The ferrite sheets are stacked in a module and four modules make up a call store, each holding 196608 bits of read- write information. An office of about 10,000 lines generally requires two or more call stores while as a 65,000 line office with a high cutting rate may contain 40 call stores.

4.3 First Wave of Imports: The Strowger Switching System

India was one of the few third world countries, which understood the importance of developing a domestic manufacturing base. The IPR (1956) acknowledges the role of industrialization in economic development and the need for early and large scale development of a domestic industrial base. Thus, in telecommunication industry too which was totally reserved for the public sector, attempts at manufacturing telecommunication equipments domestically was made. In fact a decision to start a manufacturing unit for automatic telephone systems was taken in 1947 itself. For want of experience in this line as well as of the necessary patents and manufacturing rights the assistance of foreign firms of repute who were specialists in this line was sought.

4.3.1 Process of Selection of Technology

True to its nature of being an unsure and technologically dependent player in the high technology field, India initially attempted to look for corporations which would be ready to collaborate with the public sector arm ITI, in setting up a unit for domestic manufacture of telecommunication systems. And the initial short listing of firms was done by establishing direct contact with potential firms with no formal procedures like tendering was followed. It was explained later to the Estimates Committee that no global tenders were invited since there was no question of making purchases of any stores and equipment and the idea was to enter into an agreement for developing the manufacture of telephone equipment (Estimates Committee Report, 1957-58, p.2). The Post and Telegraph department, the operating department in charge of telecommunications sent their technical officers abroad to contact the leading manufacturers of telephone equipment between late 1947 and 1948. While, in hindsight it may look odd, to discover a country scouting for technology in such an unorganised manner, during the nascent period of late 1940s, the nation may not have had much of a choice in its selection modalities. Four offers were received including one from UK, which were communicated to Government of India on 25^{th} and 26^{th} of February 1948. Amongst them, only the offers from Automatic Telephone and electric Company Limited, Liverpool (ATE) of UK and a Swedish firm were considered, since the terms of other two offers were not considered favourable and also because they did not agree to supply the equipment immediately.

Among the two favourable respondents, the Swedish firm had demanded a payment of Rs. 23 lakhs as royalty as against Rs. 87 lakhs demanded by ATE - the British firm for a period of 15 years. This led to the initiation of negotiations with the Swiss firm. However, during the course of the negotiation the Swedish firm put up revised terms that involved a cash payment of Rs 146 lakhs for a period of 15 years. Since there was also an additional obligation to place orders for a specified quantity of equipment with the same firm, the negotiations with the British firm ATE began.

When the decision to finalise the collaboration with ATE was almost made another offer came from an American firm, International Standard Electric Corporation (ISEC). This offer consisted of a composite deal, wherein, in addition to telephone equipments and switching systems, ISEC's offer included some more equipment like radio and wireless systems for a payment of 133 lakhs. This offer was not even considered and as per the Estimates Committee (1957-58, p. 3), after a few years Bharat Electronics Limited (BEL) had entered into collaboration for the same products with another American firm (CFS). The Government of India's (GOI) inability to see, technology as a system, and absolute lack of clarity on the future needs of technology were visible even during the negotiation stage. The lack of enthusiasm shown towards ISEC's offer clearly shows the tunnel vision of the negotiators, who were just not able to unbundle a bundled offer. Government of India explained the selection of ATE for collaboration to the estimate committee as under: (Estimates Committee, 1957-58, p.3)

(i) The terms offered by ATE were more favourable than the other three offers.
(ii) Sterling expenditure was preferred to the expenditure in dollars.
(iii) Almost all the telephone equipment at that time in use in India was of British pattern.

While the agreement was signed between ATE, UK and ITI, India to collaboratively manufacture Strowger telephone exchanges within the country, no project report was part of the agreement which would have provided details of plan and targets for setting up the factory, cost, program of production and expansion and so on. While asking on the absence of such a benchmark document by the Estimates Committee, the GOI had no viable answer. In this regard the Estimates Committee felt that it would have been advantageous to get a project report from the ATE not merely to serve as a short term and long term plan of action but also as a means of watching and judging the progress made from time to time and that in its absence it was somewhat difficult to make a correct assessment of the actual progress (Estimates committee, 1957-58, p.10). Thus one could see, the absolutely haphazard manner in which the negotiations to acquire technology was performed by the officials of ITI. While some of the lacunas could be partially explained by the ignorance on the nitty-gritty of technologies, one observes a clear lack of conception of what entails the setting up of complex manufacturing set-up engaged in manufacturing products like telephone exchanges. The conception of a technology as a given, as an input to be borrowed if one does not possess it, seems to be the prevailing mood of the companies, and such a conception led to the subsequent difficulties in the indigenisation of the Strowger system.

4.3.2 Road Blocks in Technology Assimilation; Restrictive Contract Clauses

Contrary to the meaning of the term technology transfer, which implies literally transfer of technology, the advanced countries which generate technology are guided by the philosophy that invention is the property of the inventors who is entitled to guard it in order to recover the cost of research and development incurred by him and then, to enjoy the fruits of his labour by using the invention to his own advantage. Hence instead of transfer of technology, the multinational corporations transfer dependency on foreign technology by imposing restrictive conditions in the agreement and project their over monopoly right on the technology supplied by them. Such a phenomenon was fully visible in the case of the Strowger technology transfer agreement too (Hawthorne, 1970).

4.3.2.1 Cost of Technology

According to the clause 13 of agreement with ATE, the payments were to be made by ITI for various services and assistance rendered to it. The money paid by the government to ATE has been listed under the different heads. The direct economic cost under which this technology transfer took place is set out in Table 4.1.

Table 4.1: Price paid to M/s ATE for Strowger Technology

Particulars of Payments	Actual Payment effected (in lakhs of Pounds Sterling)
Payment for the patent rights and manufacturing data made available at the commencement of agreement (in cash and equity shares in equal proportion)	1.00
Payments for: a) Supply of manufacturing data and information throughout the life of the agreement (15 years) reckoned at 1.5 per cent of the invoiced output less the amount of equipment already invoiced and embodied in the said output.	2.62
b) Technical development and research at the rate the invoiced output referred to above.	0.50
Payment for the services of experts, technicians, tools designing and detailed layout of factory etc.,	0.40
Grand Total	4.02 (or equivalent to Rs. 53.78 lakhs)[19]

Source: Committee on Public Undertakings (COPU), ITI 34th Report, Fifth Lok Sabha, 1972-73, p4.

The fact that the experts from ATE, and their technicians were paid for their services, throughout collaboration period, and that during the entire period, payments were made for the supply of manufacturing data and information, it clearly shows that this technology was not fully absorbed by ITI and that ITI had to perpetually depend upon its partner. To use Tyabji's (2000) words "ITI while learned to make, never learned to make it better". But some others like Mani (1989) would even question that premise that ITI even learned to make, in the first place.

4.3.2.2 Restrictions Regarding Territories of Operation

Any firm which enters in to manufacturing as it matures would seek new markets, to grow, to achieve economies of scale, to gain learning curve economies (Hill, 2001) and for a variety of other reasons. Hence it is in the interest of the technology providing firm to restrict the market availability for the collaborating firm. Thus there were restrictions regarding the territories of operation and export of telecommunication equipment by ITI. According to the agreement with the ATE, ITI was not allowed to supply these goods to nearby markets like Pakistan, Burma and Ceylon. But it was allowed to find export markets

[19] This Payment is net of all Indian taxes paid by ITI on behalf of the collaborator, Gross of these taxes the total amount paid aggregated to Rs. 112.14 lakhs.

in Egypt and Afghanistan for a limited time. This shows that ITI was not free in extending its operations to other neighbouring countries where it could find a ready market.

4.3.2.3 Restriction Regarding Technical Know-how from Other Manufacturers

According to the clauses 4 and 5 of the agreement, the ATE undertook to grant ITI an exclusive royalty-free license under all patents owned by it or under which it was in a position to grant the license for manufacture and use of equipment. Also if ATE had got any technical know-how from any other party and was paying royalty or other consideration in connection with the use of such patents, calculated on a priority basis having regard to the extent of the use in items manufactured by ITI under this agreement. If ITI invented anything regarding telephone equipment; it had to grant ATE a non-exclusive royalty-free license to use such inventions outside the territory assigned to ITI. Not only this but in case of all other patents which become vested in or were acquired by the government, the ATE would be provided a non-exclusive license of the agreement on such terms and conditions as may be mutually agreed to. It not only effectively prevented ITI, from unbundling the technology package, but also made ITI, legally bound to feed into ATE's production system or any innovation it may care to achieve in the future. The estimates committee rightly showed cause for concern (Estimates Committee, 1957-58, p.5).

In the estimates committee's opinion these clauses prevented ITI from getting any technical know-how from any other manufacturers for the production of items which were either outside of the scope of agreement or which the ATE themselves were not in a position to manufacture efficiently. The reason being that while such manufacturer may be willing to pass technical know-how to ITI for adequate consideration they may not do so if the information is to be further passed on to ATE , who may be their competitor. Another point in favour of ATE was that if any information of developmental nature resulted from research or development work, carried out by any organisations in this country and made available to ITI, it would automatically go to ATE. It is interesting to note that ministry had no information available to show that how these clauses were included in the agreement (Estimates committee Report 1957-58, p.5).

4.3.2.4 Restriction on the Choice of Telecommunication Equipment

According to clause 9 of Agreement it was mentioned that import of telephone equipment would be affected exclusively from or through the ATE. In one of the clauses, it had been mentioned that government would obtain all its transmission equipment from the ATE and also when ATE manufactures any new item, Indian Government would subject them to a field trial of four months and if they were satisfactory, such equipment would be placed in the schedule of items that would normally be obtained from the ATE. In other words, the primary cause of rejection of the Swiss firm, in terms of tying up ITI to a single machinery supplier came true even with ATE.

This clause had placed a very severe restriction on the choice that could have been exercised in obtaining telecommunication equipment from manufacturers other than ATE especially those in which the ATE itself has not been fully established. In one of the purchases of switching telephone from General Electric Company there was a delay in the supply of equipment and price paid through ATE was much more than that of direct supply. This condition of purchase was raised with ATE and matter was taken up in 1954 but the company was not willing to accept the change (Estimates Committee Report 1957-58, p.6).

4.3.3The Indigenisation Process: Failures and mis-steps

ITI manufactured the Strowger switching systems, initially in the Bangalore plant, and later in the Rae Bareili plant in Uttar Pradesh. Though manufacturing began in early 50s, data on annual out put was available only from 1991. Tabulating the annual production data of both the plants Mani (1992) argued that there was much fluctuation in production pattern and the growth over this period had been about 3 percent per annum only. Though the capacity utilization had been over 100 per cent (with the exception of a few years) till 1983-84 it was mainly statistical in nature. This was because the installed capacity of the Rae Bareili plant was assessed only in 1984-85, but its actual production had been counted from1975-76 onwards (see Appendix 1). Another important point was that though the licensed capacity for both the plants had been 4 lakhs lines, the actual installed capacity was only about 2 lakhs lines or exactly one-half of the licensed Thus the establishment of the Rae Bareili plant had only led to the fragmentation of capacity and also prevented the company from enjoying economies of scale in operation. This was especially so when the total capital investments in this green field plant had been about Rs 18 crores, and consequent upon the government's policy to replace electromechanical switches with digital electronic ones it had decided to completely phase out the Strowger facility at the Rae Bareili plant and at the Bangalore in 1989-90 and 1990-91 respectively. There were evidences supporting the given statement, of ITI not performing on this account (Mani, 1995).

It is point to consider that the Rae Bareili plant which was set up in 1973 was completely built-up indigenously with no foreign assistance. The fact that ITI had been able to set up a second plant at Rae Bareili without foreign collaboration is sometimes held forth as an illustration of a successful absorption of the borrowed technology. Though ITI was able make Rae Bareili plant by its own effort, but on the contrary ITI had not been able to effect any improvements neither upon strowger switching system nor on the manufacturing process (Mani, 1992).

4.3.4 Defects in Strowger System

Even while manufacturing of the system was on, several defects were noted in the Strowger equipment, which was hampering its smooth operation in exchanges throughout the country. A 'Standing Committee for Improvement of Strowger System' was constituted by Post and Telegraph Department in October 1974 for effecting directive measures to obtain smooth operations. The main purpose of this committee was to finalize and recommend improvements in the older systems. An analysis of the recommendations made by this committee showed that not all of these were implemented. (See Table 4.2)

Table 4.2: Progress of Implementation of the Recommendations of Strowger-Improvement Committee

Nature and Number of recommendations by the standing committee (1)	Number of cases implemented by ITI (2)	Remarks (As of 1981-82) (3)
A Rationalisation and standardization of selector and relay sets.	Not available	Not available
B Wrapped connections	Not available	Not available
C Circuit Improvements	14	Two of the recommendations awaiting completion of field trial.
D Better maintenance/test facilities (Total eight recommendations)	5 One was finalised in April 1981.	Of the three pending one was finalised in April 1982.
E Improvements in parts, components and raw materials	6 To be implemented by 1983-84	The remaining two will be implemented by 1983-84
F Revised construction practice.	Partly implemented	

Source: COPU, ITI: R&D and New Projects, 39^{th} Report, 7^{th} Lok Sabha, p.8., 1981-82

The information in the table shows that even though a number of improvements were suggested, they did not indicate whether these recommendations helped in actually improving the performance of the Strowger System. In fact, the percentage of rejection of this equipment on inspection by the user, the Post and Telegraph showed an increase, though with fluctuations: it was 6.5, 28.7 and 11.5 per cent in 1979-80, 1980-81 and 1981-82 respectively. Exports, the crucial indicator for technological capability had been extremely low due to the fact that ITI was not able to indigenise the imported technology and the restrictive clauses used in the agreement with ATE, in the case of Strowger system: in all Rs. 42 lakhs worth of equipment had been exported since inception.

4.3.5 Policy Issues and Learning

Thus through the given facts and figures it is evident that foreign technology absorption although at a high cost of nearly Rs 1 crore had been extremely slow. Moreover the efforts for even effecting improvements upon it had been subdued. The Strowger case thus brings home the point that despite a foreign collaboration which was on for nearly 15 years (as against five years normally), the technology assimilation process was most unsatisfactory. Strowger equipment, though quite old, continues to be used even in advanced capitalist countries. A mere jump across the technology frontier without assimilating previously imported technologies was meaningless, which was done by importing another switching system called Crossbar switching system. (Mani, 1992).

Thus based on the above discussions one could conclude that, taking into consideration the many restrictions regarding export of equipment, technical know-how information, telephone equipment purchasing or importing, the government went in to agreement with ATE, even when there were choices for other collaborations. Not only was there the question of restrictions placed on the production of ITI, Mani (1995) opines that the government imported this telecom switching technology on a high price when this technology was in the downswing phase of its product cycle.

4.4 The Second Wave of Import: Crossbar Switching System

In the early 20th century the technology frontier in the switching equipment moved upwards to new automatic equipment called crossbars and the first patent was granted in 1915 to Western Electric, USA. This technology was readied for commercialization in 1940 by a Swedish firm Ericsson. Event though the technology was commercially available by 1940s itself, the reason for India's selection of Strowger switching system as late as 1949 was a matter of concern. The Gershenkronian (1962), the late comer advantages did not seem to apply to Indian telecommunication industry, where in the country was bent on going through the learning process from the beginning. The cross bar technology was imported in India by the 1960s (Viswanathan, 2001)

Even before ITI could absorb the Strowger technology for full scale of production, the growing need of the Post and Telegraph department for higher capacity switching systems led ITI to set up a technical committee in 1959, to select the system of equipment to be put into production for meeting the growing needs. This committee after studying different systems and different manufacturing countries, made a recommendation in favour of crossbar system. Tenders were invited in December 1962 for the supply of 48,000 lines local exchange[20] equipment and in March 1963 for the supply of 6500 Telephone Automatic Exchange (TAX) equipment[21]. The 1962 tender invitation also covered the terms of collaboration to set up a manufacturing unit for production of the crossbar type equipment in India and supply of know-how for the same. As early as 1962, the 'the conception of service over self-reliance' shows its presence, where in the tendering process was partly for supplies to meet the immediate needs and partly to enable domestic production in the medium term.

4.4.1 Process of Selection of Technology

In response to the tendering process, offers from five different firms were received. A technical committee appointed for the purpose, considered the lowest three offers from Nippon Electric Corporation, (NEC) Japan, LM Erickson (LME) Sweden and Bell Telephone Manufacturing (BTM) Company Belgium (a subsidiary of ITT, USA) in detail. Theses three companies had given their offers for supply as well as for manufacture. The quotation of the NEC was the lowest for the supply of local as well as for trunk exchanges[22]. One major consideration for evaluation of tenders was that the type of ready-made exchanges to be supplied against the bids and ones to be manufactured should be of same type. For final choice, therefore, the manufacturing proposals were given higher consideration. A negotiating committee was formed in July 1963 for negotiating with foreign collaborators for undertaking the manufacture of crossbar equipment in India. After detailed deliberations the committee rated LM Ericsson Sweden first, Bell Telephone Manufacturing Company (BTM) Belgium next and Nippon Electric Corporation (NEC) Japan the third. But the final decision was to enter into collaboration with BTM of Belgium.

[20] This is an exchange to which a given subscriber has a direct line. It is sometimes called local central office.

[21] Equipments used to make exchanges which connects long distance lines of one such exchange to another exchange

[22] It is an exchange in a telephone area, which is, connected by trunk or long distance lines, to other trunk exchanges and to subscribers through local exchanges.

According to negotiating committee BTM was selected even though the offer from NEC was the most advantageous and its offer for the setting up of factory and supply of equipment was much cheaper than BTM by as much as Rs 18 lakhs. The selection of BTM was explained to the Estimates Committee on the grounds that BTM in conjunction with ITT (their principals) had vast experience in the manufacture of varied types of switching systems and had set up production units in different countries while NEC's experience was limited to Japan. BTM as part of ITT group had experience of compelled sequence type and their offer had been for this type of equipment while NEC had not yet developed such systems. Moreover the process of manufacturing of BTM crossbar equipment was simpler than that of NEC according to the ITI. The BTM and ITT had substantial experience in interlocking of crossbar equipment with different types of automatic exchanges in different countries including the Strowger which was present in India at that time, while NEC's experience was limited largely to interlocking with switching equipment in use in Japan (Estimates Committee Report, 1972-73, p.).

Thus a recommendation was made in favour of BTM Belgium for the supply of Penta Conta type Cross Bar system of equipment and its manufacture in Bangalore. After government's approval, the first order for the import of crossbar telephone exchanges was placed to BTM, Belgium on 21st May 1964 at a total cost of Rs 2.55 crores. Later supplies were to be manufactured in ITI Bangalore (Estimate committee, 1972-73)

4.4.2 The Technology Transfer Agreements: Lessons Not Learned

Even after the pitfalls encountered in the Strowger switching system contract with ATE, UK due to vague contractual terms, ITI repeated the mistakes in the next contract with BTM too. ITI entered into two separate agreements in May 1964, one with International standard Electric Corporation (ISEC) the parent company of BTM regarding investments, loans and issue of patent licenses and the other with BTM relating to the supply of know-how, machinery, tools, components and technical personnel. Such an agreement process watered down the whole issue of accountability, since in large technological systems like Switching systems, these two areas were interconnected and ideally one composite agreement with BTM alone would have had better impact for project management.

4.4.2.1 Agreement with ISEC

ISEC made an investment of US$ 12,50,000 (Rs. 59,52,400) in accordance with the terms of the agreement in the equity shares of ITI out of which $ 500,000 were given for technical know-how and $750,000 were given in cash. In addition, a loan of $10, 00,000 was also advanced for financing the purchase of machinery and equipment. Thus the agreement with ISEC provided the much needed foreign exchange for the immediate purchase of equipment, and know-how. Interestingly such product linked loans and assistances have always ended up costing the recipient in the long run since it ties up funding to a large set of restrictions. Such a predicament visited ITI too as we would see in later stages of the project implementation.

Royalty was payable at the rate of one per cent of the gross ex-factory selling price, excluding sales taxes and all local taxes of all contract equipment manufactured in India and sold by the Company. The total amount of royalty was not to exceed the US$ 100,000 in any year. The royalty was to be paid from 31st August 1966 to 21st May 1971 and within three months of the close of the financial year (Clause 11 & 12 of Part II) of agreement with ISEC (see Table 4.3). As per clause 11, the company was required to furnish to ISEC within the three months of close of financial year, a statement certified by an Independent Chartered Accountant settling forth such gross sales less applicable deduction during the year.

Table 4.3: Royalty Paid Till 1971

Year	Rs. in Lakhs
1966-67	0.52 Gross
1967-68	3.61 "
1968-69	2.47 "
1969-70	3.17 "
1970-71	3.36 Subject to audit certification*
From 1-4-71 to 20-5-71	0.39 "

Notes: The amount in 1970-71 and 1971-72 was not paid by 1971-72

ii) Agreement with BTM

According to the agreement, BTM had to provide advice concerning the manufacture, use and maintenance of the Penta conta type crossbar telephone switching system and equipment and the installation, maintenance and operation of the required factory equipment (Clause 3). The main points of agreement were:

- To make available the necessary engineers and technicians for installation and maintenance and operation of the required factory equipment [Clause 4 (c)].
- To train in their factories the personnel of ITI with living expenses of such personnel for up to 33 man-months to be borne by BTM [Clause 4(d)]; and
- To supply machines, tools and equipment and other items required for the setting up of the factory and production of equipment up to 167,000 lines of Jorbagh type [Clause 5]

Table 4.4: Money Paid By ITI to BTM

a)	Supply of special machines, tools and other equipments and Equipment Clause [6A(I)] Supply of standard machines, and tools (under deferred payment arrangements Clause[6A(ii)]	BF 190602502 BF 34114000 Total BF[23]: 224716500
b)	Personnel Charges Clause[6A(iii)] and Clause[6B(ii)]	BF 6855800
c)	Credit Insurance Expenses paid by BTM but not exceeding 0.5% of the total amounts covered Clause[6A(iv)] and Clause[6B(iv)]	BF 17682003
d)	Living Expenses and Travelling in India of BTM Engineers Clause[6A(iv)] and Clause[6B(iii)]	BF 519840

BF: Belgium Franc

Source: (COPU 72-73 pages 16)

The actual amount of BF 224716500 given in the table was to be paid in accordance with the escalation formula of the agreement. This amount was payable as

a) 5% within 30 days of the signing of the agreement

b) 10% of the invoice value of each shipment against shipping documents and

c) The balance in ten equal annual instalments commencing from the 36th month from the date of signing of the agreement. In order to cover freight marine insurance and escalation charges a supplementary agreement for BF 44.95 millions was entered into

[23] BF: Belgium Frank

government with BTM in October 1967 in consequence of which the total Belgium credit amounted to BF 269.67 million (COPU, 72-73)

4.4.2.2 Territories of Operation

Learning from the earlier contract with ATE, ITI negotiated a license for the manufacture and sale of contract equipment (Pentaconta Crossbar Telephone Switching System and equipment) for a period of seven years including an exclusive license to export and sell contract equipment for that duration to Afghanistan, Burma, Cambodia, Ceylon, Indonesia, (limited to Sumatra, Java & Bali) Laos and Nepal and non-exclusive license to export during the life time of patents, contract equipment manufactured to any country in the world except certain specified countries where Penta conta crossbar switching equipment was being manufactured or assembled by ISEC or BTM as on the date of agreement (Clause 4, 5 and 7 of Part II) (COPU, 1972-73).

4.4.3 The Domestic Manufacturing Process: Failures and Mis-Steps

The agreement with BTM envisaged the setting up of a plant capable of manufacturing 100,000 lines of Jorbagh basis of contract equipment in a single shift working excluding the other equipment, which were to be purchased or manufactured by the company. It was expected to achieve the full production capacity in a total period of 36 months (i.e. July 1967) divided into six months periods commencing from 1st August 1964. (COPU 1972-73)

In order to start the training of the operating personnel and the programmed output of 5000 lines of local exchanges in period 1 (Feb 1965 to July 1965), the collaborators had to supply the necessary equipment as semi-equipment assemblies, but these supplies were given only by July 1967. As a result the training schedule for period 1 could not be adhered to as the collaborators attributed the delay in the supply of these equipment to the late finalisation (March 1965) of the exchanges by the Post and Telegraph to the extent of nearly 8 months. Similarly for the manufacture of 15,000 lines during period 2 (August 1965 to January 1966) and 22,000 lines during period 3 (February 1966 to July 1966) BTM had to supply sub-assemblies and piece parts to give training in the assembly and testing of the equipment.

Table 4.5: Schedule of Ordering and Delivery of Machinery

Sl. No	Particulars of machines	Date by which required by factory	Date of ordering	Date of Receipt
1	Automatic Plating plant	January 1965	Feb 1965	July 1966
2	Power Shear	January 1965	Dec 1964/Mar 1965	June 1966
3	Vicker's Press Brake	January 1965	Nov 1964	Sep 1966
4	200 Ton Press	July 1965	Dec 1964	Dec 1965

Source: (COPU 72-73 page. 47)

From the above table one could observe a consistent pattern of delay on order placement and delivery with respect to all the required machinery. Besides these delays, even when supplies came from BTM they were neither regular nor balanced in respect of both the periods and were received in batches spread over from September 1965 to July 1967 thus affecting the training and production programme of ITI. Yet another factor for concern was that even with respect to the machines or equipment required for production and to be sourced from sources other than BTM, there were delays noticed on the part of the ITI.

4.4.3.1 The Delays in the Production Schedule

As per the Report of Committee on Public Undertaking, 1981-82, the local manufacture of piece parts was to begin from period 2 (August 1965 to January 1968) so that complete local manufacture of all piece parts for the crossbar equipment was completed during period 5 (February 1967 to July 1967). But the local manufacture of piece parts was however taken up only from May 1966 and the manufacture of all the piece parts was established from May 1967. Manufacture of special relays was not taken up during the programmed period 5 (February 1967 to July 1967).

The delay in the production target and performance was due to different reasons according to management and the following reasons attributed the shortfall in programmed production in (June 1968).

a) Phase 1 covering periods 1 to 3 (Feb 1965 to Jul 1966) consisting of training in assembly adjustment and testing of local exchange equipment;

i) delay in finalisation of facility schedule/specification for the 1st 5000 lines by the Post and Telegraph

ii) delay in receipt of engineering manufacturing and testing know-how

iii) delay in supply in semi-equipped assemblies and piece parts by BTM

iv) delay in the supply of test equipment by three periods

v) delay in ordering and receipt of machine and

vi) delay in erection of imported machines which were damaged in transit

b) Phase 2 covering period 4 and 5 (August 1966 to July 1967) consisting of local manufacture of some piece parts required for cross bar equipment in addition to assembly, adjustment and testing of local exchange equipment.

i) the backing of nearly 18 months in assembly programme in Phase 1; and

ii) delay in supplies of sub assemblies and piece parts by the collaborators

c) Phase 3 covering period 6 (August 1967 to January 1968) consisting of complete local manufacture of all piece parts of the crossbar exchange equipment.

i) Vital deficiencies in machine capacity in respect of certain components; and

ii) Non availability of sufficient tools in many cases affecting continuity of production of piece parts.

At the time of signing the agreement, BTM made available the categories of special machinc, tools and test equipment. But according to the ITI management, the list did not contain many items and there were changes in actual specification of equipment required by the Post and Telegraph in variation of the Jorbagh pattern. Additional facilities were asked for to be provided such as called number identification, subscriber to subscriber dialling, single and multi link operator dialling and inter working equipment. When this problem was pointed out to BTM, a supplementary catalogue (2361 items) was received by the company in December 1966 listing out the various items together with prices of items ordered out by the company till then. Even the original and supplementary catalogues together were not found exhaustive. Consequently the items till the date remained uncovered, pricing details were obtained by the company as and when the requirement for such items came up. Most of these quotations were received during the period May-August 1968.

From the above sequence of events one could clearly conclude that both at the level of technological understanding and at the level of project management, the cross bar project did not learn any lessons from the previous project. The lack of understanding of the diverse and complex needs in terms of machineries and technological processes required in the manufacture of the Cross–bar system led to the complete and total dependence on the foreign collaborator. Since, there was no performance clauses in the agreement *inter-alia* BTM was not liable for any loss of production or profit of trade. This coupled with callous treatment of the project schedule led to a scenario wherein, although the agreement was reached in early 1964, complete equipment required for manufacture of the switching systems had not been ordered until 1968. It was seen that there was delay on provision of various products and engineering know-how and company was not in the position to show the actual dates of receipt of production and engineering information vis-à-vis the scheduled dates.

When Committee on Public Undertakings (1972-73) drew the attention of management regarding the delays in various equipment and technical know-how the ITI management stated in written reply: "It is true that the finalisation of facility schedule or specifications of the exchanges by Post and Telegraph took some time and consequently there was delay in finalisation of the specification etc by BTM. There was no provision in the collaboration agreement for delayed supply of specification, know-how." When Committee on public undertakings asked Ministry of Communications on delay in receipt of know-how, the Secretary of Ministry of Communication replied - ".... I don't think there was any serious delay in receiving this know-how for the major part of the equipment particularly for the large exchanges. In case of small exchanges the know-how came very late but that really did not affect our production" (COPU, 1981-82). From the above statement it was clear that the there was a totally callous attitude towards indigenous manufacturing in the part of the GOI where in even cumulative delays to the tune of over two years in contract with a validity of five years were not a matter of concern.

4.4.4 Performance of Domestic Manufacturing of Cross Bar Type Switching Systems:

Even when ITI finally managed to begin production of the Cross bar exchanges by 1968-69 the actual production was far from the targeted production levels. The following table provides details of targeted and actual production.

Table 4.6: Production of Cross-Bar Switching System (1968-69 to 1971-72)

SNo	Year	Programmed Production	Actual Production
1	1968-69	70000 lines Jorbagh Pattern	35,000 lines
2	1969-70	80000 lines Jorbagh Pattern	52,500 lines
3	1970-71	100000 lines of Jorbagh Pattern	Approx. 60000 lines of Jorbagh pattern (overall)
4	1971-72	100000 lines of Jorbagh Pattern	Approx. 80,000 lines of Jorbagh pattern

Source: COPU, 1972-73

When the committee asked for the reason behind the low production of ITI Bangalore unit, as it produced only 60% of the target fixed for the manufacture of equipment during the year 1970-71, the chairman and managing director of the company stated that the capacity when assessed in terms of lines was likely to give misleading picture, since ITI was still assembling exchanges, in a tailor made manner, and was yet to graduate to assembly line manufacture of exchanges, partly due to absence of a balanced assembly line and partly due to lack of skilled manpower. In this regard Chairman, ITI explained that shortage of these machineries came to be known at the time of installation and running, when the rate of production did not come exactly with the quantum production specified in the project report. In 1968-69 a team was sent by the collaborator which found that there was some calculation error and the number of machines specified would be inadequate to meet the required quantum of production. There was a gap of almost two years between the first and second supplies of machines and earlier machines were running at very low capacity and their optimum production could not be known. According to the management of the ITI the BTM was responsible for the delays in receipt of know-how supply of equipment and parts, tendering advice regarding erection of imported machine supply of sub-assemblies and piece parts and the backlog of nearly 16 months in assembly programme in Phase 4.[24] (COPU, 1972-73).

According to management due to initial deferred credit being insufficient to cover the value of the total supplies supplementary credits had to be obtained after observance of necessary formalities. BTM did not dispatch the supplies as originally visualised due to the time taken

[24] Feb1965 to Jul 1966.

for the establishment of supplementary credits. There was one more lacuna with respect to the agreement, since there was no provision for taking action on delayed supplies of specific know-how or other supplies or for claiming damages from BTM. Thus to summarize the reasons for the shortfall in production, they would be primarily lack of commitment on the part of the foreign collaborator and lack of clarity on part of the corporation. Yet another factor which played a major role in acting as a road block for indigenisation is the changes in the needs of the user department, namely Post and Telegraph department mid-way though the collaboration.

4.4.4.1 Change in Demand Pattern of the User Department

The entire costing, scheduling and the manufacturing plant's capacity utilization, production schedule and requirements of components etc. were incorporated in the agreement on the basis of the projected need for Jorbagh type exchanges. But the entire project got materially altered once the Post and Telegraph department demanded a different pattern of exchanges in variance of the Jorbagh type. In this connection the Ministry stated in June 1970 - "...it may be mentioned that when the agreement was signed the government had before them the Jorbagh exchange pattern as a standard. The actual orders would however be different as each exchange is of different capacity depending on its size and traffic handled. It is not possible to lay down any fixed parameters for computing the performance". Thus the pattern of orders given by the Post and Telegraph were entirely different from the Jorbagh pattern, which was agreed upon with BTM and therefore required much more production and scheduling efforts. According to management 50% additional effort was called for the types of exchanges ordered by Post and Telegraph as compared with the Jorbagh pattern (Committee on Public Undertakings, 1972-73).

Yet another matter of concern was under Clause 4(a) of agreement with BTM, the company had undertaken responsibility subject to certain conditions for ensuring that the machinery, tools and equipment installed in the factory were such as to be capable of producing the quantities of contract equipment specified in the schedule of manufacture. In accordance with the schedule, full production capacity of 100,000 lines of Pentaconta equipment was to be attained by the end of period July 1967. In view of the collaboration agreement expiring in May 1971, the investigation revealed that there was still shortfall of machinery and there was shortage of 21 machines in all, which were in 13 groups. After reporting to BTM in August 1970, another agreement with BTM was negotiated that BTM would supply the equipment in order to bring the rated capacity to 100,000 lines. Machinery was expected to be received by the first quarter of 1972-73, but due to shortage of the machine capacity, the build in capacity of the machinery for the year 1972-73 was 65,000 lines (COPU, 72-73, p.39)

Thus if one considers the total cost of the technology imports including the estimates of the total payments made to ITT, BTM works out to be approximately Rs 36 crores (exclusive of the interest payments on loan from the collaborator). In addition, one also needs to take into consideration indirect costs associated with. a) The possible overpricing of capital goods and b) the possible exports lost due to restriction placed on ITI. One also needs to take into consideration the costs associated with, irregular, delayed and non-balanced supply of machinery and drawings (Alam, 1981). Admittedly the cost of this technology purchase had been high and this was made worse by the defects in the design (Mani, 1989).

4.4.5 Defects in Crossbar Switching System

As given in the Estimate Committee Report, 1972-73 and COPU 1981-82, according to Post & Telegraph department, defects were found in Crossbar equipment and there were defects regarding:

- Corrosion
- Inadequate contact protection
- Component failures
- Instability of mechanical adjustments
- Circuit deficiencies
- Highs call failure rate and delays in service due to selective congestion and fault and
- Inadequate traffic measuring arrangements for analyzing abnormal situation.

During evidence, the Committee invited the attention of the Chairman of ITI to the statement of the Minister of Communications that there were defects in the Cross-Bar equipment and enquired as to what the defect were. The Chairman of the ITI stated that there were three main defects in the crossbar equipment. He stated that "In India, the calling pattern of our subscribers is probably the highest in the world. It is not only the total time we speak, but also the number of calls, which a subscriber initiates in the busy hours that it gives the equipment the worst possible beating... Crossbar is very sophisticated equipment. When you dial a six-digit number, each digit gets stored in a register. This register is the Common Equipment. We are going in for a tremendous amount of sophistication and development in communication for which this equipment is essential. In this common equipment, what happened was that, due to the tremendous load this equipment had to work so much that the contacts burnt off and once it is burnt off one cannot proceed further. They also found that there are certain defects in respect of what is called the Spark Quench, which prevents contact burning. The BTM had used them in their equipment and they had given them no problem before. Another defect noticed was that on certain parts there was certain corrosion. Due to the tropical climate of India, its heat and humidity, it started corroding certain parts, which was not experienced in other countries. The third problem was that of certain circuit defects and certain changes had to be brought about."

4.4.5.1 Call Handling Capacity of Cross Bar System:

There was one major point associated with the Penta Conta design that it was developed against the exclusive call-pattern characteristics of developed world. Since the density of telephones in all these countries was quite high, the number of calls per telephone was quite low. The density of telephone in India was 0.4 in 1976 on the other hand density in other developing countries like Brazil and Mexico was 5.31 and 4.72 in 1976. And it was only a small fraction as compared to the developed countries like Sweden (63), Belgium (31), USA (50), UK (38) and Japan (39). The low density of telephone in India meant that each available telephone was used more frequently. In order to understand how this low-density high usage per phone had a deleterious effect on the load carrying capacity of the Penta Conta crossbar equipment and in order to understand the call pattern of India and the Penta Conta design sustainability, the telephone exchanges were classified in three categories according to the traffic pattern,

a) Exchanges in provincial towns and in residential areas of multi-exchange network which had an average busy hour call attempt (BHCA) of 4 to 6 subscriber[25].

b) Exchange in semi-commercial areas in multi-exchange system with an average BHCA of 7 to 70 per subscriber and

c) Exchange in commercial areas in multi-exchange networks, which had an average BHCA of 11 to 14 per subscriber.

The average BHCA per subscriber in Japan, Europe and the US carried from 3 to 5 calls per subscriber, which was more or less the same order as in (a) but much of the telephone exchanges fell into either category (b) or (c). (Mani, 1989)

In case of Penta Conta crossbar system, once the number of calls carried by this system exceeded the design limit (i.e., specified call carrying capacity of each equipment), the efficiency rate started falling to what was called saturation point beyond which there would have been a drastic reduction in the number of calls carried. If there was any congestion in any part of the telephone network, if any piece of equipment suffered temporary breakdown due to overloading, the repeated call attempt by subscriber increased the number of calls which exchange had to handle[26]. The Penta Conta design, 'line marker' which handled call of 1000 subscriber had a design limit of 6000 calls of BHCA of 6 calls per subscriber (Mani, 1989).

The committee further enquired as to why the technicians did not point out the defects before ordering for the design and accepting the same. The secretary of the ministry stated in reply that even if technicians had gone into the case in greater detail, they would not have been able to find out this technical defect unless that equipment actually worked under these traffic conditions (COPU, 1972-73). The statement made by Secretary Shows that the choice of technology was not seriously examined. It also shows that the technical committee also

---

[25] BHCA indicates the throughput of the switching system and as such it is one of the most important technological parameter for measuring the capacity of telephone exchange

[26] Since there were many defects in Cross-bar system regarding the technology imported from BTM, when the committee asked whether ministry had fixed any responsibility on anybody for selecting this technology on which several crores of rupees were spent, the secretary communication stated: "Everybody took part in the decision. The fixation of responsibility is done when a particular person takes a decision. Here everybody was involved in decision making process. It was a decision of Government as a whole" (COPU, 1981-82).

known as the Telephone switching system committee, which studied different systems and different manufacturing units, was either not able to understand the BTM system completely or their study regarding the technical know-how, was inappropriate.

4.4.6 Indigenisation: The Initial Attempts

The indigenisation efforts required the rectification of deficiencies in the Cross-Bar system that was being used in order to further develop them domestically. In order to rectify the deficiencies, a task force was formed in October 1971 to improve the design and requirement of the Cross-Bar system according to Indian condition. When the committee asked for the recommendations made by the Task Force, ITI summarized the main recommendations of task force:

1. **Corrosion:** increasing the thickness of plated parts and lacquering of components used in the non-magnetic items, increasing the drying time of plated parts rigid process and quality control.
2. **Contact failure:** provision of adequate spark quenching relay contacts to be loaded only up to rated capacity by suitable circuit redesign, adopting principle of dry switching, increasing the contact dome size, use of plug in type arrangement for relays frequently used.
3. **Loss of mechanical adjustment:** addition of holding spring at the bottom spring pile of relays, bricking of core at both ends use of high tensile screws, structured manufacturing tolerance use of ball bearing for horizontal bars etc.
4. **Component failure:** use of materialized polyester capacities, use of carbon resistors in place of film resistors, pot cores in place of torroidal cores etc.
5. **Circuit deficiencies:** introduction of positive battery metering improvements in MFC signalling introduction of more rigid components and raw material better quality control etc.
6. **High call failure rate:** the task force hoped that with the improvement suggested for overcoming contact failure loss of mechanical adjustment components failures and circuit deficiencies the failure rate and delays in service (COPU, 1981-82)

The ITI implemented the first recommendation of task force in 1971 itself. The final recommendations of the task force were available in August 1974. ITI introduced all these changes in their products progressively. Apart from introducing the improvement in the production item at the ITI, a progressive plan for updating the crossbar exchanges manufactured to the earlier specifications and was under installation or working was taken up. It needs to be noted that the delay of nine years in identifying the problems connected with the system, was not explained when the committee had pointed out about the problem in Cross-bar technology that it was obtained from BTM, Belgium in as early as May 1964.

On the question that why ITI could not foresee the amount of traffic in India under which the equipment had to work before placing the order with the collaborators and why circuit defects could also not be envisaged particularly when there was a telecommunications research centre; the ITI Chairman explained: "The equipment, which they were using in the country, was inadequate to meet the latest telephone requirements. The most sophisticated system known anywhere in the world at the time of entering into agreement was the crossbar equipment. This equipment was completely new to this country and they started from zero and by then they had no research on the crossbar at all. The problem cropped up only after they had worked and experienced it." He assured the committee that for each one of the problems there was a solution and most of the problems had already been analysed, detected and rectified which later led to the famed Indian Crossbar Project.

4.4.7 Indian Crossbar Project

After the final recommendation of Task Force in June 1974 government setup a combined group of Post and Telegraph, Telecom Research Centre (TRC) and ITI in order to indigenise the Pentaconta design to Indian condition by completely revamping the imported technology (Sunil Mani, 1992). The aim of this project was to improve its reliability and traffic handling capacity and economies whenever possible. The combined group was called the Indian Crossbar Project (ICP). This group redesigned, manufactured and sent for field trial, a complete local exchange and one Trunk automatic exchange. The first trial exchange (Local) of ICP was installed and tested during 1977-78. It was commissioned into service in October 1978. The ICP Trunk Automatic exchange at Rae Bareili was commissioned in June 1980

(COPU 1981-82). ITI started the production of ICP designed switches at Rae Bareili and the first supply was expected from 1982-83 onwards while supplies from Bangalore unit were expected from 1983-84 onwards. For productionising the ICP based switching system ITI entered into fresh technical collaboration with BTM in 1981, after the expiry of the first collaboration agreement[27] but the total cost of the crossbar project was quite enormous as it was composed of the payments paid for the original Pentaconta design (Rs 36 crores) plus the payment made for the new collaboration agreement in 1981. In this regard, the Ministry of Communication Secretary stated that, "we needed the collaboration because it has been our experience not only in this field but in many other fields also that even when we design the product say electromechanical switching equipment we do not have the expertise to manufacture the necessary, tools for productionising purpose, ITI is still manufacturing the Pentaconta switching equipment in the Bangalore factory. But the improved design will be indigenous. In so far as productionising collaboration is concerned, we are entering into an agreement with BTM of Belgium."

Even after establishment of ICP, the Bangalore unit kept on producing BTM equipment as modified to the task force level. The percentage of rejection of crossbar equipment at ITI on Inspection by Post and Telegraph during 1979-82 as furnished by the ministry was quite high as shown in the table below.

Table 4.7: Crossbar equipment of Bangalore:

Items	Percentage of Rejection		
	1979-80	1980-81	1981-82
(i) Selection frame	21.9	21.9	24.7
(ii) Junctor	35.0	29.4	27.8
(iii) Register	42.0	37.0	25.4

Source: (COPU, 1981-82, page 3)

Absorption of Penta Conta Design:

As far as absorption of Pentaconta design was concerned the Bangalore Plant had been working to full capacity and the Rae Bareili plant, which was manufacturing ICP design, was in initial stage with an extremely dismal production record. (see Table 4.8)

[27] The terms and conditions of this new agreement are not available.

Table 4.8: Capacity utilization in the Crossbar Equipment

Year	Capacity				Actual Production		Capacity utilization (in per cent)	
	Licensed		Installed					
	Unit (in lakhs line)							
1977-78	(a)	1.02	(a)	1.00	(a)	1.00	(a)	100
	(b)	Nil	(b)	Nil	(b)	Nil	(b)	NA
1978-79	(a)	1.02	(a)	1.00	(a)	1.00	(a)	100
	(b)	Nil	(b)	Nil	(b)	Nil	(b)	Nil
1979-80	(a)	1.02	(a)	1.00	(a)	1.01	(a)	101
	(b)	Nil	(b)	Nil	(b)	Nil	(b)	NA
1980-81	(a)	1.02	(a)	1.00	(a)	0.54	(a)	54
	(b)	Nil	(b)	Nil	(b)	Nil	(b)	NA
1981-82	(a)	1.02	(a)	1.00	(a)	0.88	(a)	88
	(b)	Nil	(b)	Nil	(b)	Nil	(b)	NA
1982-83	(a)	1.02	(a)	1.00	(a)	1.10	(a)	110
	(b)	2.00	(b)	UI	(b)	0.12*	(b)	NA
1983-84	(a)	1.02	(a)	1.00	(a)	1.10	(a)	110
	(b)	2.00	(b)	UI	(b)	0.31	(b)	NA
1984-85	(a)	1.02	(a)	1.00	(a)	1.03	(a)	103
	(b)	2.00	(b)	UI	(b)	0.25	(b)	NA
1985-86	(a)	1.02	(a)	1.00	(a)	0.97	(a)	97
	(b)	2.00	(b)	UI	(b)	0.34	(b)	NA
1986-87	(a)	1.02	(a)	1.00	(a)	0.75	(a)	75
	(b)	2.00	(b)	UI	(b)	0.46	(b)	NA

Note: 1. a = Bangalore; b = Rae Bareili 2. UI = Under Implementation 3. NA = Not applicable
*These are manufactured out of CKD imports from the collaborator M/s BTM, Belgium.
Source: Sunil Mani 1992

Though the Bangalore plant was working with full capacity and Rae Bareili plant had taken initiative for production of crossbar project, the government had a plan to phase out the cross bar production at Bangalore by 1988-89 and at Rae Bareili by 1994-95. From above table we may conclude that till 1986-87 Rae Bareili project was under implementation and actual production was dismal. This means that by the time Rae Bareili plant reached its full capacity, production would have phased out, which would make a mockery of entire process of indigenous effort. From Crossbar project case we could raise a number of questions regarding the rationality of selection of Crossbar technology. The efforts made by TRC team to indigenise the crossbar technology finally became of no use and result of the effort was discouraging.

4.5 The Third Wave of Import: Electronic Switching System

ESS was one major technology where in there was sufficient amount of indigenous research effort, prior to its imports. This analog device saw an interesting phenomenon of a successful lab level indigenous technology losing out to a commercial foreign technology which was digital, though commerce might not have been the only consideration in the selection of the foreign partner.

4.5.1 Telecom Research Centre's Indigenous Effort:

It was in 1964 that the Bell Telephone Laboratories put out the world's first electronic switching system, which was called Number 1 Electronic Switching System. Almost immediately India also initiated the steps to move towards the electronic switching system in 1965 by analyzing the No. 1 ESS of Bell System and newly acquired British Elliott 803 scientific computer, which provided information to TRC team regarding computer Jargons used in No.1 ESS system (Meemamsi, 1993).

The TRC's ESS although was derived from American No 1 ESS; its hardware was quite different mechanically as well as electronically. And though its software was close to the American No. 1 ESS most of its parts were either locally developed or they were imported from abroad. The bulk of semiconductors used in the TRC developed Indian Exploratory switch, was manufactured by Continental Devices of India Ltd, New Delhi, Semiconductor Ltd, Pune and Bharat Electronics Ltd. (BEL), Bangalore. While the ferrite core memories were imported from Germany the Pentaconta crass Racks manufactured by Indian Telephone industries (ITI), were used to mount all the hardware of the computer as well as the speech path network.

The TRC group taking into consideration the specific design requirement for India and in the light of development abroad, was able to develop certain concepts of design and as a result a 100 line laboratory model of local exchange was fabricated and successfully tried out in 1974 (Mani, 1992). Encouraged by this success the Post and Telegraph department sanctioned a project for development and field trial of 1000 lines ESS known as SPC-1. This project was to be tried out at Rajouri Garden, New Delhi and the cost of the project was Rs 15 million (MOC page 102). The design of Exploratory switch underwent drastic change to keep up with advances in Integrated Circuits (ICs) and also overall system architecture to handle high calling rates due to repeat attempts phenomenon in Indian Network (Meemamsi, 1993). Development of SPC-1 was a unique achievement of TRC in designing an electronic switching system right from scratch. Though the useful feedback of this project was obtained in confirming local capabilities in software generation, the effort could not be productionised due to lack of infrastructural and industrial support (Ministry of Communication, page 102).

While the project was on from 1977, Transnational Companies (TNCs) began their attack on the domestic technological efforts. According to Meemasi (1993) TNCs "with their glossy publications and slides, scared of being kept out of a growing India telecommunications markets, started knocking at the Indian doors. With their well proven talent for brain-washing accompanied by soft loans from World Bank for factory establishment, they started arguing for direct import of equipment for network expansion and the telecom policy makers were made aware of their responsibilities of "Service before self-reliance". The Department of Telecommunication then the wing of Indian Post and Telegraph, stated: "Our ESS Research and Development people are brilliant but their outstanding efforts are marred by poor production know-how"(Meemamsi, 1993).

Thus while the indigenous development of analog switching devices were going-on on one hand , on the other hand a global tender for the import of analog ESS technology was floated in 1979, which had to be funded by the soft loans of World Bank. In early 1980 the SPC-1 was ready for commercial trials as evaluation of foreign collaboration offer was in progress. This trial performed better than the cross bar exchange. But the exchange was closed down after four months and Research and Development effort for this system was stopped (Meemasi, 1993).In other words even before the SPC-I could be scaled up, steps were afoot to accelerate its demise.

4.5.2 The Built-Up Towards the Burial of Domestic Technology

An interdepartmental committee of the Post and Telegraph and the DOE was established in 1979 to examine the policy of ESS. This committee laid out the nitty-gritty of introducing the ESS. It also recommended the setting up of two ESS factories under foreign collaboration and framed elaborate rules for identifying the foreign collaborator. This committee also worked on the time frame and production schedule of new ESS plant. It was supposed that these plants would produce 5 lakhs lines in four years beginning at 0.5 lakh lines in 1983-84. Details of installation and training of personnel were also part of the report.

India's telecommunication requirement was not fulfilled by the existing telecommunication system, as they were not able to meet the growing demand of telephones. On the other hand the technology was not supporting the Indian condition and demand. If we look at the data we find that in 1980, India's telephone service with only 2.5 million telephones and 12,000 public phones was providing service to a population of 700 million. Only 3% of India's 6, 00,000 villages had phone service (Rogers and Singhal, 1989).

In another development a committee on telecommunications popularly known as Sarin Committee submitted its second report on July 10, 1981. It recommended the use of digital electronic technology both for transmission and switching for the future development of Indian telecommunication network. On the recommendation of Sarin committee, India went into the import of digital technology for telecommunication development. Before this Indian telephone exchanges were Electro-mechanical exchanges like Strowger and Crossbar Exchanges. These Exchanges in operation moved vertically and rationally and due to the physical motion, the systems flexibility in call handling was limited. Against these, the Electronics Exchanges eliminated the physical motion of the electronic equipment and the response time of an electronic exchange is one-thousandth of an electro-mechanical switch. Therefore Sarin committee recommended the digital switching system manufacturing in the proposed new ESS factories. It also recommended that only reputed manufacturers of switching system should be considered for the supply of know-how and equipments and such manufacturers should have at least commercial exchanges of roughly 5000 lines in Public service before March 1982 (Mani, 1989).

4.5.3 Technology Imports: Driving Conditions

As interdepartmental committee had suggested that the import of new technology should be based on global tenders, the phase of technological change was ushered in with the signing of technology collaboration agreement between CIT- Alcatel of France and ITI in 1982 for the manufacture of E-10B digital switches. It was the government choice to select CIT-Alcatel, though Alcatel-CIT had not responded to the tender. (MOC, Mani, 1992) Alcatel entered India aided by Political backing of the French government where decision to adopt the technology was made by Indira Gandhi (*Telematics India*, Sept. 1993). Thereafter Alcatel's E-10B switch established an almost unchallenged position in Indian market. The quality of exchanges as well as the success of indigenisation improved significantly through this agreement (*Telematics India,* October 1994, page 46) As far as the Alcatel-CIT technology was concerned at that time many other competitors of CIT-Alcatel technology were in the world market and some of them responded to the global tender floated by India. It is interesting to look at the technology of different manufacturers of digital switching system at that time with respect to the CIT-Alcatel technology in the home country as well as abroad.

Table 4.9: Various Competing Electronic Switching Systems

Type of systems		Countries wherein systems were in operation or on order	Number of lines of (millions) in operation or on Order					
			Domestic Market		Foreign Market		Total	
1	DMS (Canada)	24	24.1	(32.18)	3.6	(5.59)	27.7	(19.90)
2	5.ESS (USA)	9	18.6	(24.83)	9.0	(13.98)	27.6	(19.83)
3	E10-B (France)	57	19.9	(26.57)	3.6	(8.70)	25.4	(18.25)
4	AXE (Sweden)	71	2.2	(2.94)	20.7	(32.14)	22.9	(16.45)
5	EWSD (Germany)	30	0.8	(1.07)	7.6	(11.80)	8.4	(6.03)
6	1240 (Belgium)	21	1.4	(1.87)	6.9	(10.71)	8.3	(5.96)
7	NEAX (Japan)	43	Nil*		8.2	(12.73)	8.2	(5.89)
8	K (UK)	4	7.9	(10.56)	0.1	(0.16)	8.0	(5.75)
9	FETEX (Japan)	12	Nil*	(2.7)	4.19		2.71	(1.94)
	Total		74.9	(100)	64.40	(100)	139.2	(100)

Notes: 1. For the domestic market, Japan uses its own standard equipment known as D-70, produced by a number of manufacturers.

2. Figures in parenthesis indicate percentage share respective total.

Source: Sangal, D K "India Made Wise Choice in E-10B",*Telematics India,* Vol.5, No.11: February, 1989, p.3

From the table it is clear that AXE system of Ericsson was the most popular system in the foreign market. But Ericsson did not respond to government's tender. According to Sunil Mani the reasons for not responding to government tender has a historical dimension, which is enumerated by B-G.[28]

4.5.3.1 Cost of Technology:

The price of this technology was quite high. The agreement between ITI and Alcatel-CIT given in the table shows the services rendered by the collaborator and the products for which agreement was made. The estimate of explicit price of both these collaboration agreements amounted to Rs 48 crores which may be underestimated due to the way in which royalty payments had been estimated/computed. The amount paid for the ESS technology of Alcatel-CIT as compared to that demanded for the technology of the AXE Ericsson was quite high.

Table 4.10: Salient Features of the Collaboration Agreement between ITI and Alcatel-CIT

Sl.No	Product	Date of signing the agreement/ effective date	Broad scope of services rendered by the Collaborator
1.	Digital electronic Switching equipment and manufacture of critical components like: (a) relays, (b) Hybrids, (c) PCB, (d) Connectors, (e) Metal parts at Mankapur Plant	July 24, 1982 (Aug/Sep, 1982)	Alcatel-CIT will provide ITI technical know-how for setting up the factory for manufacture of 5 lakh lines of digital switching equipment by means of providing documents/ drawings and related information for procurement of capital goods, and details of raw materials, components consumables etc. to be used in the system. Further the collaborator will also train it is engineers at the formers works and will depute their technical expert to it is ESS plant.
2.	Digital Trunk Automatic exchanges at Palghat Plant	Not Available	

Source: ITI various reports (Mani, 1989)

[28] For details see BG: Brundenius Claes, and Bo Goransson. The Quest for Technological self reliance: the Case of Telecommunication in India

According to Mani (1989) - "B-G has however presented some quantitative evidence to show that this was quite high in a relative sense too. They have compared this with the price paid by a Brazilian firm for a similar technology from the Swedish firm Ericsson (For the AXE system, which some consider to be better than the E-10B). In this collaboration the price of technology worked out to approximately Rs 9 crores."

Thus based on the above details, if the price paid by ITI to Alcatel-CIT was compared, it would come to almost five times higher than what the Brazilian firm had paid to Ericsson for the same type of technology. According to the agreement government paid money for technical know-how, technical assistance, and training of Indian technicians, supply of capital goods and estimated royalty at 3 per cent ex-factory selling price. A lump sum payment was also paid for this agreement. In the table payment made by ITI under different heads had been mentioned which showed that high price was paid under the head of royalty and technical know-how. (Table 4.11)

Table 4.11: Price (Contracted) for the ESS

Particulars of payments		Mankapur Large local exchange project		Palghat digital Trunk Automatic Exchange		Grand Total	
		Million F.Fr	In Rs Crores	Million F.Fr	In Rs Crores	Million F.Fr	In Rs Crores
1	Lump sum payment	17.78	2.79	0.165	0.03	17.945	2.82
2	Technical Know-how	120.00	18.84	Nil	Nil	120.000	18.84
3	Technical Assistance	44.77	7.03	1.65	0.26	46.42	7.29
4	Training of Indian Technicians	13.02	2.04	Nil	Nil	13.02	2.04
5	Supply of Capital Goods	25.30	3.97	9.50	1.49	34.80	5.46
6	Estimated Royalty at 3 percent ex - factory selling price	75.00	11.78	NA	NA	75.00	11.78
	Total	298.97	46.45	11.315	1.78	310.29	48.23

Notes:

1. The estimates of royalty are taken from the ITI document, *Feasibility Report for Manufacture of 5000 line of Electronic Switching*, Bangalore, 1982.
2. In addition there is a royalty of 8 per cent on export sales.
3. The Payment in French Francs have been converted into Indian Rupees using an exchange rate of IF.Fr = Rs 1.57

Source: ITI

The Indigenisation Process: Failures and Missteps

Though the ESS technology was imported on a rather high cost, the factor of choice of location of electronic switching system factory also increased the cost of this project. As there were two projects: large local switching equipment and trunk automatic switching equipment they had to be manufactured at two different physical locations across the country. The large switching equipment plant was located in an industrially backward district Gonda, Uttar Pradesh while the trunk automatic switching equipment was located in Palghat in Kerala.

According to ITI *Annual Report*, 1991, the fragmentation capacity of different locations besides raising transport costs also affected the skill development, economies of scale and so on; this became very important when both the units were far away from the main production unit which housed the R&D Centre of the firm. Thus the information of particular know-how, technical support and solution of any problem would not have been immediately possible to handle.

4.5.3.2 Choice of Location:

As it was expected that 54 percent of exchange line would be of electronic type, 26 percent of crossbar type and remaining would be of Strowger and manual type by the year 1990; it was decided to manufacture 5,00,000 lines ESS by 1989-90 in a phased manner beginning from 1985-86 in Gonda. The lines were also manufactured at the second unit at Bangalore and at the third unit for Trunk automatic exchange at Palghat (Department of Electronics, 1983-84, p. 36).

The Public Investment Board (PIB) recommended an approved capacity cost of Rs 1,491 million and also suggested Bangalore as a manufacturing location. The main production unit and Research and Development centre were situated in Bangalore as it coincided with phasing out of the Strowger and Crossbar division and the resultant labour and technicians after due retraining were used for the ESS plant. But Cabinet Committee on Economic Affairs (CCEA) which is the ultimate decision making authority in such matters turned this suggestion down. According to CCEA recommendation it was decided to set up the plant in the green field area of Mankapur in Uttar Pradesh (Mani, 1995). Since Mankapur lacked the requisite infrastructural facilities, the estimated investment cost was revised upwards. Plant was fully operationalised by the 1990 with an investment cost of Rs 211.58 crores (Baark, 1990). It increased the cost by 20% from the earlier estimated cost. The actual cost of the project was 177 crores, which increased due to selection of remote location.

Table 4.12: Extent of Cost Overrun at the Large Local ESS Plant (Rs in Crores)

Particulars	Capital Costs		
	As per feasibility Reports (a)	Revised Actual Expenditure (b)	Excess of (b) over (a) as Percentage of (a) (c)
1. Land and land development	6.23	10.52	68.86
2. Factory building and civil works	30.79	39.62	28.68
3. Machinery and equipment	81.80	92.71	13.33
4. Services and utilities	10.83	13.01	20.13
5. Know-how, documentation training and technical assistance	47.37	56.22	18.68
Total	177.02	212.08	19.81

Source: Sunil Mani, ITI, Bangalore, firm-level data.

Thus one could observe that in case of ESS, the domestic capability building was of reasonably high order. The TRC's initiatives, if they had been pursued to their logical end would have provided India with a robust, domestically built Switching system. But interdepartmental wars between DOT and DOE, myopic considerations of the State which oscillated between considerations of self-reliance vs. a vs. considerations of servicing a growing population, and the general lack of faith in the domestic technologies, all contributed towards the failure of the domestic system of switching manufacturing.

4.6 The Genesis of C-DOT

The TRC, whose attempts at developing a domestic ESS were thwarted by various factors, was provided a consolation in the form of Research and Development agreement with the foreign collaborator, which was CIT-Alcatel of France and such a willingness to collaborate, was a pre-condition for the selection of the collaborator. Though Meemamsi (1993) opines that such an arrangement was a meagre consolation to more than a decade of pioneering Research and Development efforts and that the Research and Development collaboration agreement, which was included as a part of the tender would be the least weighing factor in deciding the collaborators, compared to the cost of the technology transfer establishment of factory and directly imported equipment. But based on the agreements with French collaborator, TRC acquired comprehensive software development and maintenance facilities for the E-10B system. TRC also acquired extensive software development management systems based on contemporary tools.

Thus by 1984, TRC had built up sufficient experience in digital ESS system too. At the same time, large scale changes were taking place in the political realm. The then Prime Minister envisaged a major role for technology in taking India in to 21st century. The technology missions were thus conceived and the directives of "Technology Policy Mission" applicable to field of telecommunication were:

(a) Attaining technological competence and self-reliance to reduce vulnerability, particularly in strategic and critical areas making use of indigenous resources.

(b) Providing maximum gainful and satisfying employment to all strata of society with emphasis on the employment and weaker section of society.

(c) Using traditional skills and capabilities.

(d) Ensuring correct mix between mass production technologies and production of masses.

(e) Ensuring maximum development with minimum capital outlay

(f) Identifying obsolescence of technology

(g) Developing technologies, which are internationally competitive, particularly those with export potential.

After considerable deliberation in the Department of Electronics (DOE), Department of Telecommunication (DOT) and Department of Science and Technology (DST), the proposal to establish a National Centre for development of indigenous technology of ESS was submitted to the Urban Cabinet and was approved in January 1984. After completion of all other formalities, the Centre for Development of Telematics (C-DOT) was established on 25th August 1984 as a registered scientific society under the society's registration act 1860. It was modelled on the line of TIFR, Bombay.

The causes and mode of establishment of C-DOT has been articulated differently by different groups and researchers. According to MOC (p. 102) a core group of TRC unit formed the Centre for Development of Telematics (C-DOT) in 1984, while Meemamsi (1993) opines that DOE which had supported TIFR in the development of a digital Automatic Switch for specific requirement of Indian Army, took initiative to follow up the proposals made by Sam Pitroda to the Prime Minister for indigenous development of Indian Digital Switch which in effect led to the birth of C-DOT. The General Manager System and Network development of C-DOT concludes that the efforts made by TRCs, which were not up to the product ionisation level, led to the development of C-DOT to develop digital switches indigenously with the objective to increase telephone accessibility, improve reliability and develop rural communications.

Ray (2002) opines that two men, Rajiv Gandhi and Sam Pitroda were responsible for conceiving the C-DOT project. Rajiv Gandhi, who declared that India must move quickly into 21st century, encouraged Non-resident Indian (NRI) technocrats to return to India and also encouraged bureaucrats such as Abid Hussain in the planning commission to identify five projects which would leverage IT to improve living standards. Pitroda was a successful telecommunication technologist who wanted to play a role in the impeding Indian telecommunication revolution. According to Dr Roy, C-DOT was one of the enterprises, which emerged from their joint initiative.

According to Sunil Mani (1989) much of the money that was spent by ITI, was in importing and adopting wrong technology. The imported technologies were not fully absorbed by ITI and its Research and Development efforts were meagre, and most of the times technology was thrust on ITI by Government especially in case of ESS. In the case of switching equipment the relationship between technology import and domestic technology or Research and Development was that of substitution. In fact this seems to be the overriding rationale for establishing an exclusive and autonomous research centre known as C-DOT in 1984 to develop digital electronic switches.

Singhal and Rogers (1989) say that it was Sam Pitroda's idea to develop C-DOT who presented this idea before Indira Gandhi and later before Rajiv Gandhi, where Sam Pitroda argued that Indian Telecommunication was characterised by high traffic, low density and extreme climatic conditions unlike the industrialized countries in the West. Further, it was stated that India had to achieve self-reliance in developing appropriate telecommunications technology, and therefore it should not utilize its scarce foreign exchanges to import telecommunication equipment. Hence C-DOT finally came in existence in 1984, which was funded by Indian government and was mandated to design indigenous telecommunication switching system.

Evans (1992) traces the origin of C-DOT in the background of inadequate infrastructure function, centralised telecommunication bureaucracy and inability to produce according to the raising demands of telecommunication. He says that C-DOT was set up not as a central bureaucracy or even as a state owned corporation. The origin of C-DOT could also be traced to the "Technology policy guidelines" which placed emphasis on the development of indigenous technology and on efficient absorption and adoption of imported technology appropriate to national priorities and resources.

4.6.1 The Objectives of C-DOT

The Objectives of C-DOT could be listed as follows:

1. To initially undertake design development and engineering of digital ESS technology and subsequently telematics technology products and services by

(a) Its own direct effort at national level.

(b) following assisting and working with co-operation for the telecommunication research and making use of activities in the related fields at other Research and Development institutions, universities and industries in the country and abroad

2. To undertake as part of its own direct effort at the national level, the development of the next generation of Digital ESS, as per the requirements of the government of India using state of the art concepts which are relevant and appropriate to country and international competitiveness.

3. To subsequently undertake further R&D for the introduction of ISDN (Integrated Services Digital Network). The system to be developed should initially cater to the

present needs of the country for planning ordinary telephone services but would have an in-built flexibility for the future introduction in a phased manner of the emerging telematics like integrated voice, data, teleconferencing and facsimile

4. To make efforts in the indigenous digital technology, such that the so developed technology would be used for production in the new switching factory.

5. To become a leading R&D institution for ESS technology appropriate to the developing countries. (Standing Committee, 2001 and Mayank Chhaya, 1990, also see Meemamsi, 1993).

4.6.2 The specific missions in the immediate term

It may thus be seen that C-DOT had two clear missions at the time of its inception:

(a) First mission was to design, develop and engineer a large digital electronic exchange suitable for Indian condition providing plain ordinary telephone services with capability for future introduction of Telematics services. This mission was to be accomplished within a period of 36 months, with a budget of Rs. 35 Crores and staff of 350 Research and Development engineers and 100 support personnel. (Mayank Chhaya, 1990 and Meemamsi, 1993).

(b) Second mission was to develop indigenous technology for ISDN and other remaining systems in the family of digital switching systems.

Summing up the background to the formation of C-DOT it is possible to conclude that:

i. C-DOT was born out of a desire to create a dynamic Research and Development environment suited to the development of a highly sophisticated electronic technology like ESS technology outside the usual government norms with total authority and flexibility to ensure a dynamic "mission oriented approach" with the following objectives.

  (a) Develop sophisticated ESS technology indigenously

  (b) Gradually introduce the indigenously developing digital ESS technology in Indian Telecom Networking to improve overall services.

  (c) Prepare for Integrated Service Digital Network (ISDN) of the future.

ii. The benefits of this indigenous development of technology could be felt in the following ways:

(a) increase phone "accessibility"

(b) Improved overall reliability of services

(c) Better rural communication

iii. The strategy for this indigenous development was to be guided by the following factors:

(a) Self-reliance in design and manufacture

(b) Labour Intensive production technology

(c) Sensitivity towards Capital outlay.

4.6.4 C-DOT: A Story of Success

The centre for the development of Telematics came in to existence on 25th August 1984 as an autonomous scientific society under the leadership of Sam Pitroda. C-DOT as an autonomous society got the authority and flexibility to ensure dynamic operation outside the government norms. The Department of Telecommunication (DOT) gave C-DOT a mandate to develop a large main exchange beyond 500 lines as the first priority because a tender for import of rural digital ESS technology had already been floated on global basis. Its real mandate was to develop a 40,000 line main automatic exchange (MAX) which could provide up to 40,000 phone lines to subscribers by 1989 (Chhaya, Page 125-127). Keeping in view the special needs of the Indian telephone system with respect to the environmental conditions, traffic parameters and maintenance skills, C-DOT set to design the systems with the following objective

1. Development of a single family of digital switching system for multiple applications.
2. Commonality in hardware and software
3. Use of indigenous components without sacrificing reliability by resorting to measures like redundancy automatic diagnostics
4. Remote and centralised maintenance for economic operations
5. Universal interface in networking with different types of network
6. Incorporation of special subscribers features to meet the specific needs of Indian subscribers.

4.6.4.1 Design Concept of Switches:

The technical design evolved by C-DOT works on the family concept, which means that the same "basic switching block" is used for different applications namely PABX, RAX, MAX, and TAX (SGK Pillai, page 67). Unlike E10B switching technology, C-DOT chose the modular design for the architecture of its technology. The working principle adopted by C-DOT was simple one as it focussed its attention on one single unit called a module and worked out ways of linking it up with similar other modules in manner that would linearly enhance switching system capacity by addition of more and more modules. In one sense therefore, C-DOT's main task was to ensure the design appropriateness of one single module capable of "communicating" compatibility with similar brother module. The C-DOTs step of this development was production of RAX, which was installed at Kittur in Karnataka. The small exchange of 128 lines was a successful experiment and was not because it worked out but because its capability of withstanding the ambient conditions of dust and heat in a typical north Karnataka village. After this successful start a strong foundation was laid down for the huge project. All it needed after that was to develop a configuration of similar modules and create a mechanism for their mutual communication, the so called central module, which behaves somewhat like the central processing unit in a computer. In the subsequent years, the centre developed a configuration whose line handling capacity was a linear function of the number of the number of Base Module (BM) of 512 ports each in the switching system (Meemamsi, 1993). First it came up with a Main Automatic Exchange (MAX) with 2 Base Modules for handling 800 lines which was set up and commissioned at Ulsoor in August 1989. Within two months the Ulsoor exchange was upgraded to 11 Base Modules of 2,400 lines. At the beginning of 1990 though C-DOT was two years late in the delivery of its main mandate i.e. MAX 1600 port, yet its achievements list was impressive. The significance of C-DOT products is that they are developed to meet the specific requirements of India in particular and most of the developing countries in general like low telephone density, hostile environmental conditions; unstable main power supply specially in rural areas; the need for establishing local manufacturing and maintenance capabilities so as to save foreign exchange. (Mantage and Hariharan, 1990, p.76-79). They are able to function without air conditioning and are generally low cost technologies in comparison to imported one. (Chhaya, p.150).

The product philosophy of C-DOT is based on family concept as has been mentioned earlier. This helps a factory which is set up for any C-DOT product and which can, with minimum additional investment, produce other products as most of the hardware of RAX, EPAX and MAX are common. This not only helps in technology transfer and production but also in telecommunication administration in terms of easier maintenance, training, mobility of personnel and spares inventory. It is mainly labour intensive and capital sensitive

The hardware architecture of C-DOT family of products has four basic hardware units.

1. Base Module: Base Module (BM) is the primary growth unit of C-DOT Digital Switching System (DSS). It performs the task of actual switching through various interfaces, like dual and multi-frequency receivers (DTMA) on the subscribers side.

2. Administrative Module (AM): This module provides administrative support to the DSS for administrative and maintenance functions such as support for maintaining billing records and traffic information. The function performed by AM includes call processing functions, software recovery and overall initialisation.

3. Central Module (CM): This provides the interconnection facility for the Base Module, it has a message switch which handles the communication between BM and AM, BM and CM and between BMs. Interconnections are provided through high level data links. CMs are used where three or more BMs are to be linked together (C -DOT, various years).

4. Input–Output Processor (IOP): It acts as a front end processor for C-DOT DSS. Its main functions are:

1. Down loading software for DSS
2. Handling Database for traffic and billing data
3. Printing and billing of other reports
4. Providing man-machine interface for various maintenance and administrative operation.
5. for fault detection and recovery
6. System status display

4.6.4.2 Progress of C-DOT's Technology Development in Digital Switching Systems

Rural Automatic Exchange (RAX)

Date of cut-out into service: July 1986

As has been discussed that these exchanges are suitable for Indian conditions of harsh climate, high temperature and dust as also of erratic power supply, after the field trials it was offered to DOT in 1988. Eleven State Electronic Development Corporations were licensed to produce C-DOT RAX. The C-DOT set up a pilot production facility at Bangalore in collaboration with ITI to manufacture RAX for field trials ITI launched 'RAX-a-day programme' from March 1988 but the prototype was submitted to DOT for environmental test and quality assurance. The test however failed and the results showed charring of tracks in the Printed Circuit Board (PCB), these were subsequently corrected. As of September 1988, 75 such exchanges had been produced by ITI. RAX technology was upgraded from 128 to 256 lines capacity which has been widely accepted as a cost-effective switching system for rural areas even in countries of Asia and Africa. In March 2003, a total of 32990 C-DOT RAXs were serving 4.56 million lines (Meemamsi, 2000 and www.cdot.com).

4.6.4.3 Main Automatic Exchange (MAX)

Date of cut-out into service: May1987

With the growth of telecommunication network, it became essential to provide switching nodes or exchanges in a manner that it enabled a subscriber to call one another in the network. Thus keeping in mind the spread of population in the country, exchanges were classified into three, namely Local, Tandem or Transit and Trunk. A local exchange directly connected the subscriber's telephone instrument while a Tandem or Transit exchange interconnected local exchanges. The Trunk exchange connected the long distance circuits.

The digital switching system provides the subscribers several services like call locking, call waiting, conferencing and home metering which are common to all exchanges. One should note that the most crucial factor for any exchange's success depends on the Busy Hour Call Attempt (BHCA).

- Main Automatic Exchange – Medium (MAX-M) - to serve a few hundred lines
- Main Automatic Exchange – Large (MAX-L) - to serve up to 10000 lines
- Main Automatic Exchange – Extra Large (MAX-XL) – to serve up to 40000 lines

4.6.4.4 MAX-M: In the smallest configuration, the exchange consists of a single cabinet, known as Base Module (BM) to serve 400 subscribers. The exchange can further support up to 1500 lines if it is added with two more cabinets, known as Line Modules (LM) equipped only with subscriber lines. Development work is being done to increase the capacity to over 4000 lines. The technology of MAX-M has been transferred to over a dozen companies in India and in January 2000, there were more than 5400 MAX-M serving over 5 million subscribers in rural towns.

4.6.4.5 MAX-L: Due to the change in Union government in 1990, and in view of the financial irregularities and mismanagement of purchase by C-DOT, the efforts in development of MAX-L suffered to a great extent which, after the subsequent change of government in 1991 and also clearing of false charges by Comptroller and Auditor General of India, the 10000 line MAX-L went into commercial service at Ulsoor in Bangalore. The technology for this urban exchange has already been transferred to 11 companies and in March 2003, a total of 874 C-DOT MAX-L were serving 3.52 million lines (www.cdot.com).

4.6.4.6 MAX-XL: Under the liberalised New Industrial Policy (1991) the delay of four years in the development of MAX-XL exchanges was mainly due to the exodus of talented and experienced software engineers from C-DOT to the giant telecom Multinational companies that entered the Indian Territory. In December 1995 only, the commercial trial of 30000 lines had commenced at Indiranagar in Bangalore which was finally dedicated in March 1997. The 40000 lines MAX-XL with ISDN services and catering to high calling rates in metro areas of 8 lakhs during the busy hours, was commercialised on December 27, 1998 at Yelahanka, Bangalore. The capacity enhancement to 100000 lines is in advanced stage. This technology was also transferred to 11 companies and in March 2003, a total of 1237 C-DOT MAX-XL were serving 7.329 million lines (www.cdot.com).

4.7 Achievements of C-DOT

While the above data on product range, and their degree of penetration would provide a quantitative perspective of the achievements of a domestic technological initiative yet another way of examining the success or otherwise of C-DOT is by critically evaluating its performance in terms of the degree of success in transfer of lab technology to mass production, with respect to the nature and type of backward linkages which the institution was capable of creating and finally an analysis of its impact on the soft dimension of research , like employee morale, organizational setup and research pride and output management so as to draw out lessons for the future.

4.7.1 Transfer of Technology Scheme

Transfer of technology in or across national boundaries is an essential factor in the development of industry and is most effective when it is absorbed in such a way as to provide a springboard for the move into next stage of development of industry. Successful absorption of domestic or foreign technology by recipient depends not only on the transfer of technical knowledge and methods but also on the ability to introduce new development in the administrative and financial fields, which constitute the infrastructure of industrial activities (Mann, 1982). In the technology transfer scheme offered by C-DOT, the recipients are chosen on the basis of factors like infrastructure availability, financial status, past performance, geographical location in the country, category (public sector, state owned industry or private) and share of market for each manufacturer. C-DOT collects a nominal technology transfer fee spread over three of four instalments during the completion of various stages of technology transfer.

In the technology transfer mechanism C-DOT provides training and technical assistance to the recipient of technology, where it offers adequate system hardware software training to the manufacturers for understanding manufacturing testing, testing installing and maintaining its products and in technical assistance experts are made available during establishment of production infrastructure, prototype fabrication testing, fabrication of testers and system integration. As a result of technology transfer process C-DOT has successfully transferred the technology for all the products, which have been developed to a large number of manufacturers and enabled them to achieve bulk production. As technology transfer includes extensive assistance in the form of documentation, training, proto type development and follow-up services; C-DOT has spanned a wide base of equipment manufacturers and component vendors for the electronic industry. Today more than twenty licenses from the public, private and joint selector industries manufacture equipment (C-DOT release, 2002, also Pandey, 1990).

4.7.2 Vendor Development: The vendor development program was started to develop the switch around indigenous components, already available or likely to available either through indigenous effort or through local manufacturers, after technology transfer. The main objective of this program was to increase indigenous content so that spare parts could be had locally. Emphasis on the indigenisation was given to the components, required in large numbers. For this purpose C-DOT selected more vendors in a particular type of equipments, which was needed in large numbers. The purpose for selecting more vendors was to ensure competition for holding quality and price line. The vendor development program has identified more than 380 component vendors to provide components and parts to C-DOT product manufacturers, while more than 175 supply electrical and electronic components, 106 supply mechanical items. Due to the vendor development program, C-DOT developed PBX (Private box exchange), that had an indigenous content of 80 percent, RAX (Rural automatic exchange) 75 percent and MAX (Main automatic exchange) 70 percent currently (Meemamsi, 1993 and Pandey, 1999).

4.7.2.1 Organizational management and employee morale

C-DOT was as much an organizational innovation itself as it was to do with the process of technological innovation. It was the first research outfit created outside the prestige sectors (defence, space or atomic energy) with adequate funding, clear mandate and sufficient resources. The leadership was given adequate political support and relatively substantial autnomy with respect to day to day functioning. The degree to which such a set up contributed to the success of C-DOT has to be examined further in detail. The major success of C-DOT was to build a reservoir of highly motivated and enthusiastic young talented scientists for Research and Development activities in field of digital switching system

(*Telematics India*, October 94, page 61) and because of Research and Development activities in the field of digital switching system, C-DOT was able to transfer the technology, which was developed by its indigenous effort.

Currently in its 18th year of existence the C-DOT is on the cross roads. It is operating in an environment where in continued state support may not be forthcoming. The preferential treatment offered to it in purchases by DOT is also being phased out. To survive C-DOT need to reorient itself into a business like, market Friendly Corporation

4.7.3 Effect of Politics in C-DOT

Towards the end of 1989 when National Front government came into power, within a month of formation of National front government Mr. K P Unnikrishnan, then the Minister for Communication indicated the need to review the C-DOTs performance. In this regard a high level committee of 13 members was formed under the leadership of Mr. K P P Nambiar. Two members from C-DOT were also included namely Mr. D R Mahajan, Director and Mr. G B Meemamsi, Executive Director of C-DOT. The reason for the assessment was the delays in delivering its main product i.e. 40,000 lines MAX system. The way in which committee launched a massive attack against the organisations puts a question mark on the functioning of our entire institutional and political system. Though instituting a committee to assess the performance of a scientific institution specially on a totally funded by the government is not out of question yet the report which finds fault with C-DOT at every stage is however very generous with its praise of ITI (Indian Express 25th April 1990). Even the way of functioning of committee was alleged to be totally partial by none other than G B Meemamsi himself (Meemamsi- 1991).

The Nambiar committee was split in two groups, and two reports were presented. Seven members signed one report and four members signed other report. It was alleged by dissenters (four members) that their dissent not was included by chairman and this was the main reason of submission of another report. The main report was itself contradictory as in the beginning it had justified the purchase procedure of C-DOT while in the conclusion it mentioned that there were many irregularities regarding the purchase, and the management of C-DOT was faulty. These developments de-motivated, demoralised the engineers and scientists of C-DOT and translated into massive brain drain from this centre providing a set back to export potential of C-DOT products to 15 developing countries and delay of the project to deliver its mandate due to the uncertainty created over its existence. The NF (National front) government directed that Chairman of Telecommunication commission would not deal with C-DOT and announced a review of Nambiar Committee report and special audit on C-DOT. In the CAG (Comptroller and Auditor General) Audit it was found that there was no malafides or financial burgling in C-DOTs purchase of equipment. But in this audit it criticised C-DOT for its failure to deliver the RAX a day' Trunk Automatic exchange (Mayank Chhaya page 169). However its worth mentioning that multinational like Alcatel despite being competitor, had voiced approval for C-DOT technology (Telegraph, 26 March 1990).

After the Congress government came in to power there was a fundamental shift in the economic policy it was decided that technology for big exchange. (30,000 lines) would now be supplied by TNCs. This was again a measure set back for a institute which was involved in indigenous effort to produce big 30,000 exchange. The exchanges for which MNCs are being called serve the purpose of densely populated metros. Even these exchanges will have to in the process of adaption and by the time that in through C-DOT is expected to be ready with its own 30,000-line exchange. According to DOT (department of telecommunication) data during 8^{th} plan and further ahead over 90% of the country's requirement of exchange can be met by exchanges of 10,000 lines and less.

4.7.4 Effect of New Industrial Policy

The New Industrial Policy of government in 1991 adversely affected the development and proliferation of domestic initiatives in telecommunication sector. The case in point here is C-DOT which was basically established and nurtured by government. The telecommunication sector was opened for the FDI without the requirement of an industrial license (*Telematics India*, November 1995, p.23). The reserve bank of India permitted foreign equity participation up to 51 percent through automatic approval. Shortly afterwards, DOT asked several multinational enterprises to supply one lakh lines (*Telematics India*, September 1993, p.7). In order to access to foreign sources, for funding of large telecommunication projects, the Government of India put telecommunication in the list of bilateral government negotiations (*Telematics India*, December 1996, p.36). According to Meemamsi, since C-DOT was unable to produce exchanges above 10000 lines, the government decided to induct foreign technologies in the country by setting up joint ventures with MNCs. With the entry of MNCs the second exodus of talented and experienced software engineers began. Inevitably development of 40000 lines C-DOT Metro Exchange was delayed by four years. Finally it was subjected to commercial trials in 1995 in Bangalore.

4.8 Conclusion:

C-DOT is one of the few technological initiatives in the non-strategic sectors, which achieved a certain degree of success. Though commentators like Parthsarthi (2001) would argue that C-DOT is an unqualified success, from the above narrative one could observe that barring the sub 10000 line exchanges (rural exchanges), where C-DOT has a sizeable presence in most of the other cases C-DOT could not compete with the technology and market savvy TNCs, Thus, the tremendous strides C-DOT made in terms of indigenous technology development, component development and vendor development C-DOT has not succeeded in fully realising its potential. The next chapter we would present the lessons drawn from these technology choices and discuss strategies for the future.

Chapter 5
Conclusions and a perspective for the future

Indigenous technological dynamism has always been a difficult but necessary path for development for nations. In the current thesis we using the case of telecommunication switching systems, a crucial infrastructural sector industry we have attempted to trace the general pitfalls and successes which India has achieved over a period of the last five decades or so. We presented a critical overview of the telecommunication system world over and in India in our initial chapters. This chapter provided an overall understanding of telecommunication system, traced its origins from the days of telegraph and provided an overview of the state of the art.

The third chapter critically reviewed existing literature on the phenomenon of technology transfer both at the national and international levels, juxtaposing the same in the context of the Indian indigenous industrialization journey. Tracing the origins and significance of the term technology transfer this chapter reviewed the form, nature and direction of the phenomenon of technology movement from the developed to the developing countries over the years, the politics behind the same, and the role of domestic industries, state, the multilateral agencies and the transnational corporations. The chapter also reviewed India's industrialization in three time periods, and critically examined the role foreign technology played during each of the era, the response of the state, the overall level of indigenization of technology in various sectors and the current state of affairs. However no attempt has been made to critically examine the role Indian domestic industrial sector in indigenous development of technology. An analysis of the role of domestic sector or lack of it thereof would be a fruitful area of future research. It should also be mentioned here that technology transfer being a vast literature, the review has attempted to provide a critical perspective on the literature only in the overall rubric of economic literature, and the rich literature in terms of sociology, history, and management have been left out for want of time and resources.

The next chapter discusses the three major technologies which the Indian public sector imported and attempted to productionise locally. Tracing the evolution of switching system technologies internationally, the study identified three major waves of technologies in the sector, namely, strowger, cross bar and electronic switching systems. The Indian switching sector, which started nearly 30 to 40 years after the international switching sector, could have straight away moved on to the second wave of technology thereby gaining late mover advantages. An examination of the reasons as to why India did not do and insisted on reinventing the wheel would be an interesting area of future enquiry.

The study critically evaluated the three major technology collaborations and identified three stages of technology absorption. The first phase of technology collaboration for strowger switching systems is an almost imitative collaboration. The study based on different estimate committee reports and COPU reports, established that the local collaborator acted in a reactive manner in all stages of the collaboration, from the conceptualization to project planning to execution stage. By not proactively investing in adaptive Research and Development in adequate and sufficient quantity it failed to assimilate the broad contours of technology and did marginal or no improvements in technology. To use the words of Mani (1989) the project was at best imitative. The second stage of technology collaboration namely of cross bar technology, the public sector unit ITI went one step further. Here in the technology was not only assimilated, but major improvements were made resulting in the famed "Indian Cross bar project'. While one could argue that the production facility for Indian cross bar equipment is being phased out by the time the technology was fully assimilated, it needs to be evaluated also from the perspective of technology competence which the project provided. But the learning's which the project provided, the contrary pulls by way of splitting of production capabilities and the consequent dilution of accrued learning's are not in the current purview of research and would be worthwhile issues for future research.

The third stage of technology collaboration was in electronic switching system with Alcatel. While this was going on, India went into indigenous development of digital switching system with a new organization named C-DOT. The study though examined the success of C-DOT by was indigenous production of switching systems, especially in the sub-10,000 lines category catering to rural and semi urban areas, and the reasonable degree of success in technology transfer from lab to mass production, it did evaluate critically the failure of C-DOT to scale up to large switches in the 40,000 lines and upwards category. The socio-political dimensions of this failure and the impact of globalization on the same are also issues worth examining. Though the present dissertation did mention the unique dimensions of the C-DOT experiment by way of internal autonomy, mission mode of existence and experimentation with a different form of organization culture, and its consequence on employee morale, the impact of such dimensions on the overall success of the experiment was yet another area worth examining.

As Dore (1989) puts it technology transfer can be termed as successful not when, say, Indonesians establish and run a complex chemical factory. But when they understand the underlying chemistry behind the process, have mastered the requisite chemical engineering skills, can repair and improve the production process, and if possible invent a shorter, better and more efficient process. In other words, technology needs be understood in all its nuances as a dynamic process within an inherent logic of its own, an underlying philosophy of its own, interfacing with other realms of knowledge.

APPENDIX – I

OUTPUT AND CAPACITY UTILIZATION OF STRONGER SWITCHING EQUIPMENT AT ITI

Year	Output (in lakhs lines)	Capacity utilization (in per cent)
1960-61	0.74	NA
1961-62	0.88	NA
1962-63	1.14	NA
1963-64	1.27	NA
1964-65	1.17	NA
1965-66	1.30	NA
1966-67	1.24	NA
1967-68	1.23	NA
1968-69	1.21	NA
1969-70	1.06	NA
1970-71	1.17	NA
1971-72	1.33	NA
1972-73	1.28	NA
1973-74	1.28	NA
1974-75	1.39	NA
1975-76	1.67	111.13
1976-77	1.46	97.33
1977-78	1.75	117.67
1978-79	1.54	102.67
1979-80	1.48	98.67
1980-81	0.72	48.00
1981-82	1.65	110.00
1982-83	1.87	125.67
1983-84	1.65	110.00
1984-85	1.38	69.00
1985-86	1.59	80.00
1986-87	1.67	84.00

Source: (Sunil Mani, 1992) Complied from ITI Annual Reports.

REFERENCES:

- Ahmad A. and Wilkie A. S., Technology transfer in the new international economic order: Options, obstacles and dilemmas. In McIntyre, J. and Papp D.S. (edt.).The Political Economy of International Technology Transfer, New York, Quorum, 1979
- Arrow K., "On the economic implications of learning by doing", *Review of Economic studies*, June 1962
- Bagchi A, "The Theory of Efficient Neo-colonialism", in *EPW*, Vol 6, pp. 1669-76,1975
- Banerji A.P., Technology Transfer, Based on a seminar organized by the Indo-German association, Puublished by, Indo-German association Calcutta,1976
- Baark E. Elzinga A. and Bortgstrom B. E., Technological change and cultural impact on Asia and Europe- a critical review of the western theoretical heritage. Sweden: Research Policy Institute, University of Lund, Lund,1980
- Bartlett C. and S. Ghoshal, Managing Across Borders; A Transnational Solution, HBS Press, MA,1990
- Biswas N N, Principle of Telegraphy, published by: J. K. publisher,1964
- Biswas N N, Principle of Telephone, J. K. publisher,1969
- BM, Shedding hang ups about self–reliance, *EPW*, Vol. 22, Issue 3, Jan 17, 1987.
- Bryan E. Carne, Modern Telecommunications, Plenum Press, New York,1984
- Bush V., Science: the endless frontier, Govt. of US, 1945
- Chidambaram, Nuclear Technology – Power to the people, In the article Technology in India, *IEEE- spectrum,* Mar., pp. 36-39. 1994
- Chandrashekar S., Technology Priorities for India's Development; Need for Restructuring", *EPW*, Oct. 28, pp. 2739 -2748,1995
- Chhaya M., Sam Pitroda- A biography, konark publication, New Delhi, 1990
- Chidambaram, Nuclear Technology – Power to the people, In the article Technology in India, *IEEE- spectrum,* Mar., pp. 36-39,1994

- D'Mello, B, "Soviet Collaboration in Indian Steel Industry, 1954- 84", *EPW*, Mar.5, Pp. 473-485,1988
- Das J, Review of Digital Communication "State of the Art"in Digital Signaling Digital Switching and Data Network, Published by Wiley Eastern Limited,1988
- Department of Telecommunication, Forty Years of Telecommunication in Independent India, designed and produced for DOT by creative Mass communication, New Delhi(year not mentioned)
- Deccan Herald, 15th Feb. 1987
- Dhar B (1984) quoted in Tyabji (2000) pp.84
- Dickson D., The new politics of science, Pantheon Books, New York, 1984
- Dosi G., Technological Paradigms and technological trajectories, *Research Policy*, 1982, pp. 147- 162
- Dunning J.H, Multinational Enterprises and the global economy, Addison- Wesley Publishing Company, Wokingham, UK,1992
- Enos J.L. and Park W.H., The adoption and Diffusion of Imported Technology: The case of Korea, Croom Helm, London and New York, 1988
- Evans P. B., "Indian Informatics in the 1980s- The changing character of State Involvement", *World Development*, Vol .20. No.1, 1992
- Foote V. B., South Africa, another loophole in non-proliferation policy, Center for Development Policy, Washington DC,1982
- Freeman C., Technology policy and economic performance: Lessons from Japan, Pinter, London,1987
- Frye A.L.(edt.), From Source to Use: Bringing University Technology to the Marketplace, American Management Association,Washington,1985
- Galdi T. W., Development assistance policy: A historical overview. Congressional Research Service, Washington DC,1988

- Garratti G R M, History of Technology, edited by: Charles Singer et. al., published by: Clarendon Press, Oxford, 1958
- Gershenkron, A., Economic Backwardness in Historical Perspective, Harvard University Press, Cambridge, MA, 1962
- Giddens (1991) quoted in Held, D. (2000)
- Government of India, Estimate Committee Report, Industry in India, , 2nd Loksabha, 11th report 1957-58, Ministry of Transport and Communication, New Delhi, 1958
- Government of India, Estimate Committee, 1972-73, 41st Report, 5th Lok Sabha, Indian Post and Telegraph Department, Ministry of Communication, 1973
- Government of India, ITI 34th Report, Fifth Lok Sabha, Committee on Public Undertaking, 1972-73
- Government of India, Committee on Public Undertaking, Sixth Lok Sabha, Post and Telegraph Department, Ministry of Communication, 1981-82
- Government of India, Standing Committee on Information Technology, Thirteenth Lok Sabha, Eighteenth Report, Department of Telecommunication, Ministry of Communications, 2001
- Granstrand O and Sjolander S, Managing innovation in multi-technology corporations, *Research Policy*,Vol. 19, pp. 35-60, North-Holland , 1990
- Gupta K.L. Research and Development in Public Enterprise published by Indus Publishing Company New Delhi, 1994
- Gupta N K, The business of Telecommunication: Networking in New Millenium, Tata McGraw-Hill Publishing Company Ltd, New Delhi, 2000
- Gustafson T., Selling the Russian the Rope? Soviet Technology Policy and US export Control, Santa Monica, Rand,1981
- Hawthrone E. P. Transfer of Technology, Seminar Paper organized for economic co-operation for development, Istanbul 5th- 9th October 1970
- Hayden E., Technology Transfer to east Europe: Us Corporate Experience, Praeger, New York, 1976

- Hazari (1967), quoted in Swamy 2000
- Hewitt, In Srinivas R. Melkote H. Leslie Steeves, *Communication for Development in the Third World: Theory and Practice for empowerment*, Sage Publications, New Delhi, 2001, p.155
- *Hindu,* August 31, 2001
- Hirschman Albert O., Strategy of Economic Development, Norton &Co, New York, 1978
- Hogan M.J., *The Marshall Plan: America, Britain and the Reconstruction of Western Europe,* 1947-1952. Cambridge University Press, New York,1987
- GOI (1948) Industrial Policy Resolution.
- GOI (1958) Scientific Policy Resolution
- GOI, (1956), Industrial Policy Resolution,
- GOI (1970) Industrial Policy Resolution
- GOI (1969) Monopolies and Restrictive Trade Practices Act
- GOI (1977) Statement on Industrial Policy
- GOI (1980) Statement on Industrial Policy
- GOI (1983) Technology Policy Statement
- GOI (1991) New Industrial Policy
- Indian Express 25th April 1990
- Jaiswal S.L; Public Sector in India; S Chand and Company Ltd. New Delhi 1971.
- Johnson B, Institutional Learning, in Lundwall *et al* (1992) (edt) *National System of Innovation,* Pinter, London, 1992.
- Joseph, K.J " Growth Performance of Electronics in India South Korea" in Arun Ghosh et al (1992) '*Indian Industrialization; Structure and Policy Issues* 'OUP, New Delhi,1992

- Kenny M. and Florida R., Beyond mass production: The Japanese system and its transfer to the US, Oxford University press, New York, 1993
- Khader M. and William E. Barnes, Telecommunication Systems and Technology, Prentice Hall International(UK) Ltd.,London, 2000
- Khanna S., Transnational Corporation and Technology Transfer; Indian Petrochemical Industry, *EPW*, Vol.19 Pp. 1319- 1340, 1994
- Kumar D, Science and the Raj 1857-1905, oxford university press, 1995
- Lucas R.E. Jr., "On the mechanics of economic development", *Journal of monetary economics*, Vol. 22 pp.3-42, 1988
- Lundvall B.A User-Producer Relationships, National Systems of Innovation and Internationalization, in Lundvall *et al* (edt.) '*National Systems of Innovation*" ,Pinter, New York,1992
- Mani S, Foreign Technology in Public Enterprises, Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi, 1992
- Mani S, Technology Acquisition and Development: Case of Telecom Switching Equipment, *Economic and Political Weekly*, November 25, 1989.
- Mani S, Technology Import and Skill Development in a Microelectronics-Based Industry: The Case of India's Electronic Switching System, New Technology and Workers Response, ed. by Amiya kumar Bagchi, Sage Publication New Delhi, 1995
- Mann T. S. Transfer of Technology, Himalaya publishing house, Delhi,1982
- Mantage and Hariharan, "A Phone in every village", Infotel, Oct.-Dec.p.76-79, New Delhi,1990
- Mcneil I. (edited) An Encyclopedia of the history of technology, Published by, Routledge,London,1990
- Men on U. World Bank and Transfer of Technology, *EPW,* Vol.15, No. 34. pp. 1437- 1443,1980
- Meemamsi G. B., The C-DOT Story, Kedar publications, Noida India, 1993

- Meemamsi G. B. (edt.), C-DOT-2000: A Spotlight on People and Product, C-DOT published, 2000
- Meemamsi G. B., "The great Indian Telecom saga-I", Times of India, 12th May 1991,New Delhi
- Mohan D, "Promotion of modern technology a new tool of neo-colonialism", *EPW*, Vol. 24 Issue 32, pp. 1815-1819,1989
- Mohanasundaram V., Significant contribution of telecommunication sector, In Gandhi P. J. and Ganeshan P. (edt.). Service Sector in the Indian Economy, Deep and Deep Publication pvt. Ltd., New Delhi, 2002
- Matkin G. W., Technology Transfer and the University, American Council on Education and Macmillan, New York, 1990
- Nayar, Baldev Raj, India's Quest for Technological Independence, Lancer Publishers, New Delhi, 1983
- Nelson R.R, (Ed), The rate and direction of inventive activities, Princeton, 1962
- Nelson R.R., US technical leadership: Where did it come from and where did it go? *Research Policy,* 19(2),117-32, 1990
- Nelson R.R, et al. (edt), National Innovation Systems, A comparative Analysis, Oxford University Press, New York, 1993
- Nelson R.R., High Technology Policies: a five nation comparison, (Washington and London: American Enterprise Institute for Public Policy Research.), 1984
- Nelson R.R., National Innovation Systems: a retrospective on a study, I*ndustrial and corporate change,* 1: 347-74, 1992
- Ohms K., The Borderless World; Power and Strategy in the Interlinked Economy, (Revised Edition), Ballinger, CA,.1999
- Pandey Y.K., Transfer of Indigenous Technology in India: The case of C-DOT, in Binay Kumar Pattnaik (eds.), Technology Transfer and IN-house R&D in Indian Industry(in the later 1990,s) vol.1, Allied publishers ltd., 1999

- Paranjepae H.K., New Industrial Policy; A Capitalist Manifesto, *EPW,* vol.26, No. 43, pp 2472- 2481,1991
- Parthasarathi A, "Acquisition and Development of Technology : The Indian Experience" *EPW,* Vol. 22, No.48, 1987
- Parthasarathi A., "Science Policy or Technology Policy–A question of priorities", Paper presented at the Science and public policy seminar at MIT,1966
- Parthasarathi A., "The role of self reliance in alternative strategies for development", *World Development*, Vol.5, No. 3,1977
- Parthasarathi, A, "Leadership in science technology- some aspects of Indian experience", Vol., 32. Issue 38, Oct,6 ,2001
- Parthasarathi, A., "Priorities in Science and Technology for development: Need for major restructuring", *Nature,* 2002
- Pavitt K., and Wald S., The condition for success in technological innovation, OECD, Paris, 1971
- Papist K.L.R. "The objectives of technology policy", *Science and Public Policy*, 14, 182-8,1987
- Pillai S.G.K., "C-DOT- Story for developing countries" Infotel, Jan-March p.64-70 New Delhi, 1991
- Post and Telegraph Department, Ministry of Communication, Annual Report 1924-25 pp.7-10
- Post and Telegraph Department, Ministry of Communication, Annual Report 1925-26
- Post and Telegraph Department, Ministry of Communication, Annual Report 1949-50 pp.36,
- Post and Telegraph Department, Ministry of Communication, Annual Report 1974-75 pp.22

- Rahman A. Science and Technology in India, Published by Indian Council for Cultural Relation, New Delhi. 1973
- Rajan M S, The Telecom Story and The Internet, published by National Book Trust India, fourth ed., New Delhi, 2001 pp9-10, pp. 6-7
- Roche A, Development strategies for an integrated services digital network, *Telecommunication Journal*- Vol.- 47, Oct.1980
- Ray P. K., C-DOT: Switching on the telecom revolution in India, in Sumantra Ghoshal et. al. (eds.), World Class in India: A Case Book of Companies in Transformation, Penguin Books India, 2001
- Romer P.M., "Increasing Returns and Long Run Growth", *Journal of Political Economy*, 94- 1002-1037, 1986
- Rosenberg N, Inside the Black Box, Cambridge University Press, Cambridge, 1994
- Rosenberg N, Perspectives on Technology, Cambridge University Press, Cambridge, 1976
- Sangwan S, Science Technology and Colonialisation: An Indian Experience 1757-1857, pub. by Anamika prakashan, New Delhi,1991
- Schumacher E. F., Small is Beautiful; Economics as if people mattered, Harper & Row, New York,1973
- Sengupta , Arjun, *Business Standard*, August 29, 1998
- Seshagiri N., The Bomb!: Fallout of India's Nuclear Explosion, Vikas, Delhi, 1975
- Shapiro H and Taylor L., The state and Industrial Strategy, World Development, Vol.18. No. 16 pp. 861- 878, 1990
- Shridharani K, Story of the Indian Telegraph: A Century of Progress, Post and Telegraph Department, Government of India press 1953, New Delhi
- Solomon J.J., "A science policy to cope with the inevitable", *Science, Technology and Society*, Vol. I issue I, pp. 75,1994

- Solow R, "Technical Change and the Aggregate production function" *Review of Economics and Statistics* 39: pp. 312-320 , 1957
- Swaminathan K. Role of quality control ,Research and Development in Transfer of Technology, Paper presented in seminar of the Indo-German association, 1970.
- Telegraph, 26 March 1990
- *Telematics India*, September 1993, p.7
- *Telematics India,* October 1994, p. 46
- *Telematics India*, November 1995, p.23
- *Telematics India*, December 1996, p.36
- Tyabji N., Technology and Dialectics, EPW, MAR. 29, pp. 651-656., 1997
- Tyabji N., Industrialization and Innovation; The Indian Experience, Sage Publications, New Delhi,2000
- Vaidya K D, Development of Telecommunication, *Telecommunication journal*-Vol. 46 p. 46 February 1979
- Vishwanathan T, Telecommunication Switching Systems and Networks, Prentice-Hall of India, New Delhi, 1992
- Williams T I, A Short History of Twentieth Century Technology 1900-1950, Oxford University Press, New York, 1982
- www.cdot.com