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From: Mulat Demeke, A/Chairman
Department of Economics

Subject: MSc Economics Theses

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Thank you.

Optimal Telecommunications

Services Pricing

A THESIS SUBMITTED TO THE

SCHOOL OF GRADUATE STUDIES

ADDIS ABABA UNIVERSITY

IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

IN ECONOMICS

(Economic Policy and Analysis)

By

Abdulsemed Hussien

JUNE 1998

ADDIS ABABA UNIVERSITY
School of Graduate Studies

Optimal Telecommunications Services Pricing

By
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I am indebted to the African Economic Research Consortium to sponsoring this thesis and my stay in Nairobi, Kenya last summer.

I am also indebted to my sponsor the Ethiopian Telecommunications Corporation, ETC, for creating a peaceful working environment.

I extend my deepest gratitude to the following for their contribution.

.For encouragement, advice, detailed review of draft, and fertile critique.

.Ato Mesfin Haile The Managing Director of ETC

.Ato Kebede Kiros ETC

.Ato Mohamed Redi ETC

.Ato Asmare Abate ETC

.Ato Guangul Teshager ETC

. For information concerning data and methodology

.Prof. S. Arlinghas of University of Michigan

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ABSTRACT

Cognizant with the importance of optimal pricing as a guide to efficient resource allocation, this study was conducted to determine optimal prices for telephony services for selected urban areas in Ethiopia. To this end, a forward looking engineering economic technique of determination of incremental supply cost and the peak load pricing method were used to establish optimal telecommunications service prices that meet the broader national objective of efficiency in resource allocation and financial viability of the telecommunications operator.

The finding that emerged in the effort is that the telephone network utilization (traffic services) charges currently levied by the incumbent operator are well above the incremental cost, as derived in this study, of providing those services. Since network utilization services have greater sensitivity to prices, the distortions to efficiency and welfare loss are significant.

These results have implications for pricing in telecommunications and other public utilities. That is policy makers need to adapt an optimal pricing strategy based on a forward looking engineering economic study of determining incremental costs. In parallel, policy makers need to review the sector organization and policy so that the wider objectives of efficiency in resource allocation and the financial viability and promotion of the telecommunications sector are achieved.

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CHAPTER 1

INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

In Ethiopia, like many countries in the world, the telecommunications industry is a public utility. Economies of scale, political and military sensitivity and large externalities made telecommunications a prime candidate for public ownership. In this environment telecommunications development in Ethiopia focused mainly on extending universal service. However, the sector is today still characterised by large unmet demand and limited territorial coverage. The limited territorial coverage has caused significant difference in the supply of information and it is likely that this has disadvantaged regional development.

The starting point of economic analysis in public utilities like telecommunications is the examination of the state of use of resource among other factors. It is, therefore, imperative to give weight to the pricing aspect since the pricing practice signals the degree of efficiency in resource allocation. It also mirrors the state of income distribution, equity and other welfare implications. In Ethiopia, the publicly owned monopoly that dominate the Ethiopian telecommunications industry has not attempted to practice optimal pricing strategies while setting prices. The incumbent telecommunications enterprise, which was also, until recently, the regulatory agency, has been concerned with enterprise level economic viability and with the issue of fairness and equity (though in arbitrary fashion) when setting prices. The price setting approach currently employed by the incumbent operator is characterised by the backward looking traditional accounting approach that focus on the recovery of historical or sunk costs. In the determination of capital costs, for instance, straight line depreciation accounting and amortisation of debt are given to much emphasis. The approach rely on loosely-made estimates first put together at the time of initial service offering, no mater how long ago such estimates may have been made. The fallacy in this approach is its apparent implication that resources are as abundant or as restricted as in the past. The government which approves telecommunications and other public utility prices focuses on the financial viability of the publicly owned operator. It takes historical (sunk) cost as the basis for price determination. In essence the computed cost of services provided by the telecommunications operator is being used as a convenient source of information in the price determination process. In such a scenario, the concealment of profits by exaggerations of operational expenses, charges for depreciation, the application of higher return to capital on both the money capital invested over the economic life of the investment and the return on the portion of investment that remains outstanding can not be discounted. On the whole, the existing backward looking price setting process has been found to be a very inaccurate guide to how much it costs to day to provide a unit of a given telecommunications service and may subvert economic welfare, or efficiency, for the society as a whole.

To keep pace with the world-wide developments and in a bid to overhaul the sector, the Ethiopian government is undertaking a major reform in the Ethiopian telecommunications industry. The government has stated as its objective a high quality, efficient, reliable and affordable telecommunications sector. The existing price setting process, however, as discussed above, focuses on the revenue requirements of the incumbent public monopoly. Owing to the monopoly nature of the sector organisation, we can not also rely on the market to efficiently allocate resource. The theory of public utility pricing, however, recognises the existence of pricing techniques and policies that are forward looking and help achieve economic efficiency and financial requirements of the telecommunications operators. One of such techniques is the forward looking engineering economic estimate of incremental cost and the use of peak load pricing policy as price discrimination method.

The technique and policy, as indicated above, aim at two related objectives. The first objective is to equate the selling price of telecommunications service with the long run incremental cost of providing the services. The second relates to the financial viability of the telecommunications operator and other equity considerations. The importance of the last objective lies on the decreasing cost nature of the production process in public utilities like telecommunications and the phenomena of financial deficit if prices were set equal to the strict long run incremental cost, following the neo- classical criteria.

The use of a forward looking engineering economic estimate of incremental cost and the peak load price differential technique, as a strategy for optimal telecommunications services, involve, the construction of, a demand and supply analysis of a physical model (an expansion plan as envisaged in this study) and the measuring of the incremental cost needed for the physical expansion plan. The determination of forward looking incremental cost by an engineering-economic study depend, to a higher degree, on engineering and economic estimates about the quantity and the capacity of the network required to support the expected volume of services. Fundamental difficulties may arise in trying to assess forecast of services, optimisation of a telecommunications network and determination of incremental cost. Nevertheless, engineering-economic studies address the difficulties through extensive studies to establish a workable yardstick for use in determining incremental costs. The general procedure of implementing incremental cost, in an engineering economic model, can easily be understood as follows (the subject is discussed in relative detail in chapter four):

(1) Estimation of expected demand for connection into a local telecommunications network. This enables the determination of the quantity, and capacity of a local network and the determination of the forward looking cost of individual parts of the local network.

(2) The load analysis that is fundamental in the optimisation of the national telecommunications network. In the load analysis optimisation will be carried out with respect to the quantity and capacity of the long distance transmission links and the national transit switch facilities. The economic case for load analysis and estimation of demand for connection is the determination of the least cost investment of the national network that keeps pace with demand.

(3) Estimation of expected traffic service. The fundamentals behind estimating traffic demand lies in the determination of the volume of traffic service that is chargeable.

(4) The supply framework that determines the nature of the network and the quality of the service. This include the system planning (network configuration, grade of service assumptions) and the state of art of technology to be used owing to the availability of multiple alternatives of technologies.

(5) Last but most importantly, it involves the approach to marginal cost analysis that consider the entire capital and 'overhead ' cost for the optimised network. The incremental cost analysis further involves, the partitioning of the common capital cost used by more than one line of service (owing to the multi-product nature of

telecommunications), the annuatization of the partitioned capital cost and adding 'overhead 'costs to the annuatized capacity costs to reach the service specific annual cost. And of course dividing the service specific annual cost by a corresponding service demand to obtain the per unit incremental cost for each service category. The problem of determination of incremental supply cost in the engineering economic model is not that efficiency is all that matters: it is rather that efficiency does matter, along other things. To depart from the suggestion of setting prices to marginal cost which would only allow the telecommunications enterprise to break -even (when demand equals supply) or which can also lead to financial looses in the case of the sector exhibiting economies of scale the engineering economic study in this study employ slack pricing scheme whose objective is the profitability of the telecommunications operator and other equity considerations. In this connection the technique assumes the existence of a profit target that allow for the promotion of the telecommunications industry in Ethiopia.

In view of the difference in the approaches used to determine telecommunications service prices between the existing backward looking price setting practice in Ethiopia, and the existence of a forward looking engineering economic technique of determination of incremental cost as suggested by theory, there are two interrelated questions that deserve answer at micro level when the issue in the telecommunication service pertains to pricing and resource allocation:

(1) How do the existing backward looking price setting practice measures up in terms of efficiency in resource allocation and welfare implication?

(2) How can we employ the forward looking engineering- economic studies, that need extensive data and forecasting exercises, in the determination of incremental cost to achieve efficiency in resource allocation and other objectives?

1.2 OBJECTIVE OF THE STUDY

The objective in this study is to apply a forward looking engineering technique in the determination of incremental cost for telecommunications services that is consistent with the objective of efficiency in resource allocation and the financial requirements of the telecommunications operator and other equity objectives. It is note worthy that the issue of incremental cost for pricing of telecommunications pertains to the maximisation of the net economic benefit. The other objective rests on the examination of how the existing pricing practice measures up in terms of efficiency and equity. The study is motivated by the engineering-economic estimates approach to find a suitable methodology for the determination of incremental cost. To this effect, the study will use engineering economic model and the peak load price discrimination policy that have been successfully applied in other countries in the determination of optimal prices.

1.3 SIGNIFICANCE OF THE STUDY

With the advent of reform and the likelihood of competition in the Ethiopian telecommunications sector, efficient pricing policies will assume greater significance. The valuable contribution of this study may be the awareness it might cause on the importance of the use of the strict long run incremental cost and the price differential techniques in the pricing of services of telecommunications and other public utilities. The study examines how incremental cost pricing can be used as a bench mark to develop an optimal tariff structure for telecommunications. It also tries to convince policy makers and regulators of the telecommunications sector in Ethiopia that pricing based on marginal cost is not only an academic exercise. In addition the significance of the study lies in its contribution to the scholarly debate on public utilities pricing in Ethiopia. Hence the study might serve as a reference material for telecommunications and other public utilities policy planning and regulation.

1.4 ORGANISATION OF THE STUDY

This study is organised in six chapters. Before dealing with the engineering-economic studies of determination of incremental supply cost for telecommunications services in chapter 4, we will profile, in chapter 2, the Ethiopian telecommunications industry, the practices in telecommunications services pricing and the telecommunications technology in Ethiopia. Chapter 3 reviews the literature in telecommunications services pricing. Chapter 5 presents the overall empirical results obtained in the study. Chapter 6 concludes the work and presents the policy implications.

1.5 LIMITATIONS OF THE STUDY

To keep the study to a manageable size six limitations have been adopted. The telecommunication sector encompasses voice telephony, telex (text service) Internet (electronic mailing) and recently with the advent of the information super highway it also encompasses multimedia services such as teleconferencing. The focus on this study however is the voice telephony service. Second, owing to the importance of accounting rate (in the delivery of international telephone services apart from the cost of installed infrastructure) the incremental cost pricing analysis does not include international telephone service. Third, the determination of incremental supply cost for telephone service is limited to the seven large urban areas of the country that presently serve or have been chosen to serve as local transit centres in the different geographical parts of Ethiopia. Hence, demand and supply of telephony service and hence price determination exercises are undertaken for: The metropolitan Addis Ababa and the towns of Mekele, Jimma, Bahirdar, Shashemene, Diredawa, and Dessie. It means that towns and rural areas working in tandem to the telephone exchanges in these areas are not covered. The fourth limitation of the scope concerns the selection of telecommunications technology. A thorough analysis of technology selection, for the physical model network, in this engineering economic study of determination of incremental cost, is not done due to the increasingly complex decisions that relates to cost effectiveness, network efficiency, reliability and energy and space requirements of different technologies. Time does not permit for a comprehensive study that considers every possible alternative. Hence the incremental cost analysis was based on current practice technology. The fifth relates to the little effort done with respect to smoothing inter working of the expansion plan with the existing system. This has a bearing on the incremental cost analysis. Lastly, due to the substantial role of analogue technology in the existing telephone system, the incremental cost of the long distance telephone traffic service (the demand of which is extrapolated from the existing system) can not be set (due to lack of centre to centre traffic matrix) on distance sensitive basis. Despite the assumption of terrestrial radio links (the cost of which normally varies with distance) as the main physical component of the expansion plan on the basis of which the incremental cost determination study was undertaken. Hence comparison of the existing long distance telephone tariff with those derived in this study has been greatly hampered.

CHAPTER 2

2. THE ETHIOPIAN TELECOMMUNICATION INDUSTRY

2 .1 TELECOMMUNICATIONS IN ETHIOPIA A PERESPECTIVE

Telecommunications is unquestionably among the major factors capable of enhancing the socio economic development of a nation and thus adding the improvement in the standard of living among its people. With unprecedented advancement in telecommunications technology, the human civilisation is moving to the information age. This has revealed a new active role for telecommunications since the information revolution is being driven by the convergence of telecommunications, broadcasting and computerisation in the formation of the global information super highway.

Modern telecommunications were born in the period of the industrial revolution, the role has grown (as discussed above) constantly and dramatically with the introduction of telephony and the further development of technology. To keep pace with this post industrial development the telecommunications technology was brought to Ethiopia during the reign of Atse Minilik the Second by establishing a telephone link between the capital city and some major provincial cities. A long line (end to end wired) telephone link of 880 kms was in operation between Addis Ababa and Asmara (today the capital of the independent state of Eritria) in 1905. Major towns along this long line telephone link were connected. Between 1905 and 1913 a telegraph line was built to link Addis Ababa, Dire Dawa and Djibouti in parallel with the construction of the rail road. Radio telephone communication started in 1933 and greatly improved the national and international connections. During the Italian invasion of 1934 - 1941, the country's telecommunications infrastructure suffered a serious set back. The exception to the rule during the invasion was the establishment of automatic telephone exchanges in Asmara and Addis Ababa. After the war, the restoration, expansion and improvement of the telecommunications infrastructure created a chance for new national and international links. However the post war restoration and development in the Ethiopian telecommunications indicate that the limited resources available for investment have been primarily allocated to urban areas. As a result the rural areas, where 85 percent of the population live, are deprived of basic telecommunications services. Consequently the telecommunications development gap has widened substantially. Since the limited installed infrastructure is mainly concentrated in few privileged areas and owing to the physical vastness of the country, Ethiopia exhibit the lowest telephone density (0.26 telephone lines per 100 inhabitants) and inadequate physical accessibility (point of presence) of telecommunication services. What is more, the installed infrastructure that is found in major towns it self is far below what is needed to satisfy the ever growing demand in these areas.

While the telecommunications reforms sweeping the world focus on the structure of the sector, providing as much potential for competition as possible to avoid the transfer of monopoly power from the public to the private sector, considerations are underway, by the Ethiopian government, to partially privatise the incumbent public monopoly. In the regulatory aspect, the issue of policy debate in the developed north has been the removal of or a reduction in the extent of this traditionally regulated industry. In Ethiopia, like the case in most developing countries, reform in this industry includes a reassessment of the kind of control that might be utilised. In this regard, the Ethiopian government has established the Ethiopian Telecommunications Agency and empowered it to regulate the industry.

As to the statistics, the publicly owned monopoly service provides telephone, telex facsimile and Internet services. It has recently launched projects to provide mobile telephone and multimedia services. In June, 1997 the telephone subscribers in the country were 156,538. This figure will increase to 600, 000 by the end of the 7th development program scheduled to end by the year 2000. The point of presence (the telephone stations) which is now 548 will grow to 800 by the end of the development period. International telephone traffic has shown continuous growth in absolute terms (25,058,797 paid minutes in 1996) as well as exhibiting an increasing trend in the relative rate of growth when both outgoing and incoming traffic are considered. The metered interurban and local telephone traffic has also shown continuous growth both in relative and absolute terms (the metered telephone call was 540,008,163 in 1995 up by 3.13 percent from the previous year). In March 1997, there were around 26 direct international connections. In domestic network, the number of stations benefiting from automatic, semi-automatic and manual exchanges in 1997 were 97, 47, 248 respectively. At the end of the undergoing 7th development program the towns benefiting from automatic exchanges will increase to 173.

2.2. TELECOMMUNICATIONS TECHNOLOGY

It is useful to briefly review a few of the features of the changes in the telecommunications technology since technological changes have great impact on the pricing practice and the state of resource allocation. Presently the Ethiopian Telecommunications Corporation uses various technologies to connect towns and cities all over the country and to the world. The industry uses open wire connections (micro-wave technology), satellite technology, multi-access and medium capacity VHF/UHF and digital multi- access radio transmission systems as inter exchange junction systems. In the public switches, there are both digital and analogue techniques. The Ethiopian Telecommunications Corporation has introduced Stored Program Control, SPC, telephone exchanges that signal the beginning of a shift in emphasis from the use of a hardware to that of a software in switching technologies. This has brought greater equipment flexibility that was difficult to implement with electro mechanical telephone switching. Digital telephone switching has brought about the efficient use of junction and other medium distance circuits. The subscriber side connection is being transformed to wireless local loop technology to replace lead sheath and paper insulation coper cables. For international connection mainly satellite technology and fibre optic links are being used. Ethiopia is member of the international satellite organisation (INTELSAT) and the under ocean optic fiber cable system that traverses the Indian ocean, Red sea and the Mediterranean sea (SEA-ME- WE).

To an increasing degree, the cost borne by telecommunications operators: the capital cost of the local loop, switching and the transmission cost, which is proportional to the bandwidth, is on the decline. This is the result of Research and Development in the manufacturing of telecommunications equipment and technology. Almost universally, these developments have driven the cost of investment and consequently the price of services down. Although there is argument that local loop would remain relatively resilient to major cost reductions in the future, the investment needed for customer specific loop that connects subscribers to the public exchanges is dwindling with the advancement in technology. Unfortunately, in Ethiopia service charges are moving in the reverse direction of how costs are built up for operation in the sector. The benefits of reductions in the cost of investment that result from advancement in technology are not passed on to consumers when the dimension of benefit is the price reductions on services. However one could not deny the benefits with respect to the additional features and the ease of service that technology has brought about.

2.3 TELECOMMUNICATION PRICING POLICY AND PRACTICE

The telecommunications pricing practice world wide has been greatly aided by the way technological changes have progressed in the telecommunications industry. The cost of making telephone calls, especially the long distance calls (due to the efficient use of bandwidth and the multiplexing and digitalisation of the transmission system) has fallen dramatically over the past twenty years. Advancement in telecommunications, by rendering accessibility to the latest world-wide achievements in Research and Development has increased the efficiency of labour, the effectiveness of management and consequently reducing the cost of doing business. The trend in the pricing of telecommunication services, in Ethiopia, however, have been moving in the direction opposite to the advancement in technology and is reducing the income of the consumers by imposing ever higher charges.

In Ethiopia the telecommunications pricing practice has been besieged by the traditional accounting approach that is based on the recovering of historical cost. In costing and pricing exercises, primarily accounting concepts such as depreciation, etc., are given much emphasis. Efforts are always geared towards the recovering of the sunk cost. Marginal cost pricing has never been practised. In the pricing of services, nation wide averaging based on traditional cost accounting is being used. This practice results in a great deal of bundling and averaging both within and among services to result in what is called inter service subsidisation The upshot has been that, relative to cost, some routes and service have been under priced and others have been over priced.

Beyond the process and practice of tariff determination, the pricing policy in telecommunications sector in Ethiopia recognises the existence of several objectives. For the purpose of promoting what has been called universal service - the policy of encouraging as many rural areas and residences as possible to have telephones- residual pricing policy is being implemented. Residual pricing policy permits the provision of a subsidy to the residence service. The value-of-service principle is also used to determine telecommunications service rates. In this regard, subscribers who live in larger towns and hence a large exchange areas are charged more on the assumption that the services in these areas are more valuable since subscribers connected to such systems are assumed to reach and be reached by many others connected to the system. The positive subscriber externality case. The other important aspect related to the value of service pricing policy has been the business /residence differential pricing. Since willingness to pay is higher for business than residence, business service is priced higher than comparable residence service with respect to access charges. The tariff for long distance (toll) automatic telephone service is higher than the comparable operator assisted long distance telephone service. This again is the result of the universal service policy pursued by the government to favour the rural community that is deprived of the telephone access. The net result of telephone pricing policies in Ethiopia therefore is a flow of subsidy from international, interurban and urban call services to rural access and usage services. This is what we call cross- subsidisation of services. Rural services receive a proportionally larger portion of the local subsidy than the urban services .

The mainstay of this universal service obligation and inter service subsidisation is the existence of, in the international telephone service, the so-called accounting rate system which allocates the revenue derived from international telephone calls between the telephone carriers involved in their delivery. The accounting rate mechanism serves operators in developing countries to receive revenue, in settlement of the excess balance in exchanged international telephone calls, that is used in the subsidising rural telephone services and the development of the basic telephony infrastructure. For instance, settlement income accounts for 30 percent of the annual revenue of the incumbent operator in Ethiopia. This system, however, has been a long running point of contention and countries like the USA are pushing for the system to be reformed or to get it collapsed. This change of rule, if materialises, will certainly cause revenue problems for operators in countries like Ethiopia which have come to rely on the settlement income.

Chapter 3

Literature Review

3.1 HOW EFFICIENT IS MARGINAL COST PRICING RULE FOR TELECOMMUNICATIONS INDUSTRY

For most of its hundred plus years the telecommunications industry has been regarded as natural monopoly exhibiting declining long run marginal cost. Scheerer (1980) points out that such natural monopolies represent the most traditional case for regulation. Public interest theory (Bon Bright, 1961 chapter 8) argues that the goal of regulation is to produce a competitive outcome in an industry where this is impossible because of economies of scale. Braeutigam (1989) asserted that where economies of scale exist in production of a single product, competition might lead to greatly inefficient and even widely fluctuating, unstable prices so that government intervention of some sort is necessary. Other relevant arguments, in recent literature on natural monopolies like telecommunications has been the focus on the multi product case where the various forms of cost complementarity, economies of joint production and subadditivity of cost rather than economies of scale characteristics (Braeutigam, 1989). To Baumol et el (1982) the presence of economies of scope are necessary condition for subadditivity of cost. Subadditivity in an industry exists if a single firm can produce all the relevant output vectors more cheaply than two or more firms (Evans and Heckman, 1984). Economies of scope exist if the cost of producing each product separately exceeds the cost of producing all products jointly. Economies of scope and declining average incremental cost for each product are sufficient for subadditivity.

Given the natural monopoly nature of telecommunications, exhibiting economies of scale, governments have been deciding on the method of payment for telecommunications through price regulation. The conventional advice of the neo classical theory is that price should equal marginal cost. To the neo-classicals, if the price charged for a telecommunications service is less than the economic cost of producing it, people will consume more than is efficient in terms of the welfare of society. Similarly if the price charged is greater than the marginal cost, people will consume less than is optimal and again there would be welfare loss to the society. Thus economic theories of neo -classical origin teaches us that no industry is immune to marginal cost pricing if the objective is achieving efficiency in resource allocation.

In practice, however, there are many problems in implementing the deceptively simple marginal cost pricing principle. The problems include the correct definition of cost and output and the technical problems associated with the unavailability of needed cost information and the high cost of collecting it, etc. (Bird, 1983). The more basic difficulty however relates to the economic viability of the telecommunication operator. Marginal cost pricing will lead to a deficit in revenue over costs for a firm operating under economies of scale if all units of output are to be sold at marginal cost (Braeutigam, 1989). However, there are ways of pricing for telecommunications services that exhibit economies of scale throughout the relevant operating range while continuing to promote efficiency. Braeutigam (1989) has suggested strategies in which one might achieve economic efficiency by employing differential pricing practice departing from marginal cost pricing. Before dealing with the forms of differential telecommunication pricing let us review models of telecommunication pricing so that we can make comparisons about the objective in their pricing philosophies and their relevance to efficient resource allocation.

3.2 REVIEW OF TELECOMMUNICATION PRICING MODEL

The modern approach to public utilities pricing recognises the existence of several objectives. Munasinghe and Warford (1982) enumerate the following as objectives albeit for Electricity pricing. I found the objectives equally appropriate for telecommunications service and liked to discuss them as follows:

First, national economic resources must be allocated efficiently. This implies that price that reflect the private and social costs must be used to indicate consumers of telecommunications services the true cost of their consumption. Second, since the installed infrastructure provides the service over twenty four hours a day over a number of time periods having perhaps greatly different demand schedules certain principles relating to the sensitivity of customers to the cost of service need to apply. This has to do with fairness and equity in the service pricing i.e. that it should allocate costs among consumers according to the burden they impose on the system. Third, the telecommunications service price should raise sufficient revenue to meet the financial requirements and the promotion of the sector. Lastly as political requirements, the national telecommunications price should be uniform. In summery the objectives include: economic efficiency, consumer interest, economic viability and promotion of the telecommunications operator and fairness and equity. How do telecommunications pricing models measure up in terms of the said objectives? The following discussion will dwell on this although emphasis will be given to the engineering economic model of determining telecommunications pricing- the methodology adopted in the price setting exercises in this study.

3.2.1 THE TRADITIONAL ACCOUNTING MODEL

The traditional accounting approach in pricing of telecommunication service is concerned with the recovering of historical costs. This approach uses historical or sunk and embedded costs in price determination and imply that future economic resource will be as cheap or as expensive in the past. The backward looking estimate of the traditional approach creates the illusion that resource are as abundant or as restricted as in the past (Ralph & Turvey 1983). In the traditional accountting model, the items to be included in the costing exercise are primarily based on accounting concepts -physical asset, service depreciation, interest and taxes that may be affected by regulatory requirements (Munasinghe & Warford 1982). Prices based on such an approach may be quite inadequate as indicator of economic cost (Munasinghe & Warford 1982).

3.2.2 THE NEO- CLASSICAL PRODUCTION FUNCTION MODEL

Some analysts have recently taken an alternative approach of estimating the long run production function of public utility systems like telecommunications to determine the cost and price structure, economies of scale, technical progress, factor substitution possibilities. Cobb Douglas, Constant Elasticity of Substitution (CES) and trans logarithmic formulation have been used (J.Patrick Lewis 1975). It has been argued that no generalised production model derived from neo-classical economic theory could hope to capture the detailed information of physical systems like telecommunications that is included in an engineering economic model (Munasinghe & Warford). It has also been argued that sector wide production function based on cross section (or pooled, cross section and time series) data are appropriate to determine historical trends in the economies of public utility sector evaluation rather than to represent a given system accurately. Production function estimated for a single system using time series data tend to be more specific but they are still based on past rather that future oriented data (Munasinghe and Warford 1982)

3.2.3 THE ENGINEERING ECONOMIC MODEL

Recently an engineering economic model used to designing and planning of a public utility systems has become common in telecommunications pricing. In this model telecommunications prices are based on forward looking estimates of incremental costs that are set with the objective of allocating resource efficiently. The important consideration is the amount of future resource used or saved by the consumer decision. This model is more appropriate than the economic production function model for estimating future incremental supply cost and is consistent with the objective of economic efficiency (Munasinghe and Warford 1982).

Engineering economic model enable to price discriminate and hence recognises the objective of economic viability of the telecommunications enterprise when the production process is characterised by decreasing cost. To promote better utilisation of capacity and meet peak demands, the model can structure prices so that they vary according to the marginal costs of service demands by different consumer categories, at different hours of the day. For instance price determination based on engineering economic model leads to the conclusion that peak consumers pay both capacity plus variable costs (traffic sensitive) -the strict long run marginal cost- whereas off-peak consumers should pay only the variable costs -the short run marginal cost. Similarly, analysis of the engineering economic model of incremental supply cost by the elasticity of demand usually indicates that the lower the elasticity of demand of a service the greater the cost that the consumer imposes on the system (Munasinghe and Warford, 1982). This is the Ramsey pricing rule. The other feature of the engineering model of estimating incremental marginal cost and hence pricing has been the advantage of providing a transparent and independent means of estimating costs unaffected by the practice of a particular firm. If cost based service charges are to play their proper role in providing clear economic signals, they should be based on a forward looking engineering estimate of incremental cost (Munasinghe and Warford, 1982).

Economic theory has it that if prices were set equal to the strict long run incremental cost, a financial surplus would be likely since marginal cost is higher than average cost when the unit cost of supply is increasing. Conversely, if marginal cost are bellow average cost (MC<AC), typically as a result of economics of scale, then pricing at strict long run incremental cost will lead to financial deficit - a typical case in the telecommunications industry. From the stand point of economic efficiency, in the neo-classical setting, efficient production occur only when marginal cost equates price. In the engineering economic model, ways are sought to adjust the strict marginal cost criteria to meet the financial requirement objective of the telephone operator. As indicated above either through the application of peak or off peak price or through the Ramsey rule engineering economic model of estimating incremental supply cost for telecommunications services allows departure from strict marginal cost pricing and at the same time enable the achievement of efficiency in resource allocation and revenue adequacy of the telecommunications operator. This model seem superior since the existing production characteristic, the decreasing costs structure, of the telecommunications industry and the first best solution are incoherent because of the financial loss if price were set equal to marginal cost. The use of engineering economic model in telecommunications services pricing however requires modelling a demand and supply framework of a network (an

expansion plan or a new plant) to estimate the incremental cost of a particular network service.

3.3 FORMS OF DIFFERENTIAL TELECOMMUNICATIONS PRICING

The forgoing discussions indicate that there are differential pricing practices, other than the strict marginal cost pricing, that help achieve both economic efficiency and financial self sufficiency in the telecommunications industry. We are now in a position to discuss the major concepts behind some of the differential pricing techniques that greatly aid in achieving economic efficiency at the national level and financial viability at the operator level. I will not, however, discuss any of the concepts in any theoretical depth or rigor.

3.3.1 PEAK LOAD PRICING

The term peak load suggests a problem faced by many utilities like telecommunications. To Braeutigum (1989) there are three essential features of the traditional peak load problem:

(1) The operator must provide the service over a number of time periods having perhaps greatly different demand schedules.

(2) The operator must choose a single plant size (capacity) to be in place during all of the time periods over which production takes place.

3) Output is non storable.

In the engineering economic model of price setting the issue of peak load pricing often revolves around the fact that the plant is shared by users of all time periods. Efficiency in resource allocation and revenue adequacy can be achieved simultaneously with peak load pricing scheme if the industry exhibits increasing returns to scale. The idea behind peak load pricing is that in off peak (slack) periods users will be required to pay only for the variable cost of production (the short run marginal cost) with no revenue being contributed towards the cost of capacity for the telecommunications enterprise. In the peak period users will be required to pay for the variable cost of production plus the capacity cost of the enterprise or the long run marginal cost.

3.3.2. RAMSEY PRICING

Ramsey pricing stems from the work of the English economist Frank Ramsey, who developed the concept in the context of optimal taxation. Ramsey pricing helps achieve optimal pricing if a telecommunications firm is unable to break-even when price is set equal to marginal cost for each of the services offered by the enterprise without external subsidy. Ramesy pricing is relevant in a multiple product, shared cost of production industry where returns to scale are increasing. Under these circumstances the firm will need to charge prices that deviate from marginal costs in some or in all of its markets in order to avoid running a deficit. The general rule in Ramsey pricing is that prices are raised above their marginal cost in inverse proportion to the demand elasticity of the goods under review. In terms of the above analysis it means that the price of the good or service which has greater sensitivity to price (which is more elastic) is raised less than the price of the service which is less sensitive to price changes (Braeutigam 1989). As already indicated if we raise the price in the most inelastic market, we minimise the dead weight loss. On the other hand if we raise price in the most elastic market the dead weight loss and loss to consumer surplus will be much higher. If marginal cost prices do not result in the covering of the revenue requirements, prices should be raised above the marginal cost in each of market so that the sum of welfare loss is the smallest (Braeutigam, 1989). This is the Ramsey pricing rule which requires that the departure from marginal cot pricing be greatest in the most inelastic or least price sensitive market.

3.3.3 OPTIMAL NON-UNIFORM PRICES

It is useful at this point to discuss the component of differential pricing technique that allows flexibility from the strict incremental cost assumption (while achieving efficiency in resource allocation) in a non uniform fashion. Public utility and telecommunications pricing theory has confined most of their attentions to markets with uniform prices in which the price per unit charged is invariant to the level of customers purchase. Peak load pricing or Ramesy pricing schemes fall in this category. When the individual customer is charged a per unit purchase price that varies with the quantity he purchases, it is often referred to as a non-linear outlay schedule or a non- linear tariff. Unlike the linear tariff practise, in a non linear outlay scheme, the average outlay is not constant as the number of units purchased varies. In telecommunications we have declining block pricing that offers lower unit charge for large levels of network utilisation services. Goldman, Leyland and Sibly (1984) have examined the possibility of some degree of price discrimination by using non uniform price schedule. Any uniform price not equal to marginal cost can be pareto dominated by a non- linear outlay schedule (Braeutigum, 1989).

3.3.4 FAIR PRICE

Fair price is usually raised in connection with the prices charged by a multi product firm for its different services. To Braeutiguam (1989) fair pricing of public utilities like telecommunications occurs when some service (or group of services) is either not generating revenue sufficient to cover its fair share of the costs or generate revenue that cover more than its fair share of the costs.

In summary, the most frequently encountered constraint on marginal cost pricing in public utilities like telecommunications is the so-called revenue constraint. In this study engineering economic technique of determination of incremental supply cost and the peak load price differential techniques are chosen, as an optimal pricing strategies, for the following reasons:

- The incremental costs derived are based on future resources used or saved by the consumers decision.
- We can achieve the wider objective of economic efficiency and financial adequacy of the telecommunication operator by structuring prices so that they vary according to the burden consumers impose on the system.

3.4 EMPIRICAL STUDIES

Investigations on the benefits of determination of optimal pricing of public utility services like telecommunications based on an engineering economic studies have been undertaken by many authors. In Ethiopia, a Swedish telecommunications consultancy firm - SWEDTEL used the engineering economic method in the revision of the pricing of telecommunications services in Ethiopia back in 1986. SWEDTEL employed asset revaluation (replacement cost) method in the determination of the cost of services. Their finding was that the monthly average mainline cost per subscriber (using the asset revaluation engineering economic study) for manual and automatic exchanges is greater than the charges levied on consumer. SWEDTEL, however, found that the traffic charges for both local and long distance calls are greater than the average cost calculated on the bases of the method of pricing they employed. SWEDTEL has also attempted socio economic optimisation exercise to optimise the producer and consumer surplus by taking into consideration the interaction between price and demand, as is expressed by the different demand curves. SWEDTEL in "Tariff Study Final Report, 1986", concluded that:

> ...in spite of the fact that the total producer surplus for the sector is positive which means that cross subsidy from other sectors is a reality. From socio economic point of view this is unfavourable as it indicates that a better allocation of resource could be obtained according to pareto law(p 26)

In SWEDTEL's study the actual price elasticity was measured from actual demand and price to calculate producer and socio economic optimum with and with out financial restrictions of the Telecommunications operator. The difficulties with this approach are the substantial information requirements regarding elasticity for different services. At present there is little evidence available on price elasticity for different telecommunications services in Ethiopia and it would be necessary to undertake extensive research to establish some robust estimates.

Price Warehouse in association with Severn Trent Water who were commissioned to perform a tariff study for water and sewerage services at Addis Ababa Water and Sewerage Authority (AAWSA), in 1992, developed and analysed alternative tariff strategies as a basis for implementing a policy of financial self sufficiency and economic efficiency. The group recommended progressive tariff structure for water supply and sewerage and dislodging services to ensure regular supply of water and sewerage service.

The approach in the determination of prices for AAWSA was centred in estimating long run marginal cost. They used physical model (engineering economic study) for the analysis of long run marginal cost. In this connection, they used AAWSA's system planning document of the Water Supply Project Stage 3 by SEUREM and the update developed by Associating Engineering. For waste water, they used cost estimates and recommendation developed in the Masterplan Study for the Development of Wastewater Facilities Prepared by BCEOM / GKW consultants. Their findings were that, if reliable services were to be given, the average revenue required to provide one cubic meter of water supply should be three times greater than the current tariff. For sanitation, the required revenue was found to be seven times greater than the current charge per trip.

Other excellent studies that provide a sharp insight into the question of optimal pricing albeit in electric power generation and distribution include the case studies by Munasinghe and Warford (1982) and Turvey and Ralph (1977). After analysing the technical and physical characteristics of the electric power system for Indonesia, Pakistan, Philippines, Sirilanka and Thailand. Munasinghe and Warford estimated the strict long run and adjusted marginal cost of supplying electricity for different consumption category by time, voltage and geographical area. The effort was to estimate electricity price that is efficient from both the economy and the power authorities point of view. Turvey and Ralph (1977) analysed the determination of tariff policy for electricity that promote good use of resource while recognising the financial concern of electric power authorities in Thailand, Tunisia and the Sudan. The summary conclusion of these studies is that as long as the system peak is an evening one, the demand charge should be covered by peak time users that add to peak load demanding more generation, transmission and distribution capacity. Also mentioned in their conclusion was that improved pricing should give power authorities adequate finance.

While not a central feature of this study it is useful to discuss in brief some of the demand side empirical studies done with respect to comparing present prices with optimal pricing of telecommunication. The following has been gleaned primarily from Wenders (1987 chapter 4) to which the reader is refereed to for more details . A study by Jeffrey Rohlfs (1979) provides useful insight into the relationship of the old bell system prices to both marginal cost and optimal prices. His study concluded that the bundled flat - rate local access and usage price is well below marginal cost, and toll (long distance) is priced well above marginal cost. Rholf 's approach was the successive approximation beginning with strict marginal cost pricing and then preceding to account for subscriber externalities and revenue constraints.

The Griffin (1982) study is note- worthy because it was an attempt to provide estimates of welfare cost resulting from over pricing of toll services and under pricing of local services. Using data and estimating techniques, Griffin estimates a price elasticity of demand for toll of - .60 and an income elasticity of + 1.32. Griffin performs the following interesting exercise. First for a given ratio of toll marginal cost to price, he estimates the welfare loss created by raising toll prices sufficient to give the telephone company a hypothetical increase in revenue. Griffin next estimates the welfare loss resulting from raising more revenue in the local service market under varying assumptions about the size of the subscriber externality. Griffin then proceeds to roughly calculate the welfare loss from subsidising local service under various assumptions.

Egan's (1981) study is similar to Griffin's but is directed toward the calculation of welfare losses for a single state - Missouri, USA - for 1979. Recent work by Bruce Egan and John T. Wenders SC. (1985) also provides additional insights into both the economic distortions in the telecommunications industry and the distribution of these distortions. The purpose of the study was to investigate the status of economic welfare in the telecommunications industry, to estimate the potential gains in economic efficiency available through efforts to bring the industry into conformity with the competitive outcome.

Chapter Four

4. METHODOLOGICAL FRAMEWORK AND DATA

Building on the preceding introduction to the rudiments of economically efficient pricing in telecommunications, this chapter develops the methodology to be used in the determination of incremental cost as strategy for optimal telecommunications service pricing for selected urban centres in Ethiopia. The methodology used in this engineering economic study involves a demand and supply analysis for an expansion plan, load analysis to determine of an optimised national network, forecasting chargeable traffic units, acquiring of the incremental capacity and operational costs, the determination of incremental cost for unit of services and the use of the peak load pricing as price differential technique. The chapter also contains information on the data source and the method of collection .

To reiterate, the engineering economic model of incremental cost analysis is a complex task involving many interrelated issues: demand forecasting for a physical telephone network, system planning, technology and other supply side considerations load analysis and the use of peak load pricing incremental cost determination method. I will attempt to adequately elaborate the methodology to permit a comprehensive step -by -step understanding by the reader.

4.1. THE ENGINEERING ECONOMIC MODEL

Several preliminary steps must be taken before using the forward looking engineering studies for estimating incremental cost. If the telephone network access and network utilisation demand forecasts and the least cost optimised network are not prepared, the incremental cost that are derived from engineering economic study of an expansion plan is likely to be incorrect. Therefore the rationale underling the engineering economic model of determination of incremental costs are the elements of demand forecasting, system planning, technology and the peak load cost analysis exercises.

4.1.1 THE DEMAND FRAMEWORK

In this study the demand for telecommunications service focuses on the demand for telephony access and the demand for usage of that network. The distinction between access and usage is critical to the understanding of the pricing of telecommunication services. At this point it is legitimate to make further distinctions among the various aspects of telecommunications usage services. It is convenient for the purpose of this study to distinguish between local usage, interurban (long distance) usage and international usage services. Local calls are calls between consumers in a given town or urban area whereas interurban calls are calls that are made between towns. International calls are calls made between countries. This classification goes with the present usage (traffic) service provision by the Ethiopian Telecommunications Corporation and other national operators else where in the world. In addition usage or traffic service has several dimensions such as duration, time- of- a-day or a week each of which may have different demand and cost conditions. Usage or traffic service is measured and priced in pulse of uniform quality. This study will not attempt to estimate optimal prices for international call services since the service involves other costs (accounting rates) apart from the costs of installed infrastructure as indicated in the introductory part of the study. The study shall also not consider the implications of the various qualitative dimension of local and interurban (toll) usage services except of course for a single dimension- the time of the day. We also recall that in the introductory part of this study telecommunications have been considered to be a synonym to telephony even though the former include text, data and video transmission services.

4.1.1. 1 DEMAND FORECASTING FOR NETWORK ACCESS

In the operation and adminstration of a telephone system an orderly and successful development depends largely upon the consideration given to the future. Policy making decisions must therefore be based on forecasts derived from information, analysis and judgement. The planning of telephone system investment is concerned with the economical provision of plant to meet the reasonable telephone service demands. To successfully apply an efficient pricing strategy, in an engineering economic study, it is a necessary preliminary step to forecast demand and plan for least cost investment. Otherwise the prices derived from the estimated incremental supply cost are likely to be incorrect. It is, therefore, necessary to make a reliable assessment of the telephone service requirements in terms of quantity, place and time.

Econometric theory tells us that the demand for telecommunications service, like any other good and services, dependence on the following economic and social variables: price of service, price of substitutes, subscriber income and taste and preference of the consumers. According to the International Telecommunication Union (ITU) political factors including government regulation and policy and social factors such as population, dwelling, education level professional status of the key household members also are identified to impact the demand. Increase or decrease in the number of telephones demanded are governed by the behaviour of subscribers which can possibly be governed by some kind of stochastic process controlled by the above mentioned factors. Various forecasting techniques or models can be used to forecast local telephone subscription demand. According to ITU GAS 9 Hand Book B (1988), the techniques include: econometric modelling, socio-economic modelling and logistic curve modelling.

The econometric modelling combines economic analysis with statistical data and mathematical correlation. The model requires the formation of a relationship between demand for telephone lines and other independent variables such as population and gross domestic product. Other potential factors include capital investment and consumer expenditure etc. If the forecasts of these variables exist, the method of ordinary least square can be used to project future demand and plan for least cost investment (ITU, GAS 9 Hand Book B 1988) .

In Ethiopia the telephone access demand is driven by the availability of supply. There is a large amount of unsatisfied demand that might have been caused by the shortage of the supply which in turn might have been caused by sector organisation and low level of investment. Cross subsidy and inefficient pricing strategies might have also distorted the demand for telephone access. Preliminary econometric analysis, the regression of the national income on the connected lines (considered as a proxy for demand), conducted for the purpose of this study, was frustrated by histories of demand backlog, so that, evidencing, at the margin, consumption of telephone service in Ethiopia might have been determined by supply rather than demand. Furthermore, factors that affect the demand for connection also affect the supply of same. In such a situation we can not consider the demand function in isolation when we are studying the relationship between the demand for also are identified to impact the demand. Increase or decrease in the number of telephones demanded are governed by the behaviour of subscribers which can possibly be governed by some kind of stochastic process controlled by the above mentioned factors. Various forecasting techniques or models can be used to forecast local telephone subscription demand. According to ITU GAS 9 Hand Book B (1988), the techniques include: econometric modelling, socio-economic modelling and logistic curve modelling.

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The second forecasting method used to project future subscribers demand for access is the socio- economic model. The data for such a model is derived (usually from field study) from socio-economic studies related to the distribution of household expenditure and telephone density function. The model emphasises the distribution of household expenditure among products and services including telephony for projection of future demand. As there is no socio economic data in Ethiopia that took into account the proportion of household's expenditure on telephony, it seem impossible to use forecasts of expenditure distribution to project future demand. Hence socio-economic specification of telephone access demand can not be of use in the Ethiopian context.

The third forecasting technique is the logistic curve fitting model. In forecasting telephone penetration in a developed area where demand is expected to saturation a foreseeable future, the logistic curve model is generally most appropriate (ITU GAS 9 Hand Book B, 1988). The logistic model accounts for a future situation where there will be demand saturation, and hence, a gradual decrease of the annual growth rate. Since we are dealing with demand forecasting for the large urban areas, characterised by gradual decrease in the annual growth rate of the demand for telephone, the logistic curve model has been chosen for this study as a forecasting technique. The relative availability of data has also an impact in the model selection. The next section concentrates on the specification of the logistic model of the demand for access.

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4.1.1.1.1 THE LOGISTIC CURVE MODEL

Mathematical method of treating stochastic process are not sufficiently developed for telecommunications demand forecasting. When available, data inadequacy limit their application in countries like Ethiopia. Deterministic methods which can take in to account important determining factors in telephone access demand such as population can be of use. One such model is the logistic curve fitting model. The logistic curve method of demand forecasting uses the historical telephone density level for a projection of future telephone density and hence the corresponding level of future demand for telephones. Values of yearly increments are considered rather than actual values. A method of extrapolation can be used to convert the projected telephone density level into a corresponding telephone access demand level.

Mathematically the model is approached via a bounded growth on the assumption that there exists saturation of demand for telephony as each household gets connected to the network. This technique is critical to forecasting demand for access since in many cases demand for telephony correspond directly to the number of household and business units (ITU, GAS 9 Hand Book B,1988). According to ITU GAS 9 Hand Book B (1988), telephone density (the ratio of connected lines per 100 inhabitants) in a developed area of a country where demand is expected to saturate, the logistic curve model results appropriate forecasts. The model presents three phases: slow development with low growth rate, fast development with an increasing growth rate, and declining growth rate near to saturation. The model relates to bounded growth-logistic function- as opposed to unbounded growth-exponential function- where the rate of growth of $Y(t)$ is proportional to $Y(t)$ and where growth pattern is assumed to remain essentially unchanged, often assuming stable conditions.

The following equation and the complete derivation (APPENDIX A) of the logistic curve equation for telephone density is adopted from the lecture of Professor S. Arlinghas of the University of Michigan. The lecture was obtained via the Internet and originally was used to model population growth theory.

Using the following symbols :

Y_t = Telephone density at time t

q = the target saturation telephone density level

t = the year at which forecast is made

a and b are constants

We have the exponential curve

$dY_t/dt = kY_t$ 4.1

where k is a constant of proportionality.

In reality the residential telephone density level decrease due to growth dumping factors such as advancement in technology that result in the availability of a multipurpose single telephone line with integrated services and socio economic conditions that limit the number of telephone lines per household to a minimum (this subject is discussed in a relative detail in the following chapter). To express this mathematically: assume the telephone density growth decrease as more and more households are connected to the national network and that the penetration level is limited to some maximum q, where $0< Y_t < q$. As Y_t approaches to q, dY_t /d_t approaches to 0, so that the telephone penetration level tends to become stable as t approaches to infinity. The following expression is a typical characterisation of bounded growth in telephone penetration (telephone density) level.

$dY_t /dt = kY_t * q-Y_t /q$ 4.2

Equation 4.2 meets the condition of bounded growth because of the factor $q-Y_t/q$. When Y_t is small, $q-Y_t/q$ is close to 1 and the growth is therefore close to exponential. When Y_t is large that is close to q, $q-Y_t/q$ is close to 0, and the growth rate dY_t/dt is also close to zero. The factor $q-Y_t/q$, which is what alters the symbolic form of the logistic form from the exponential, acts as a dumper to growth.

Replacing k/q by K we get the logistic equation that reads

$$dY_t/dt = K\,Y_t\,(q-Y_t) \quad \text{.......... 4.3}$$

The rate of growth of telephone penetration level is proportional to the product of the telephone penetration level and the difference between the maximum size, q, and the penetration level at time t, Y_t.

Solving equation 4.3 for Y_t, and some manipulation produce a common form of the logistic function .

$$Y_t = q/\,1+ae(bt)) \quad \text{.......... 4.4}$$

With $b < 0$ and $q > 0$

It follows from equation 4.4 that :

$$a = q-Y_t/\,Y_t e(bt) \quad \text{.......... 4.5}$$

$$b= \ln(q-Y_t)-a\ln Y_t \quad \text{.......... 4.6}$$

To find the co-ordinates of the inflection point of the logistic curve of telephone density and demarcate the stage of growth, at which the curve changes from convex to concave and also to locate the maximum growth rate, we differentiate the logistic equation:

$$dY_t/\,dt = k\,Y_t\,(q - Y_t) \quad \text{.......... 4.7}$$

$$\text{derivative } d\text{^}2\,Y_t/\,d\text{^}\,2 = kq - 2kY_t \quad \text{.......... 4.8}$$

Setting this last equation to zero, we have

$$Y_t = q/2 \quad \text{.......... 4.9}$$

This is the vertical co-ordinate of the inflection point for the curve. The rate of growth increases to the left of q/2 and decreases to the right. At this point the maximum rate of growth level is achieved.

To find t, the horizontal component, put $Y_t = q/2$ in the logistic equation and solve;

$q/2 = q / (1+ ae(bt))$ 4.10

Solving $1 + ae\ (bt)) = 2$; $e(bt) = 1/a$; $e(-bt) = a$; $-bt = \ln a$, and

$t = (\ln a) / (-b)$ 4.11

4.1.1.2 LOAD ANALYSIS

Traffic lies at the heart of telecommunications network planing (Hunter, Lawrie and Peterson, 1988). Estimation of the long distance and local traffic, therefore, is useful in determining the optimal level of network needed and the required capital investment. The engineering model of estimating incremental supply cost for telecommunications, in this study assumes the dependency between traffic offered, network dimensioning and the numerical value assigned to performance of the telephone system. There is a relationship between traffic carried by a telephone system, the performance of calls lost and delayed, and the supply (Hunter, Lawrie and Peterson ,1988).

Before discussing the methodology used in this study for network dimensioning and optimising of the expansion plan let us expand on the aspects of traffic engineering for a telephone system. Hunter, Lawrie and Peterson (1988) provide the following comprehensive review of telephone network as a loss and delay system:

> In a telephone system the control to return dial tone is carried out by a small number of common control devices. When many subscriber lift their telephone to get a dial tone, few will succeed. Calls in this system therefore are permitted to queue for common control devices and hence a telephone network is a delay system. In provision of these devices optimisation is done by estimating the number of telephone calls per hour together with device holding times. The speech circuit for the system on the other hand are supplied in a sufficient quantity to permit enough simultaneous conversations to meet all ordinary demands. On the other hand, a group of outgoing circuits may all be busy at a time and all attempted calls may not pass through. In this case some calls are lost and the telephone system operates as a loss system. It is clear therefore that the installation and expansion plans of a telephone system is a complex combination of loss and delay system (pp 100-151).

In the analysis of such a loss and delay system the concept of traffic intensity as measured in Erlang (the mean traffic carried over a period by a set of identical parallel devices) is fundamental. To have an optimal network configuration the forecasts of subscriber lines as specified in 4.1.1.1 and the load analysis as will be specified in this section are necessary. These will help to design the optimal switching, transmission and local loop capacities.

The methodology used in the forecasting of the common device equipment (such as long distance transmission, switching units and other common devices) is a trend method that assumes no change in the per subscriber traffic intensity level on the premise that the intensive use of existing common equipment (caused by the shortage in the supply of telephone access) has resulted in artificially high traffic intensity at the peak hour and any anticipated traffic growth by individual subscriber at peak hour shall be dumpened by the normalisation of this unusual effect with the satisfaction of the demand for access.

In this regard the following historical data (average seasonal peak hour load) on traffic intensity measured in Erlang for the selected urban areas will be used in computing: the number of common devices required to handle the particular level of offered traffic, the optimal additional long distance circuits between the selected urban areas during the busy hour.

Table 5

BUSY HOUR TRAFFIC PER SUBSCRIBER

SEPTEMBER 89-MAY 96

EXCHANGE	TRAFFIC (IN ERLANG)	DISPERSION	
		INTERNAL(%)	EXTERNAL(%)
ADDIS ABABA	0.069	82.0	18.0
JIMMA	0.069	69.6	30.4
DESSIE	0.049	38.2	61.8
MEKELE	0.062	40.6	59.4
DIRE DAWA	0.055	56.3	43.7
SHASHMENE	0.057	61.9	38.1
BAHIR DAR	0.074	50.3	49.7

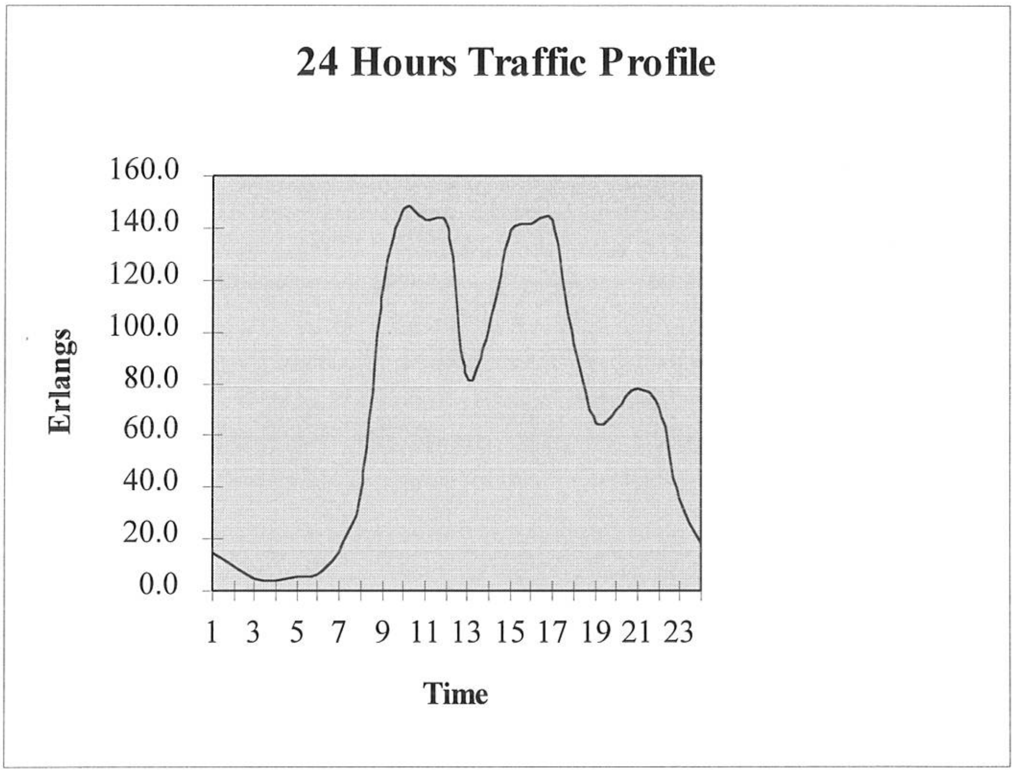
Source : Ethiopian Telecommunications Corporation

4.1.1.3 DEMAND FORECASTING FOR TELEPHONE USAGE

Telephone traffic increase can be related to changes in many different parameters such as the increase in subscriber lines, enhancement of socio economic conditions, a general practice of telephone usage (ITU, Local Network Planning, 1979). Usage in telephony also varies over time affected by the price charged for using the system, the quality and range of services and other characteristics of the consumer that result traffic intensity that undergoes periodic (daily, weakly, and seasonal) variations. To meet this demand a telephone network operates twenty four hours a day. Operating a telephone system and investing in it to meet the growing needs of users, however, requires to keep capacity to the level of the peak hour demand (ITU, Local Network Planning, 1979).

In this engineering economic model of determination of incremental cost we need to consider the nature of demand for telephone traffic to forecast the chargeable traffic units in the expansion plan for the selected large urban areas. This involves the study of call arrival patterns, call holding times and the number of calls in progress so that it enables forecasting traffic. It can be observed from Figure 1, below, that charts the twenty four hours profile of traffic monitored in one of the automatic local exchanges in Addis Ababa, that the daily pattern of traffic demand during a working day consist of a morning (9 a.m.-10 a.m.) and an after lunch (2 p.m.- 4 p.m.) peak and a lunch time (twelve noon) valley and a night time plateau (during Sunday's and holiday's the demand for usage is much lower).

Figure 1



Source :Ethiopian Telecommunications Corporation

The traffic demand estimation methodology in this study is again an extrapolation method that assumed the present intensity of traffic offered per subscriber and carried by the existing system, in the selected urban areas, taken by experimental measurement, measured in Erlang, to be constant. The assumption is based on the argument that due to the over intensive use of existing mainlines in service (because of the backlog in demand people are forced to use pay phones and business lines) the present per mainline traffic carried by the system is artificially high. And any anticipated traffic growth due to the general practice of telephone usage shall be dumpened by the decrease of this unusual value when the telephone density level or the number of mainlines increase and people use their home telephone at any time they wish to a make a call. When making any forecast of demand on a national basis in a country that already has a telephone system, account must be taken of the present trend of demand together with the number of cessation's and the reasons for these (J.J Morgan, 1958). The dispersion of the offered and carried traffic (the usage demanded) from each of the selected urban areas to the other areas will also be physically measured from the existing telephone system in the selected areas. The dispersion pattern is also assumed to be constant. The potential problem of such a technique is that it assumes present traffic intensity and dispersion to persist for some time in the future. However with this technique, it is possible to calculate the point to point (long distance) and local traffic. The result of the measurement will be used as an input in the estimation of incremental supply cost.

The technique of traffic demand forecasting in this study is a physical monitoring and examining of the 24 hours profile of telephone calls offered by residential and business subscribers during the busy and slack (off- peak) hours. Busy hours in this study are defined to run from 8 a.m. to 8 p.m. and the slack hours cover the remaining hours of a day. This classification is also used by the telecommunications operator in Ethiopia in its tariff structuring scheme. As there is no specialised measurement according to subscribers categories, no distinction is made between residential and business subscriber calls. The carried traffic is measured in Erlang and is converted into annual paid minutes by the following formula.

$Erl = p.m / n * 30 * 12 * 60$ 4.12

Where ,

Erl = traffic offered and carried in one hour and measured in Erlang.

p.m = the annual traffic minutes

n = the number of busy or slack hours of a day.

30 = the number of days in a month

12 = the number of months in a year

60= the number of minutes in one hour

4.1.2 THE SUPPLY FRAME WORK

4.1.2.1 SYSTEM PLANNING

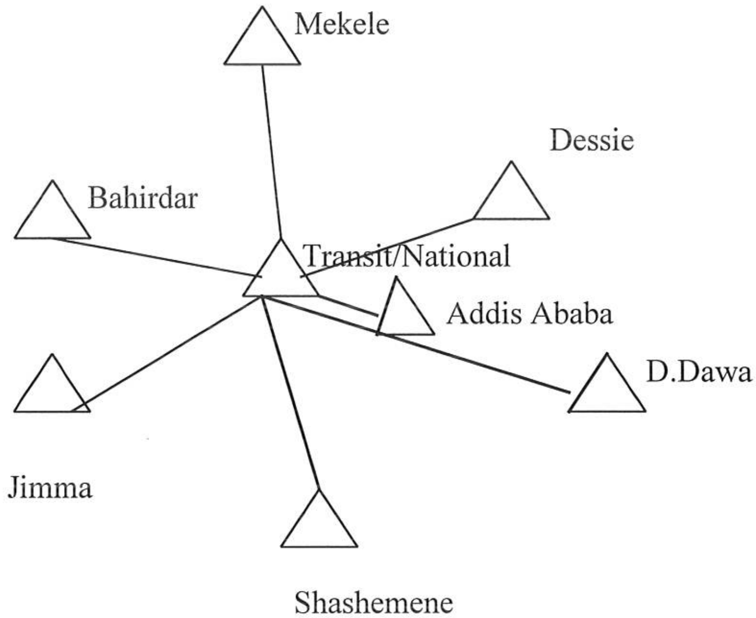
In an engineering economic model the elements of demand forecasting load analysis and system planning are essential prerequisites for the pricing exercise. The demand forecasting technique has been discussed in section 4.1.1. In this section we shall concentrate on the general principles used in system planning of the physical telephone network envisaged to keep pace with the increase in telephone demand. It is note worthy that on the supply side, engineering economic study technique of the incremental cost analysis require analysis of the system planning and technology of the physical model. This is because system planning and technology are associated with the quality of the service.

At an early stage of development a telephone network may be quite simple, i.e. a single exchange may serve a whole country. As demand grows with time, however, there may be requirements for several exchanges located at various parts of the country. Obviously there is a need for communicating between these various parts. In these days of globalization we cannot in fact, think of an independent national telephone network. These developments lead to the installation of self contained and as well as inter communicating local, rural, trunk (inter city) and international sector of a national telephone network. The general principles used in system planning for the telephone system in this study include:

4.1.2.1.1 NETWORK CONFIGURATION

The optimised telephone network for which incremental supply cost is to be determined divides Ethiopia into seven areas. This division follows the future local/ transit existing configuration of the telephone system in the country with the exception of course of the Nazareth local/transit centre, deliberately done due to the proximity of the Nazareth town to Addis Ababa where the national transit is situated and the interest in this study to determine long distance call services incremental cost for a relatively distanced local/ transit centres. The local/ transit exchanges are connected to one another via a national transit exchange in a star shaped configuration. Figure `2` charts the planned star shaped telephone network. One has however to note that local areas can also be connected to one another in a mesh - shaped configuration where by adjacent local areas can intercommunicate either through the national transit or directly. A combined mesh and star network is also possible.

FIGURE 2



4.1.2.1.2 ROUTING PLAN

The objective in the routing plan is to regulate the routing of traffic within one area as well as between the various areas. The aim in this case is to attain substantial savings in investment through the efficient use of costly circuit while safeguarding the grade of service and the quality of transmission. In this study circuits and equipment are used in a direct routing plan where- in traffic between two exchanges is carried on direct link bases via the national transit. Tandem and alternative routing plans are not allowed for to simplify the analysis.

4.1.2.1..3 NUMBERING PLAN

The objective of the numbering plan in the expansion plans for the telephone system is to allocate a unique local area number to each subscriber connected to the national system. The number to be dialled is composed of trunk prefix, trunk code and subscriber number. In this study the country has been divided into seven areas which is assigned with a specific area code.

4.1.2.1.4 TRANSMISSION PLAN

The transmission plan in this engineering economy model for telephony assumes that subscribers should communicate to each other with an acceptable standard of clarity and quality of service such as acceptable echo, stability, minimum noise and interference. The transmission plan in this study assume a nominal reference equivalent of 29 dB for complete connection. The amount of reference equivalent into the local and trunk sectors respectively are assumed to be 6.5 dB and 18.5 dB. Following ITU's recommendation.

4.1.2.1.5 SIGNALLING PLAN

The purpose of signalling is to regulate the transmission of signals over the long distance and local network. The system planned is fast so as to lead to an efficient utilisation of the long distance circuits and local network that makes the operation of the trunk lines more economical. This study assume full automatic network and signals used to carry the digital information required to route the call to the desired subscriber. Also assumed in this system is automatic line signals used for general purpose such as seizure, metering, clear back, forced release, answer and re answer signals. The telephone signalling scheme in the expansion plan of this study is assumed to be ITU-T signalling system No.7.

4.1.2.1.6 GRADE OF SERVICE

The grade of service objective, as discussed in load analysis for the national network planning, for long distance connection shall be:

- Inter exchange circuits in the direct route 0. 01 per circuit on each direct route group. This is the final trunk group grade of service
- Transit exchange 0.01.

4.1.2.1.7 CHARGING

The telephone charge is composed of a recurrent monthly rental fee for network access service and usage sensitive per pulse call charge for local and long distance. The pulse interval for local call is time sensitive-six minute being a pulse. Long distance calls are charged on a time sensitive basis, the pulse interval being one minute. Normally long distance telephone call service charges are distance and time sensitive. Due to unavailability of centre to centre traffic matrix, distance sensitive charges can not be derived in this study. The charging equipment envisaged is a software.

4.1.2.2 TECHNOLOGY

The technology framework for the price determination process in the engineering economic model is the equipment to be used in the expansion plans for telephone networks arising from additional demand for telephone access and load analysis. The inter exchange transmission network consist of terrestrial line-of-sight digital radio and fiber optic. No satellite system is envisaged. Local cable networks for obvious reasons are exposed to damage in higher degree than other parts of a telephone network. It is therefore important to use material which combines first-class quality and suitability with lowest possible overall cost. In this study high quality local network has been considered a good investment. The system, therefore, consist of duct runs and manholes and the use of poles to stretch homogenous solid coper wire. In the expansion plans due to long economic life time and quality of service the switching technology assumed is the digital SPC technology with duplicated central and regional processors. Subscriber terminals and systems include telephone sets, multi-line telephone sets, private branch exchanges, answering machines and facsimile machines. The telephone sets have been assumed to be provided by the telecommunications operator .

4.1.3 DETERMINATION OF INCREMENTAL COST

Having analysed the demand and supply framework of the expansion plan the next stage in the engineering economy model of determination of incremental cost, in the peak load pricing setting, is the collection of the relevant investment and operational costs needed to acquire and operate the physical network and determine the incremental cost. The cost determination process begins by the collection of information in four main areas:

. The magnitude of the incremental purchase cost of investment and the corresponding operational and maintenance costs for the optimised network.

.The forecasts of telephone access and network utilisation service demand.

.The expected economic life year of each equipment

. The interest rate of money

.The projected rate of return on capital

Since the methodology of forecasting future demand has already been discussed this part of the study concentrates on the structure and partitioning of costs and other assumptions made with respect to economic life year of equipment and the interest rate. Finally the methodology of arriving at incremental cost is discussed.

4.1.3.1 COST STRUCTURE AND PARTITIONING

4.1.3.1.1 COST STRUCTURE AND MEASUREMENT

Knowledge of the telecommunication service process and the inputs used at each stage of the process is vital if one is to determine the short and long term incremental supply costs. There are many conceptual as well as practical problems in defining supply cost in an expansion or a new plant of a telephone network. There are also problems associated with measuring those costs. In this study the service outputs have been defined as network access (monthly rental) and network utilisation (local calls and long distance calls) services. In the provision of telecommunication services investment streams for individual services or products in most cases is lumpy. This results in conceptual and practical problems in partitioning incremental cost for service categories.

In the process of local telephone service, for instance, we can identify activities of the subscriber terminal equipment, the local cable network and local switching. In the long distance call service the activities include those mentioned above plus inter exchange junctions or long distance trunks, transit exchange and common control toll ticketing. This evolution tell us that at some points services share common equipment and the need arises to disentangle the specific cost increments. In the engineering economic model, engineering estimates will be used to assign the specific cost increments to specific services. The next section discuss the approach used in this study in assigning incremental costs to specific services.

4.1.3.1.2 COST PARTITIONING

The partitioning of capital and operational costs among services is vital in incremental cost analysis. Services in telephony include: network access and network utilisation (local and long distance) traffic service each of which need a separate or jointly used facilities. The task of cost partitioning in this regard is that of allocating the cost of these installations among the various service groups. Network access cost can be defined as the connection and ongoing operation and maintenance costs of having additional subscribers connected to the system. This would obviously include the cost of ducts, cable pairs, main distribution frame and so forth. It would also include that portion of subscriber stage switching facility necessary to accommodate the additional subscriber. On the other hand additional capacity for group selector switching, common control, and long distance transmission media are needed to accommodate the additional demand for network utilisation services. Hence, the cost of additional call or traffic are allocated as traffic related cost.

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Given these general principles, the following proportion of incremental capita cost based on the ITU, GAS 9 Hand Book B " Case Study On The Economic And Technical Aspects Of The Transition Of A Mixed (Analogue & Digital) National Network Into A Digital National Network " , 1988, will be used in this study (See Table 7). This partitioning assigns a causal responsibility for a share of the common capacity costs, with great empirical accuracy gained from experience, and provide results adequate enough for setting incremental cost.

Table 7

COST PARTITIONING

EQUIPMENT	ACCESS SHARE	TRAFFIC SHARE
CABLES AND DUCTS	100%	
SWITCHING UNIT SUBSCRIBER STAGE	40%	60%
SWITCHING UNIT GROUP SELECTOR STAGE	0%	100%
COMMON CONTROL : CENTRAL PROCESSOR SYSTEM ,INPUT OUTPUT SUBSYSTEM AND COMPUTERS ;;	0%	100%
MAIN DISTRIBUTION FRAME AND DIGITAL DISTRIBUTION FRAME	100%	0 %
# LONG DISTANCE TRUNKS	0%	100%
# TRANSIT EXCHANGES	0%	100%
# COMMON CONTROL TOLL TICKETING	0%	100%
BUILDING AIR CONDITIONING	40%	60%
POWER EQUIPMENT	20%	80%

NB # relates to long distance call service only

SOURCE : International Telecommunication Union

In further partitioning the cost of additional network utilisation capital cost into local call and long distance call services, the study will adopt a cost distribution scheme used by ITU GAS 9 Hand Book B (1988) . Per the distribution scheme the share of joint costs between long distance and local traffic service is on a 40:60 bases. This quantitative proportion is adopted to avoid arbitrary allocation of joint cost. A number of other cost components also increases with the system expansion plan. Each additions to the national telephone network incurs costs of maintenance and of running the exchanges, the transmission lines and the system adminstration and control. This study assumes the annual maintenance and operation cost to be 35% of the annual capital cost following ITU's recommendation. In a telecommunication investment program of a developing country, the cost of plant and equipment account typically for 60-75 % of the total expenditure, the remainder is direct labour and overhead (ITU GAS 9 Hand Book B, 1988). Finally the installation and building requirement for the expansion plan have been assumed to be one-third of the investment in purchase of telecommunication equipment. Investment in purchase of telecommunication equipment represent about two thirds the remaining third largely correspond to expenses related to installation, land and building (ITU GAS 9 Hand Book B , 1988).

4.1.3.2. ANNUATIZED CAPITAL AND OTHER COSTS

The cost of telecommunications plant includes the cost of material equipment and other associated costs such as storage, handling and installation cost, initial training of personnel, etc. Once the forward looking purchase cost of equipment is determined, annual capital cost is easily determined by applying a capital recovery factor which gives the true equivalent annual payment to be made to recover the original investment with interest. The capital recovery factor recognises the interest earning capacity of money and gives equal annual payments over a fixed period of time which will recover the original investment and pay interest on it (J.J . Morgan,1958).

Let us expand on the aspects of the determination of annual incremental costs. According to Saunders, Warford and Mann (1983), the annual incremental cost (IC) definition makes use of two concepts: short run marginal cost (SRMS), which reflects increments in operating and maintenance cost brought about by increase in output and the long run marginal capacity cost (LRMCC), which reflects increments in capital expenditure (capacity) that are necessary to increase output. Since these cost and output are considered only one year at a time, the incremental cost definition reflects a relatively short time horizon.

Saunders, Warford and Mann (1983) define incremental cost as :

$$IC = SRMC + LRMCC \quad \ldots 4.13$$

$$= \frac{R_{t+1} - R_t}{Q_{t+1} - Q_t} + \frac{rI_t}{Q_{t+1} - Q_t} \quad \ldots 4.14$$

Where t = year for which the increase in cost is being calculated

R_t = operation and maintenance expenditure in year t

Q_t = network access or utilisation services in year t

I_t = capital expenditure in year t

r = The capital recovery factor or the annual payment that will repay a Birr 1 loan over the useful life of equipment with compound interest (equal to the opportunity cost of capital) on the unpaid balance.

The capital recovery factor is also defined as

$$r = i(1+i)^n/(1+i)^n - 1 \quad \text{.......................................4.15}$$

where,

I = the purchase cost of investment

i = the appropriate rate of interest

n = the economic life year of equipment

As indicated above in the annuatization of cost the following are vital:

. ECONOMIC LIFE YEAR OF EQUIPMENT

Economic life year of a plant unit is a critical factor in the annuatization of cost. The investment cost for a plant unit is presumed to be recovered during the economic life time of the equipment. The determination of the amortisation of the physical investment is possible with the knowledge of the economic life year of the equipment. In this study economic life time of for the major types of physical components of the expansion plan are assumed to be :

.Digital switching equipment	10 years
.Inter exchange carrier and multiplex equipment	15 years
.Radio and microwave equipment	15 years
.Underground cables	30 years
.Computer equipment	10 years

This assumption is adopted from ITU-Local Network Planning, 1979.

INTEREST RATE

It is essential that the interest rate be used for annuatization of investment costs needed for the expansion plan. The interest rate should be based on the current effective average rate at which capital may be borrowed. This would allow a minimum return to capital on both the money capital invested over the economic life of the investment and the return on the portion of investment that remains outstanding. The use of the effective rate of interest in the annuatization process guarantee a return on investment whether it is acquired through borrowed fund or from internal sources. This study assumes borrowed fund and an opportunity cost of money of 12%.

The annual capital cost is computed by annuatizing the forward looking capital cost over the life year of the equipment and the cost of money (the borrowing interest rate in Ethiopia). The annual traffic sensitive (variable) cost of maintenance and operational cost (assumed to be 35% of the annual capital cost per the recommendation's of the ITU) will be added up. The incremental average cost per unit of service shall be arrived by dividing the sum of service specific annuatized capital cost and the variable cost by the unit of the respective service demanded.

4.1.3.3. INCREMENTAL COST DETERMINATION

Pricing long distance and local calls according to their incremental cost could result in financial losses as the unit cost related to long distance and local call telephone call are expected to decline. This is due to economies of scale. Consequently, there is a need to use price discrimination to help achieve the financial viability of the telecommunications enterprise. In this engineering economy model of determination of incremental cost the peak load pricing has been selected as the price differential technique. The first stage in the structuring of telephone pricing in peak load setting is to calculate the strict long run marginal cost that emphasises the criterion of economic efficiency. In this setting the annual capacity and maintenance and operational costs will be applied on the peak hour network utilisation (long distance and local call) services and as well as on network access (the monthly recurrent rental) service. The demand of service by this group justifies the further investment and expansion of capacity. It follows that those customers placing demand for usage during the peak hours and those placing demand for connection shall pay both the long run capacity (the annuatized capital cost) and the short run maintenance and operation costs. By introducing load pricing we can signal to consumers of telephone services the economic value of future resource required to meet extra consumption. Price are the amount paid for extra consumption and need to be related to the incremental cost in meeting extra consumption (Turvey and Andersen, 1977) .

In the slack hours, however, the incremental cost for network utilisation should be based on the consideration of financial self sufficiency, equity and other fairness objective. This is mainly because:

.The efficiency criteria and equating incremental cost to price would only let the telecommunication enterprise to break-even.

.Slack our demand does not need further expansion of capacity and we need to structure prices based on the burden consumers impose on the system.

.The profitability objective for the promotion of the sector.

In this study, slack hour incremental cost is based on the existence of a profitability objective (without which we can not think of the promotion of the telecommunications sector) and the recovery of the short run variable cost. By taking in to account the world-wide average on the returns to capital invested in the telecommunication industry (it ranges between 15-40 percent) this study assumes a 20 percent rate of return on the capital, as profitability target, which together with the variable cost, albeit negligible, for telecommunications services at the off-peak hours, would be used to determine the incremental cost for the slack hour network utilisation services.

4.1.4 DATA SOURCE AND METHOD OF COLLECTION

4.1.4.1 SOURCE OF DATA

The basic data for the analysis of the determination of incremental supply cost in the engineering economic study setting in this study consists both primary and as well secondary data. The primary data relates to the physical monitoring and measurement of the twenty four hours traffic profile, taken for the purpose of this study, from a sample automatic exchange (Filwoha 3) in Addis Ababa, representing 10% of the total subscriber mainlines that are of concern in this study. The reasons behind the selection of this exchange are basically two: First, Addis Ababa accounts for the 75 percent of the subscriber lines in Ethiopia and the study can not afford ignoring Addis Ababa and secondly the Filwoha 3 exchange is a digital one with a computerised traffic monitoring device. The secondary data collected include: time series data on connected telephone lines, population level, average incoming and outgoing telephone traffic intensity and its dispersion used in the load analysis and network dimensioning exercise and the forward looking purchase cost of investment. The data were collected from published and unpublished reports of the Ethiopian Telecommunications Corporation and The Central Statistical Authority.

4.1.4.2. METHOD OF COLLECTING DATA

4.1.4.2.1 TELEPHONE DENSITY LEVEL

Telephone density is the number of connected telephone lines per 100 inhabitants. It indicates the correlation between telephone lines and the population level . To obtain the actual time series data on telephone density level, for the selected areas, the following manipulations were done:

- The population data was based on the 1984 national and regional population census and the population projection resulting from this census. The 1984 census was considered because it was the first ever census that furnished population data from 1984 onwards which happens to be interest in this study. The population projection used the Cohort Component method that take into account the mortality, fertility and migration rates. The census used both the dejure and defacto approaches to population counting. In this study the result of the dejure approach to population counting (every person counted on the basis of his/ her usual residence) is considered. The results however are only available at provincial level. Since we are interested in the population data of the selected areas, extrapolation has been carried out to get reliable data by disaggregating the province level population data using the percentage distribution of the population of the selected areas at the time of the census. Except for Addis Ababa for which separate data was available the population of the other areas have been adjusted accordingly.

- The data on connected subscriber lines is collected from the Ethiopian Telecommunications Corporation. The data is only available in aggregate form i.e. at the national level. Manipulation of the national data was necessary to obtain the time series data on subscriber lines that are of interest to this study. Hence the subscriber lines for the period 1984-1998 was obtained by multiplying the 1997 proportion (out of the national total) of the subscriber lines in the selected areas on the national aggregate in a retrospective fashion.

4.1.4.2.2 TRAFFIC DATA FOR LOAD ANALYSIS

The average per subscriber traffic carried, at the busy hour, used in the determination of the optimised national telephone network is obtained from the records of the Telecommunication's Corporation. This data (Table 5) originally was obtained by physical measurement of counting the number of busy inter exchange circuits on the existing system at reasonable spaced intervals during the period September 1989- May 1996.

4.1.4.2.3. TRAFFIC DATA FOR CHARGEABLE MINUTES

The data utilised in the projection of traffic demand is taken from physical monitoring of the traffic intensity and dispersion (on route) of one of the automatic telephone exchanges in Addis Ababa (Filwoha 3 telephone exchange). Measurement of traffic has been carried out for twenty four hours for ten different days at reasonable spaced interval. The data from this sample were used in determining the average peak and off peak traffic intensity per subscriber. The dispersion of this traffic data has been used to determine the local and long distance chargeable telephone traffic minutes or pulses.

4.1.4.2.4 PURCHASE COST OF INVESTMENT AND OPERATION COST

Once the necessary equipment has been optimally dimensioned (on the basses of the relevant demand and other assumption about the grade of service) acquiring the initial investment cost is imperative. In this study the purchase cost of investment is obtained from the latest bid evaluation reports of the Ethiopian Telecommunications Corporation. With the exception of data on initial investment cost, however, adequate data on cost were not available, because of limitations in the cost accounting system of the incumbent operator. This limitation coupled with the complexities involved in evaluating the cost of the telephony system has led to the adoption of extrapolation about the maintenance and operation costs based on the annual investment cost. Thus, the annual maintenance and operation cost has been assumed to be 35 percent of the annuatized capital cost. Per ITU's recommendation.

CHAPTER 5

5. THE RESEARCH FINDINGS

This chapter presents the empirical findings of this study in five sections. The first attempts to forecast the demand for residential access service based on the specification of demand for residential access service. Load analysis and network optimisation will be presented in section two. The third section dwells on the demand analysis for chargeable traffic services. The main objective of this study, the analysis of the determination of incremental supply cost for access and traffic services based on projected demand, capacity of the optimal network and collected purchase cost of investment will be contained in section four. In this same section comparisons will be made between the incremental cost derived in this study and the current pricing levels to see the welfare implications. Summary of the incremental cost analysis will be exhibited in section five.

5.1 LOCAL ACCESS DEMAND FORECAST

In the previous chapter the frame work for analysing the demand for residential telephone lines for the selected urban areas have been examined. In this section the results of the estimated demand for residential telephones will be presented as follows: The first part deals with measurements of the logistic curve model. And the last part deals with the results, inferences and the judgements about projected telephone density and hence access demand. Assumptions about the target telephone density level and the measurement procedure, however, will be discussed before examining the empirical results.

5.1.2 TARGET OF HOUSEHOLD SIZE AND TELEPHONE DENSITY

The potential users of telephone services are households. When all households have been equipped with telephone lines, the expansion and hence rate of growth of telephone density will decline. The point of saturation in demand for telephony access service is reached when the distribution of telephone lines is close to the needs of the household.

What level of telephone density should be considered as a saturation point for the selected urban areas in Ethiopia?

The demand for telephone grow with the number of households (dwelling) in one given area among some other factors. This demand however gets saturated due to demand dumping factors both on the supply and demand sides. On the demand side access service is price and income inelastic. One the supply side due to advancements in technology the telephone network is becoming an interconnected communication with integrated services (such as Integrated Service Digital Networks, ISDN) where a given exchange line satisfies all the needs of a household with respect to communication and entertainment. The price inelastic nature of access service and advancement in technology imply that the demand for telephone access saturates as each household gets connected to the telephone network. Hence assessment of future demand for telephone access needs determination of household number or the size of the household.

If we assume that in some future years from now a household constitute six persons and we assume one telephone line (with an integrated service) per household, the number of mainlines we are targeting per individual household is 0.17. This result from simple division of the number of telephone lines by the household number. When converted into telephone density (per 100 inhabitants) this value will be 17 main lines per 100 inhabitants. Other scenarios about the number of persons per household could be four or five persons per household. Assuming one telephone line (again with an integrated service) per household, a household size of four or five persons will result a telephone density level of 25 and 20 lines per 100 inhabitants respectively. In our analysis of demand for access, the household size of six persons and the corresponding telephone density level of 17 mainlines per 100 inhabitants is chosen because of the moderate household size that commensurate with urban household reality in Ethiopia.

5.1.3 MEASUREMENT OF THE DEMAND EQUATION

Given the access demand specification the logistic distribution equation of telephone density, for each of the scenarios about the household size, is estimated on the basis of the actual telephone density data for the selected urban areas (see APPENDIX B). The logistic curve equation for each of the variants is shown below.

SCENARIO ONE

$Y_t = 17/1+4.33e(-0.004 * t)$.....................................5.1

SCENARIO TWO

$Y_t = 20/ 1+5.27e(-0.004 * t)$.....................................5.2

SCENARIO THREE

$Y_t = 25/1+6.83e(-0.004 * t)$.....................................5.3

5.1.4 RESULTS AND INFERENCE

The result of the telephone density level projected for the coming ten years - starting from 1998 the end point of the actual data under the different scenarios are presented in the following table. We can observe from the table that in year 2002, chosen as target year for this study because of the interest for short term forecast, the telephone density level would be 3.368 per 100 inhabitants in all of the scenarios. The table below shows the projected telephone density level for the coming 10 years starting from year 1998 the end point of the actual data.

TABLE 8

PROJECTED TELEPHONE DENSITY LEVEL

YEAR	ACTUAL TELEPHONE DENSITY	SCENARIO 1	SCENARIO 2	SCENARIO 3
1998	3.33	3.33	3.330	3.330
1999		3.339	3.339	3.339
2000		3.349	3.349	3.349
2001		3.358	3.358	3.358
2002		3.368	3.368	3.368
2003		3.377	3.377	3.377
2004		3.387	3.387	3.387
2005		3.396	3.396	3.397
2006		3.406	3.406	3.406

The inflection point of the logistic curve equation for telephone density level in the first scenario indicates that telecommunication development in these areas need 366 years ($\ln 4.33/(0.004)$ per equation 4.11) in order to reach the maximum telephone density growth level (achieved when the telephone density level reaches 8.5 mainlines per 100 inhabitants) after which the rate of growth of telephone density is expected to decline. This result is ridiculous when one compares the above result with the already achieved large city telephone density level by some African countries. The African average by 1994 has been 5.44 according to the ITU - Telecommunication Development Bureau .The following table speaks for it self .

Table 9

LARGE CITY TELEPHONE DENSITY LEVEL 1994

country	telephone density
Egypt	9.53
South Africa	52.08
Botswana	15.88
Ethiopia	3.01
Gabon	9.05
Nigeria	1.65
Kenya	10.60

Source: African Telecommunication Indicators, ITU, 1996.

In countries where rationing due to demand backlog has been the rule rather than the exception, under-estimating forecasts of telephone density is expected. It is note worthy that demand backlog (that might have been caused by the ongoing sector structure) in telephony service coupled with the high rate of population growth might have resulted in this tortoise pace forecast of growth rate of telephone density. Thus projections based on historical data collected from such sector structure and policy may not be reliable. Reconciling and adjusting the underestimated telephone density level will therefore have great technical and economic impact. Reconciliation and adjustment is needed because given the disparity between the rate of population growth (3 percent on the average) and the rate of growth of telephone density (0.004 percent), projection of future telephone density level seems to be constrained by historical trends which may have been influenced by sector organisation and policy and the level of service tariff.

An alternative way of looking at this result is the transformation of the projected telephone density level into the demand for access. If the sector's organisation and policy continues to be unchanged, that is, if the backlog in demand continues, the telephone density level will remain 3.368 lines per 100 inhabitants in five years from now. When we transform this projected telephone density level into forecast of subscriber lines we arrive at 138,654 (owing to the projected population level of 4.116 million in 2003) mainlines. In this case the additional supply needed to keep pace with demand in five years from now would only be 25,907 mainlines. Unrealistic when one considers the ever increasing population level and the actual waiting list for telephony in these areas. The forecasts of the demand for telephone density and hence residential subscribers is a result of many suppositions- demography being the only determining factor. No matter how intelligently forecasts may be made, the unexpected can often happen and indeed the unexpected has happened to this study. Therefore there is good reason in reconciling and adjusting the forecasts of residential telephone density and hence residential subscriber demand for mainlines to real situations.

Owing to the discussion regarding the use of realistic judgement and the reconciliation of the projected telephone density and hence access demand in this study, we need to review the projected telephone density level on the bases of the changing telecommunications sector organisation and policy in Ethiopia. In this regard this study assumes a shift in sector organisation and policy that allows entry in to the market or introduces liberalisation that encourages fresh and new investment (through strategic partnerships as envisaged by the Ethiopian government for instance). This assumption is based on the official policy of the Ethiopian Government regarding its will and commitment to introduce reform in the Ethiopian telecommunications sector. The policy goal of the government in the restructuring of the sector mainly aims at narrowing the telephone gap and further development in the telecommunications sector. This calls for the narrowing of the resource (financial, management and technological) gap that characterises the sector. Attracting resource and narrowing the telephone gap can only be achieved by opening the sector to competition and introducing other forms of liberalisation. One can not rule out achievement of narrowing the telephone gap and further expansion of the sector within the existing sector organisation framework if in fact capital enough to meet the requirement is allocated to the sector.

However in the process of the liberalisation of and shift in sector policy and organisation (as assumed in this study) the forceful provision of universal access in lieu of the franchise (for a monopoly) to be given can not be discounted. The maximum that the Ethiopian Government can impose as universal service obligation on would be entrants to the sector or on a would be strategic partner (as the government is envisaging) is the raising of the national telephone density level to one line per 100 inhabitants -the frequently cited gaol for sub Saharan Africa. This goal has been recommended by the ITU (later adopted by African countries) after having carried out demand analysis on the basis of the supplied lines, waiting lists and hidden demand for telephony in Africa. Increasing the national telephone level (presently it is 0.26 per 100 inhabitants) to 1 mainline per 100 inhabitants means the raising of the national and urban telephone density by four fold. One has to note that the national telephone density average (0.26 per 100 inhabitants) is less than the urban average (3.01 per 100 inhabitants). Assuming the sector shift can fully be implemented before the target year, the raising by four times of the national teledensity level would automatically raise the projected telephone density level (that assumes the continuity of the present statuesque), for the selected urban areas, to 13.47 mainlines per 100 inhabitants. When translated into the actual demand for access, this telephone density level amounts to 554,532 residential telephone lines, making the additional demand to be 441, 785 residential mainlines (the difference being the already supplied telephone lines). This is Plausible when compared with the waiting list figures for telephone lines in the selected urban areas (See appendix C for complete derivation).

The projection for telephone density levels in our logistic curve model focuses only on residential subscriptions. Business and official telephone users are not included and will have to be estimated separately. This user group dominate in Ethiopia with respect to the telephone revenue contribution. Presently, 70% of all telephone lines are residential while 30% are business and government subscribers. Assuming business subscription will maintain the present proportion, while generating the largest part of telephone revenue, the forecast for telephone lines in five years from now (both residential and business) would be 631,752 mainlines lines. This sum is reached by raising the projected residential subscriber demand (441,785 mainlines) by a factor of 1.43 to accommodate the business subscription demand for telephone lines.

The result obtained in this initial overall forecasting at the aggregate level will be used as a guide for determining localised forecasting at each of the selected local areas. The final value of the forecasts of telephone lines as indicated above is for all selected local areas together. This value will be used as a reference in order to determine similar values for each local areas. The localised forecasts of the access demand together with the results of the load analysis help in the designing of the optimum network of the expansion plan on the bases of which we exercise the incremental supply cost analysis.

5.1.4.1 LOCALISED FORECASTING

Based on the reconciled projected demand level for telephone lines, for the year 2002, and on the basis of the actual data for "expressed demand" for telephones (the data on expressed demand is the sum of connected lines plus waiting list as defined and recorded by the incumbent operator) in each of the selected local areas, the following localised demand for telephone mainlines has been projected. Since there is no way to check on the reliability of the data on the expressed demand (there is no answer why the incumbent operator uses the phrase "expressed demand" while telephone is a rationed commodity in Ethiopia) the reports of the incumbent operator has been taken for granted.

TABLE 10

LOCALISED FORECASTS

TOWN	EXPRESSED DEMAND	PERCENTAGE OF EXPRESSED DEMAND	PROJECTED DEMAND FOR SUBSCRIBER LINE
ADDIS ABABA	208940	87.44%	487073
MEKELE	5970	2.5%	15794
DIRE DAWA	8394	3.5%	22111
JIMMA	4641	1.94%	12256
SHASHEMEENE	2321	0.97%	6128
DESSIE	4188	1.75%	11056
BAHIRDAR	4564	1.9%	12003

TOTAL			631752

5.2 THE OPTIMISED NATIONAL NETWORK

Using the specification for access demand and the load analysis for network dimensioning in chapter four, and other variables such as the grade of service assumption, optimisation of the target national network capable of satisfying the increasing network access and peak hour network utilisation demand has been undertaken. The target network is configured to be most economical. It creates the preparedness to satisfy demand. The incremental cost analysis based on the overall costs of this optimised network will be assessed in 5.4. In this section, planning of the national switching networks and transmission networks is done using the historical average traffic intensity and dispersion data (Table 5) that show the busy (peak) hour traffic records for each route in the localised selected areas for which, after averaging, the mean busy hour traffic characteristics is obtained. Also considered in load analysis and dimensioning process of the national network is the projected demand for local access-Table 10. The result of network optimisation process are organised in three sections. First the computed long distance circuit requirements will be demonstrated. Second the estimated capacity of the national transit switching and other common equipment shall be presented. Third the new additions into local switching equipment will be depicted.

5.2.1. REQUIRED TRUNK GROUPS

The number of optimal long distance circuits between a local exchange and a national transit depends partly on the traffic which can be carried out in that route measured in traffic units -usually Erlang - and the permissible proportion of lost calls for the route under consideration. In order to compute the optimal trunk circuit requirements between the national transit and the respective selected local areas the following inputs were used:

- The traffic intensity measured in Erlang and the dispersion of same from the existing telephone system as shown in Table 5. This provides the per subscriber incoming and outgoing traffic in Erlang to and from all the selected areas.
- The assumption of 1% permissible proportion of lost calls i.e. the grade of service of 0.01.
- The maximum efficiency of overflow circuit of 90 %.
- The localised access demand forecast as shown in Table 10.

On the basis of the framework for network optimisation and the direct routing assumption (as discussed in the supply framework in this study) the following numbers of trunk groups and circuits are determined for use between pairs of transmission nodes (between a local exchange area and the national transit). The trunk group is grouped on a both way bases in order to maintain good efficiency.

TABLE 13

OPTIMISED LONG DISTANCE CIRCUIT

FROM TO THE NATIONAL TRANSIT TO	PROJECTED LOCAL ACCESS DEMAND	LONG DISTANCE ERLANG PER SUBSCRIBER	TOTAL LONG DISTANCE TRAFFIC IN ERLANG	OPTIMAL CIRCUIT AT 0.01 GRADE OF SERVICE
MEKELE	15794	0.0368	581.21	615
DIREDAWA	22111	0.0239	528.45	560
JIMMA	12256	0.0209	256.15	280
SHASHEMENE	6128	0.0217	132.97	154
DESSIE	11056	0.0302	333.89	360
BAHIRDAR	12003	0.0367	440.51	470
ADDIS ABABA	487073	0.01242	6049	7200
TOTAL				**11140**

The optimised number of trunk groups or circuits are obtained by multiplying the localised projected demand for access by the corresponding long distance Erlang per subscriber (split from the pre subscriber incoming and outgoing traffic -Table 5), by taking into consideration the proportion of the long distance traffic over local and dividing the product by the maximum efficiency factor 90% -the efficiency factor for all digital networks. This generates the total long distance Erlang of subscribers. The optimal circuits were obtained from Conny Palm Table of the Erlang Loss Formula that tabulate the number of circuits required as a function of the target probability blocking (grade of service) and the traffic offered.

5.2.2. REQUIRED NATIONAL TRANSIT AND LOCAL SWITCHING CAPACITY

The design for national transit switching depend on the traffic intensity per subscriber and the distribution of these traffic. The optimal capacity required is the sum of the optimal long distance trunk groups or circuits since each of these units need specific ports or servers in the national transit. Assuming full availability of access, the total number of port capacity required for the national transit is 11140 (See Table 13). The availability of a traffic route is defined as the number of trunks in the route that can be reached from a given inlet to the switching stages. In this study availability is constant and numerically equal to the number of servers in the trunk group concerned. The result of the optimal local switching units that relate to the demand for subscribers access as indicated in 5.1.1 is 631752(See Table 10).

5.3 THE PROJECTED CHARGEABLE TRAFFIC

Chapter four of this study provided the specification of demand forecasting for telephone traffic service- traffic measurements from the present system. The purpose of this section is to provide the estimates of the four different categories of traffic service as per the specification of demand for usage. We need to estimate the peak and slack period chargeable traffic minutes for both local and long distance calls. We use these for the determination of incremental cost. The different traffic services categories are: local peak, local off - peak, long distance peak and long distance off- peak. The forecast is also useful for traffic revenue forecasting and the welfare optimisation exercise.

The exchange traffic projected is based on measuring the calls carried during the busy and slack (off peak) hours at Filwoha 3 exchange. To arrive at the chargeable traffic minutes, 20 % of the carried traffic has been taken off. The traffic carried on each circuit group has been split into outgoing flows of traffic via the national transit and into those which are local calls. There is no specialised measurement according to subscriber categories so no distinction is made between residential and business subscriber calls. The traffic is measured in Erlang and is converted into annual minutes and or pulses using equation 4.1.2.

The result of the projected usage of traffic in paid minutes for all subscribers (residential + business), for the selected areas, in the two different categories (peak and off peak) for both local and long distance hours is presented by the following Tables. TABLE 11 shows the projected traffic for busy hours and Table 12 depicts the projected traffic for slack hours.

Table 11

BUSY HOUR PROJECTED TRAFFIC

TOWN	LOCAL CALLS IN ERLANG	LONG DISTANCE CALLS IN ERLANG	LOCAL CALLS IN MINUTES	LOCAL CALLS IN PULSE	LONG DISTANCE CALLS IN PULSE /MINUTES
ADDIS ABABA	10686.38	988.75	2769909696	461651616	256284000
MEKELE	344.21	32.06	82219232	14869872	9309952
DIRE DAWA	481.88	44.88	12490296	20817216	11612160
JIMMA	267.1	24.87	69232320	11538720	6446304
SHASHEMENE	133.55	12.43	34603200	5767200	3221856
DESSIE	240.35	22.44	62298720	10383120	5816448
BAHIRDAR	261.59	24.36	67804128	11300688	6314112
TOTAL				**536,328,432**	**298,004,832**

Table 12

SLACK HOUR PROJECTED TRAFFIC

TOWN	LOCAL CALLS IN ERLANG	LONG DISTANCE CALLS IN ERLANG	LOCAL CALLS IN MINUTES	LOCAL CALLS IN PULSE	LONG DISTANCE CALLS TIN PULSE MINUTES
ADDIS ABABA	3713.44	312.7	962523648	160420608	81051840
MEKELE	120.41	10.13	31210272	5201712	2625692
DIREDAWA	168.57	14.19	43693344	7282224	3678048
JIMMA	93.43	7.86	24217056	4036176	2037312
SHASHEMENE	46.71	3.93	12107232	2017872	1018656
DESSIE	84.29	7.09	21847968	3641328	1837728
BAHIRDAR	91.51	7.7	23719392	3953232	1995840
TOTAL				**215,695,152**	**94,245,116**

5.4 INCREMENTAL COST ANALYSIS

Once the optimum network capacity (the least cost investment) and the forecasts of service demand has been determined, the incremental cost relevant to optimal pricing can be derived. The incremental cost of each of the services category is calculated from the following components: the annual capital cost, the annual maintenance and operational cost and the 20 percent profit target on invested capital and of course the respective service demands. The annual equipment cost is annuatized over the life time of the equipment. The cost of equipment used in the analysis was a forward looking and is determined at border price. The analysis assume no tax , subsidy, administered price and market distortion hence shadow pricing for the domestic components of costs were not employed.

5.4.1 INCREMENTAL COST FOR NETWORK ACCESS SERVICES

The network access incremental costs were determined at the network access component level at which they are incurred. The costs considered are the long run incremental cost of the system that include both capital and the recurrent maintenance costs. The capital cost is converted into annual costs by annuatizing at 12% interest rate over the life year of the equipment life span. The recurrent annual access charge per subscriber is determined by dividing the annual long run incremental access cost (corresponding to the recurrent access part) by the subscriber line to be installed. To arrive at the monthly rental, the annual recurrent incremental access cost per subscriber is divided by 12 months. The monthly rental incremental cost derived in this study is Birr

23. This is 2.86 times more than what the incumbent operator charges as a monthly rental. However, the incumbent operator charges Birr 315 as initial payment for access. In such a scenario, comparisons of price disparity will not be an easy exercise. Appendix D1 present the computation of the fixed recurrent monthly rental.

5.4.2. INCREMENTAL COST FOR NETWORK UTILISATION SERVICES

5.4.2.1. BUSY HOUR CALL CHARGES

Telecommunications operators provide network utilisation services over a number of time periods (twenty four hours a day) having greatly different demand schedule. Network capacity however should be kept to the level of peak hour demand. In this engineering economic model of incremental cost determination, the system is optimised so as to keep the probability of loss of calls to a minimum by designing the optimum network at 0.01 grade of service. Therefore, the peak load incremental cost for network utilisation services is determined by the investment cost of the equipment, discounted to the present time, appropriately annuatized. The per unit incremental cost for peak hour is determined by dividing the sum of the annuatized peak hour component of capacity cost and the maintenance and operational cost by the projected local or long distance traffic pulse levels at the busy hour. The objective for the peak hour incremental cost is the attainment of economic efficiency. Hence, peak time users pay both the capacity and the variable cost .

5.4.2.2. SLACK HOUR CALL CHARGES

Implicit in the peak hour incremental cost pricing in this study is efficiency and the approximation to the perfect competition scenario. In this case the telecommunications enterprise would be set a profit target of zero, and is required simply to break-even. However, telecommunication service pricing must be used for a wider national interest that aim the promotion of the telecommunication industry along with efficiency. It is useful therefore to structure incremental cost to permit industrial promotion and financial self sufficiency. Therefore a 20 % return on invested capital and the variable cost at slack hours are used to calculate the slack hour traffic services incremental cost. The per unit slack hour traffic service is arrived by dividing the service specific slack hour cost by the corresponding projected slack hour traffic services. The study assumes exante and expost monitoring and auditing of the out turns by the regulatory watchdog so that the profit target is maintained. One has to note here that such control is normal else where in the world though it take the form of a " price cap". Appendix D2 and D3 show the computed incremental cost for local and long distance telephone call services at the busy and slack hours.

It is important to note that the analysis of determination of the incremental cost for each service category were based on the expansion programme of the telephone network for the selected urban areas. The incremental cost derived for optimal pricing is a forward looking one. The results in this study indicate that the current network utilisation (local and long distance calls) service charges that the incumbent operator levies on the consumer exceed the incremental cost derived in the study assuming infact the current tariff structure and level of telecommunication services remain unchanged (in Ethiopia tariff revision for telephony seldom occur and when revised they are usually raised) in the coming five years. The case for the monthly recurrent access charge, however, is completely different. The current charge is found to be only 34 percent of the incremental cost derived for the monthly access service in this study to be specific. The strict long run incremental cost for the busy and slack hour local calls charges are found to be 50 and 25 percent of the current charges. For the long distance calls the busy and slack hour incremental costs are only 33 and 21 percent of the current charges per pulse interval. Implicit in the determination of incremental cost for long distance telephone service was that it is distance insensitive. The comparison in the price disparity in the long distance case give sense when the dimension of the comparison is the time (not distance) and when we assume all the selected areas are equidistantly positioned. The over pricing of the local telephone service as indicated in chapter three of this study was also one of the findings of SWEDTEL. One further point regarding the local call is that it has grater sensitivity to price than any form of network connection or access services. All other things equal the welfare losses or distortions to efficiency caused by high call charges will be greater. On the whole in the realm of supply shortage the existence of the marginal opportunity cost of high level tariff in excess of the marginal physical cost of making services available may not be surprising. The following table depicts the price disparity between the existing tariff structure and the findings of this study :

Table 14

TARIFF COMPARISONS

1 SERVICE TYPE	2 EXISTING CHARGE IN BIRR	3 DERIVED INCREMENTAL COST IN BIRR	3 /2 DERIVED CHARGE OVER EXISTING CHARGE
LOCAL CALLS			
BUSY HOUR	0.20	0.10	0.50
SLACK HOUR	0.20	0.05	0.25
LONG DISTANCE CALLS			
BUSY HOUR	0.60	0.20	0.33
SLACK HOUR	0.48	0.10	0.21
MONTHLY RENTAL	8.00	23.00	2.88

5.5 SUMMARY OF INCREMENTAL COST ANALYSIS

5.1.1 . ANNUAL COST

(a) Network access component	
- Rental fee	Birr 174,051,703
(b) Network utilisation component	
(1) - Local calls	
- Busy hour	Birr 54,484,703
- Slack hour	Birr 10,784,758
(2) - Long distance calls	
- Busy hour	Birr 60,464,274
- Slack hour	Birr 8,957,670

5.5.2 SERVICE DEMAND

(a) Network access component		631,752
(b) Network utilisation component		
(1) - Local calls		
- Busy hour	pulses	536,328,432
- Slack hour	pulses	215,695,152
(2) - Long distance calls		
-Busy hour	pulses	298,004,832
- Slack hour	pulses	94,245,116

5.5.3 INCREMENTAL COST PER UNIT

The marginal cost per unit was obtained by dividing the annual cost in 5.5.1 by estimated demand in 5.5.2.

(a) Network access component

. Fixed monthly rental	Birr 23 per month

(b) Network utilisation component

.Local calls	
.Busy hour	Birr 0.10 per pulse
.Slack hour	Birr 0.05 per pulse
. Long distance calls	
.Busy hour	Birr 0.20 per pulse
.Slack hour	Birr 0.10 per pulse

CHAPTER 6

6. CONCLUSION AND POLICY IMPLICATIONS

This study adds to the limited empirical body of knowledge about the supply side determination of optimal pricing by public utilities in Ethiopia, focusing in the telecommunications industry. It asses the determination of incremental costs for telecommunication services in the seven main urban areas using engineering economic estimates and the peak-load price differential technique. The main aspects of the engineering economic study in the determination incremental cost were: the demand and supply analysis of a physical model (the expansion plan envisaged in the study) and the determination of incremental cost through annuatization of relevant costs.

The result in this study revealed that both the fixed charges (the recurrent monthly) for access or connection services and the usage sensitive local and long distance call service are badly distorted. In other words, the present connection and usage charges deviate from the incremental costs derived in the forward looking engineering economic estimates.

Underling the existing traditional method of pricing telecommunication services in Ethiopia are: First, the pricing philosophy is concerned with recovering sunk cost not actual resource cost used or saved by the consumer decision. In this context if the past holds a number of projects, the sunk cost of mistakes, if reflected in prices, will overstate the cost to the consumer of extra consumption. Second, fairness and equity in the existing traditional approach is couched in rather narrow terms, not on costs considered in isolation. As such it depends on, for example, whether the consumer is residential or business user, whether the consumer is in the big towns or in the rural interior (the-value-of-service-case) and of course whether the consumer deserves special concession -the political consideration. Not on the cost burden that the consumer imposes on the telecommunication operator. Third, the focus has been the financial requirement of the incumbent operator. In this connection the incumbent enterprise has never been a burden to the public budget and rather has been significantly contributing to the fiscal budget. High profits are maintained because of the focus on financial adequacy that might have caused the significant excess of the existing usage service prices over their incremental cost. This could cause significant inadequacy and inefficiency in the management of the public monopoly since the financial incentive to effective management is lost. Fourth, the traditional pricing model based on sunk cost recovery will not allow the benefits of the decline in investment, price reductions, to pass on to consumers.

Three stylised facts emerge with the acquisition of incremental cost, as optimal pricing strategy, for telecommunication services:

First, the engineering economic estimate of incremental cost pricing will lead to a more efficient allocation of resource than the prevailing traditionally based telecommunication service pricing since it is based on the forward looking resource cost rather than the backward looking sunk cost. This is because forward looking resource cost reflect to the economy the real costs of the resources used. In other words, the consideration in the determination of incremental cost in engineering economic model is the amount of future resource used or saved by the consumer decision.

Second, beyond economic objectives, the application of incremental cost in the peak load price setting give due weight to the financial aspect of telecommunications pricing to ensure not only solvency of the telecommunications enterprise but also its ability to generate cash internally and raise in the form of debt and equity and in short the promotion of the industry .

Third, incremental cost determination in the peak load price differential setting enables the consideration of equity in relation to the cost burden consumers impose on the system.

The general conclusion is that the Ethiopian telecommunications industry should proceed toward an optimal price structure based on incremental cost that is determined by the forward looking engineering economic studies. Whether other objectives prevail, they should be analysed with the full knowledge of economic cost of diverting from the strict incremental cost approach. Incremental cost, in other words, should be a bench mark by which other pricing policies should be evaluated. Furthermore, this analysis of incremental cost must also be applied to other public utility sector with a care full case- by- case study on the implication of incremental cost pricing to the sector under review.

The following policy implications can be drawn from this study:

First telecommunications policy makers should stop approving the computed-cost-of service presented to them by the telecommunications operators since it has costs that outweigh benefits. To this end, the regulatory watch dogs of the country's telecommunications sector should start imposing optimal pricing so that there be an incentive to hold costs to a minimum.

Second, there appears to be a need to evaluate the managers of public owned telecommunications monopoly on the basis of performance indicators based on incremental cost pricing scheme. In this respect, managers of the public monopoly should be given freedom of decision on how resources should be used. This has an inestimatable virtue in giving a clear-cut guidance to the decision on the quantity and quality of telecommunications investment.

It is note worthy that in public utilities like telecommunications, the only way in which the minimum economic worth of investment can be determined, by managers of public monopolies, is by giving consumers themselves the chance to let the managers know how much they value the services, by being charged a price that reflect the incremental cost of supply.

Third, there is a need for improving telecommunication service prices to reflect the economic cost of producing it. In this regard, prices should make real costs apparent to the respective beneficiaries of services. Thus prices should give due emphasis about the degree of demand consumers place on the telecommunications operator.

Fourth, there is also a need for sector review. Given the importance of telecommunications for economic development and in view of the supply back- log that led to the rationing and overpricing of telecommunications services, policy makers should design sector policy that could lead to the maximisation of the net economic benefit.

APPENDIX A

LOGISTIC MODEL

In forecasting telephone penetration or telephone density in a developed area where demand is expected to saturate in a foreseeable future such as the metropolitan telecommunication area of a country the logistic curve model is generally the most appropriate .It accounts for a future situation where there will be demand saturation and hence gradual decrease of the annual growth rate. The model relates to bounded growth -logistic function as opposed to unbounded growth exponential function where the rate of growth of Y(t) is proportional to Y(t) .Algebraically

$dY_t / dt = kY_t$...A.1

where k is a constant of proportionality.

Assume now that in reality when the telephone penetration level gets large - when every household gets connected to a telephone network -growth dumpens. To express this algebraically : the telephone penetration growth rate dY_t/dt eventually decrease and assume that the penetration level is limited to some maximum, q, where, $0< Y_t <q$ .As Yt approaches to q dY_t/dt approaches to 0 ,so that the telephone penetration level tends to become stable as t approaches to infinity .The following expression is a typical characterisation of bounded growth rate in telephone penetration.

$dY_t/dt = k Y_t * q-Y_t/q$...A.2

This equation meets the condition of bounded growth in the factor $q-Y_t/Q$ .The factor $q-Y_t/q$ alters the symbolic form of the logistic form from the exponential and acts a dumper to growth.

Replacing k/q by K so that the logistic equation now reads :

$dY_t /dt = K Y_t (q-Y_t)$ A.3

The rate of growth of telephone penetration level is proportional to the product of the telephone penetration level and the difference between the maximum size and the penetration level at time t.

Solving for this later equation for Y_t

$(dY_t)/(Y_t(q-Y_t) = Kdt$ A.4

To yield

INT $(dY_t)/ (Yt (q-Y_t)) =$ INT K dt A.5

Use a table of integral on the rational form in the left hand integral:

$1/q * \ln |(Y_t) / (q- Y_t) | = K_t + c$ A.6

$\ln | Y_t / (q- Y_t) | = q K_t + qc$ A.7

Because $Yt > 0$ and $q - Y_t > 0$,

$Ln (Y_t / (q-Y_t)) = q K_t + q c$ A.8

Therefore ,taking antilogarithms

$Y_t/(q-Y_t) = e(qK_t) e(qc)$ A.9

Replacing e (qc) by A. Therefore ,

$Y_t / q-Y_t = A e(qK_t)$ A.10

$Y_t = (q-Y_t) A e (qK_t)$ A.11

$Y_t = qAe(qK_t) - Y_t Ae(qK_t)$ A.12

$Y_t + Y_t Ae(qK_t) = q Ae(qK_t)$ A.13

$Y_t = (qAe(qK_t)/ Ae(qK_t) + 1)$ A.14

Dividing top and bottom of the last equation by $Ae(qK_t)$. (equivalent to multiplying by 1) ,so that

$Y_t = q/1 + (1/ (A e(qK_t)))$ A.15

$Y_t = q / (1 + 1/A * e(- qK_t))$ A.16

Replacing 1/A by a and -qK by b produces a common form for logistic function : $Y_t = q / 1+a e(bt)$ A.17

with $b < 0$ because $b = - q K$

and $q , k > 0$.

APPENDIX B

INITIAL POPULATION AND TELEPHONE DENSITY LEVELS

YEAR	TELEPHONE LINES	POPULATION LEVEL	TELEPHONE DENSITY PER 100 INHABITANTS
1984	58257	1836173	3.19
1985	62085	1921046	3.23
1986	67269	1999557	3.36
1987	69156	2091172	3.30
1988	68293	2188421	3.12
1989	75775	2288629	3.32
1990	83361	2394907	3.48
1991	90028	2508709	3.58
1992	86402	2624350	3.29
1993	90908	2741931	3.32
1994	94512	2861121	3.30
1995	98441	2981962	3.30
1996	102996	3110055	3.31
1997	106898	3246978	3.29
1998	112747	3387926	3.33
1999		3527294	
2000		3663743	
2001		3807343	
2002		3960283	
2003		4116795	
2004		4272089	
2005		4424169	

SOURCE :Ethiopian Telecommunication Authority
Central Statistical Authority

APPENDIX C

LOGISTIC CURVE FIT

Using actual data of telephone density

APPENDIX C

LOGISTIC CURVE FIT

Using actual data of telephone density

Equation : $Y_t = q/ 1 + a\, e\, (bt)$, $b< 0$ B.1

Given the historical telephone density data for the selected areas to values for a and b all that is required is two values of t , and upper bound q , and the assumption that the distribution is logistic.

Supposing a household constitute six persons and we assume one telephone line per household , the telephone density level is 17 mainlines per 100 inhabitants .Supple again that the last (base) year for which we have actual telephone density level is year 1994, and assuming a logistic representation of in the form of :

$$Y_t = 17/ 1+ a\, e\, (bt) \quad \text{B.2}$$

In 1984, when $t = 0$ $Y_t = 3.19$

Thus , $3.19 = 17/ \; 1+ a$

Thus $a = 4.33$

To find b , we use the actual telephone density data end point from 1998.

In 1998, when $t = 14$ $Y_t = 3.33$

$3.33 = 17 / (1+ 4.33 * e (14 * b))$

$1+4.33 * e(14*b) = 17/ 4.33 = 5.10$

$4.33\, e (14 *b) = 4.10$

$e(14 * b) = 0.95$

$14\, b = \ln (0.95)$

$14\, b = - 0.05$

$b = - 0.004$

Thus the rate of growth of telephone density level (the yearly increment) 0.004. The logistic representation takes the form ,

$Yt = 17 / 1 + 4.33\, e\, (0.004* t)$ B3

APPENDIX D 1

INCREMENTAL COST FOR MAINLINES

RECURRENT MONTHLY RENTAL

1 Cost

A. Purchase cost of investment and installation	
1. Outside plant (cables and ducts)	Birr 818,752,935
2. Subscriber stage switching	77,033,530
3. Main distribution frame	71,229,375
4. Power equipment	7,133,056
B. Annual capital cost	
1. 12% ; 30 years , 0.12414	Birr 101,639,986
2. 12% ; 10 years , 0.17698	13,633,398
3. 12%; 10 years , 0.17698	12,606,174
4. 12%; 10 years , 0.14682	1,047,277
Total annual capital cost	128,926,835
C Maintenance and Operation cost	
(35 % of the annual capital cost)	45,124,392
D Total cost	174,051,227
2 Service demand	
E Number of subscribers	631,752
F Annual Incremental cost per mainline	Birr 275.50
G Monthly incremental access cost	Birr 23.00

APPENDIX D2

INCREMENTAL COST FOR LOCAL CALL CHARGES

(a) BUSY HOUR

1 Cost		
A. Purchase cost of investment and installation		
1. Switching unit subscriber stage	Birr	103,995,269
2. Switching unit group selector stage		5,496,890
3. Common control equipment		115,981,271
4. Power		2,567,901
B. Annual capital cost		
1. 12% ; 10 years , 0.17698	Birr	18,405,086
2. 12% ; 10 years , 0.17698		972,839
3. 12%; 10 years , 0.17698		20,526,646
4. 12%; 10 years , 0.17698		454,468
Total annual capital cost		40,359,039
C Maintenance and Operation cost		
(35 % of the annual capital cost)		14,125,664
D Total cost		54,484,703
2 Service demand		
E Number of busy hour pulses	pulses	536,328,432
F Incremental cost per pulse	Birr	0.10

(b) SLACK HOUR

A .Profit target & Maintenance and operation cost	Birr	10,784,758
B. Slack hour pulse	pulse	215,695,152
C Incremental cost per pulse	Birr	0.05

APPENDIX D 3

INCREMENTAL COST FOR LONG DISTANCE CALL CHARGES

(a) BUSY HOUR

1 Cost	
A. Purchase cost of investment and installation	
1. Switching unit subscriber stage	Birr 69,330,177
2. Switching unit group selector stage	3,664,591
3. Common control	77,320,845
4. Power	1,711,983
5. National transit	11,832,030
6. Long distance Transmission (fiber+ radio)	10,775,850
B. Annual capital cost	
1. 12% ; 10 years , 0.17698	Birr 12,270,055
2. 12% ; 10 years , 0.17698	648,577
3. 12%; 10 years , 0.17698	13,684,244
4. 12%; 10 years , 0.17698	302,981
5.12 %; 15 years, 0.14682	2,094,813
6.12%; 15 years, 0.14682	15,787,681
Total annual cost	44,788,351
C Maintenance and Operation cost	
(35 % of the annual capital cost)	15,675,923
D Total cost	60,464,274
2 Service demand	
E Number of busy hour pulse interval	pulse 298,004,832
F Incremental cost per pulse	Birr 0.20
(b) Slack hour	
A Profit target & Maintenance and operation cost	Birr 8,957,670
B Slack hour pulse	94,245,116
C Incremental cost per pulse	Birr 0.10

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Declaration

I, Abdulsemed Hussien, hereby declare that this thesis is the product of my original research work, all materials are duly acknowledged, and that it has not been submitted to any other University for an award of any academic degree.

Signature: ____________________

Date : JUNE 17, 1998

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