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TELECOM INFRASTRUCTURE MODERNIZATION AND UNIVERSAL SERVICE IN DEVELOPING COUNTRIES: THE ROLE OF CELLULAR/WIRELESS TECHNOLOGIES

By

Arno Baltais

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ABSTRACT

TELECOM INFRASTRUCTURE MODERNIZATION AND
UNIVERSAL SERVICE IN DEVELOPING COUNTRIES:
THE ROLE OF CELLULAR/WIRELESS TECHNOLOGIES

By

Arno Baltais

This thesis will examine the role of wireless technologies in telecommunications infrastructure modernization and the achievement of universal service in developing countries. In addition, the issue of cost effectiveness of wireless telephony, compared with wireline, is addressed.

To analyze the role of wireless technologies, their financial feasibility and technological availability and superiority, if any, is considered. The main source of information come from publications of International Telecommunication Union, World Bank, and from my personal contacts with senior officials of telecommunications industry.

The major finding of the study is that telecommunications infrastructure needs to be looked on as a promotional tool for national development, not just as a simple commercial service, based on direct payment. Wireless technologies need to be considered and implemented more aggressively, and especially in rural areas for achieving universal coverage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

This thesis will examine the role of wireless technologies in telecommunications infrastructure modernization and the achievement of universal service in developing countries. Specifically, it attempts to answer the questions: what is the role of wireless/cellular technologies in telecommunications network modernization in developing countries and what kind of obstacles these particular technologies face in current liberalization and privatization processes undertaken in many developing economies? In addition, this thesis will address the issue: is the wireless telephony more cost effective compared with wireline? The increasing role of wireless technologies for communications has been identified and studied by many researchers: Frieden (1993), Swensrud and Friedman (1994), Ford (1994), Westerveld and Prasad (1994), Wellenius (1992, p.12); Ashutosh and Kazeminejad (1992), and others.

In this context, the analysis of the role of wireless technologies means to analyze them in terms of their financial feasibility and technological availability/superiority, if any. The technological advances in wireless/cellular systems are widely publicized, while the the costs of these wireless systems are hidden for marketing purposes. This analysis uses investment figures for wireline connection published mainly by the International

connection published mainly by the International Telecommunication Union (ITU) and World Bank (WB), whereas the main source of information for wireless/cellular systems came from personal contacts with senior officials and public relations people during my work with Telia International AB in Stockholm and International Technology Consultants in Washington D.C. It also relies on papers presented at the Conference "Cellular Mobile" in Budapest, Hungary in May 16-17, 1994.

Technological changes in the wireless industry led to the constantly decreasing costs and improving performance of wireless networks. Recent changes in telecommunications policy, undertaken by many developing countries, have opened opportunities for wider use of wireless technologies. State-of-the art digital technology became available for those countries in addition to private capital investment, local and foreign, which has been allowed in order to facilitate network modernization and growth. In addition, internal restructuring of telecommunications entities has been taking place, which will hopefully result in more efficient structure of the industry.

There have been many discussions on how important the telecommunications infrastructure is for national development, and how a great gap has developed over a long period of time between developed and developing countries (Wellenius, 1989; Muller, 1991; Hills, 1990; Gillespie, 1988, etc.). Along with those discussions, it has been

stressed how costly the telecommunications infrastructure is and how much investment is needed in order to meet the anticipated demand, or at least reach half the level of telephone penetration of industrialized economies. This thesis views the same problem from the technological point of view, where the advances in wireless/cellular technology can help to resolve some of the issues more efficiently and faster. In addition, this paper will address concerns with recent policy changes in many developing countries which led to the selling-off of local companies and introduction of foreign-owned monopoly operators. My personal experience with these changes in my home country, the Republic of Latvia, as well as, the very well known economy of Russia and all of the former USSR, gives me valuable insight and understanding of this issue.

Finally, I want to admit that I support the idea that wireless/cellular is the technology for the next generation, and sooner or later, will be used on a regular basis in the local loop connection for basic voice and data communications either as a substitute or as a supplement for traditional wire-line connection. The same might be true not only for developing nations but also for developed countries which have already reached universal (nation-wide) penetration of telephones.

Let us look at some of the issues which have led me to believe that wireless/cellular technologies are the most appropriate for the needs of developing countries, where the

modernization of the network was given a priority status. Several countries have already started to use wireless systems on a regular basis, and not only as an overlay network (independent network interconnected to the public network), but also as a natural extension of the already existing wire-line infrastructure.

Telecommunications for National Development

Telecommunications, a rapidly changing and growing sector worldwide, is now generally recognized as an essential element of economic development strategies. The information sector accounted for one-third to one-half on GDP and of employment in OECD countries in the 1980's, and is expected to reach 60 per cent for the European Community in the year 2000 (Wellenius, 1992, p.1). Information also accounts for a substantial proportion of GDP in the newly industrialized economies and the modern sectors of less developed countries. Telecommunications constitutes the core of, and provides the infrastructure for, the information economy as a whole. According to Wellenius (1992, p.1), "telecommunications facilitates market entry, improves customer service, reduces costs and increases productivity." To effectively participate in the local and global economies, countries and firms must have access to modern telecommunications. This applies to all countries and especially to those least developed and middle-income countries which have plans to

integrate into the global economy market.

Bauer (1993) points out two important phenomena -- worldwide integration of key markets (such as the international financial system) and the transformation of multinational enterprise into global enterprise. Telecommunications is, no doubt, one of the major prerequisites for such integration and transformation, and that is why developing countries are so desperately trying to modernize or, in many instances, simply expanding telephone services.

However, the modernization process is not quite that simple. There are several considerations which must be taken into account. Financial considerations, such as, what are the sources of financing for the modernization plans and are hard currency and single exchange rates available. Political consideration should be evaluated, to clearly define telecommunications and general business related matters. Cultural issues play an important role, especially if a state telecommunications entity (traditionally viewed as a public enterprise) is being proposed for privatization to foreign investors. Infrastructure decisions, such as, whether the new technologies, such as satellite and cellular, will be implemented need to be evaluated. In addition, the dilemma for incumbent operators and governments is to decide what the priority for universal service is?

Telecommunications: The Widening Gap

In today's stage of market globalization and the prevailing role of information in successful business operation the role of telecommunications can not be over-emphasized. Calculating how much telecommunications contributes to the economic development is very difficult. It is also hard to estimate the loses due to poor telecommunications infrastructure. Despite the fact that telecommunications is one of the major revenue sources in developing countries, that sector of infrastructure has been constantly under invested. When in 1984 the International Telecommunication Union (ITU) for the first time credited telecommunications as one of the major facilitators of economic development in developing countries, a tremendous gap developed between telecommunications infrastructure in developed and less developed economies (The Missing Link, 1984). Although the overall telecommunications investment in the developing world grew in the last 20 years at 10-12 percent per annum, in real terms to about US$11 billion in the late 1980's, this averaged only 0.4-0.6 percent of the GNP. Countries which invested a much larger share of the GNP (Singapore - 1.1 per cent, Malaysia - 2.3 percent) succeeded more rapidly in the modernization of their telecommunications networks (Wellenius, 1992, p.2).

What could be the most impressive fact to support the big disparity between developed and developing economies is

that the city of New York has more telephone lines than the whole continent of Africa. Although there are 600 million telephones in the world, it is estimated that two-thirds of the world's population have no access to telephone services. Nearly three quarters of the world's population live in countries with ten telephones or fewer for every 100 people; over half the world's population lives in countries with less than one telephone per 100 people (The Missing Link, 1984).

According to ITU statistics (World Telecommunication Development Report, 1994), the average penetration of main lines per 100 inhabitants in low income countries is 0.80, where in developed economies, the average is 49.14. Among the low income countries Cambodia has the fewest main telephone lines per 100 inhabitants - 0.06. Table 1 presents the selected telephone related statistics for different countries. Among developing countries there are distinctions in general development (GDP per capita) and telephone penetration (main lines per 100 inhabitants).

Clearly, these distinctions will play a significant role in technology acceptance and implementation in modernization plans. Table 1 shows that low income, lower middle income, and upper middle income countries, based on their GDP per capita, have noticeable differences in telephone penetration rates and waiting lists for telephone services. Even though the penetration of main lines per 100 inhabitants increases for more developed economies, the waiting list also increases. The average waiting list in years in low income

Table 1 Main Telephone Related Statistics in Selected Countries, 1992.

Country	Population millions	Density per sq.km.	GDP per capita	Main Lines thousands	Main Lines per 100	Waiting list, thousands	Waiting list,years
Afganistan	21.6	34	125	29.0	0.13	125.0	...
China	1,175.7	123	320	11,469.1	0.98	1,620.4	0.8
Egypt	55.2	55	550	2,173.6	3.94	1,267.5	6.1
India	879.6	278	285	6,796.7	0.77	2,845.9	3.9
Indonesia	184.0	96	635	1,485.3	0.81	225.7	1.1
Sri Lanka	17.4	265	475	135.5	0.78	96.2	9.6
Tanzania	25.9	28	105	81.3	0.31	134.3	>10
Zaire	39.9	17	200	36.0	0.09	...	...
Low Income total 54 countries	3,214.4	84	310	25,793.8	0.80	8,586.9	2.5

Country	Population millions	Density per sq.km.	GDP per capita	Main Lines thousands	Main Lines per 100	Waiting list, thousands	Waiting list,years
Algeria	26.4	11	1,710	962.2	3.65	756.9	>10
Bulgaria	9.0	81	795	2,339.7	26.14	585.0	5.1
Namibia	1.5	2	1,530	61.0	3.99	3.1	0.9
Peru	21.9	17	2,295	613.7	2.81	346.2	>10
Poland	38.4	123	2,040	3,945.0	10.28	2,422.0	8.9
Thailand	57.8	112	1,640	1,790.0	3.10	1,591.8	7.6
Turkey	58.6	75	1,880	9,471.9	16.17	1,202.9	1.0
Ukraine	52.2	86	2,290	7,577.9	14.52	3,685.4	9.4
Lower Middle Income total 66 countries	789.8	33	1,470	55,711.3	7.05	20,205.6	4.7

Table 1 (cont'd).

Country	Population millions	Density per sq.km.	GDP per capita	Main Lines thousands	Main Lines per 100	Waiting list, thousands	Waiting list,years
Argentina	33.1	12	3,945	3,682.1	11.12	373.7	3.1
Brazil	156.3	18	2,745	10,670.1	6.83	510.3	0.8
Latvia	2.6	41	3,765	652.5	24.81	170.5	9.7
Mexico	89.5	45	3,260	6,753.7	7.54	662.5	1.0
Portugal	9.8	107	6,980	3,162.5	32.12	132.8	0.4
Russia	149.5	9	518.6	22,849.0	15.28	10,016.2	8.5
S. Africa	39.8	34	2,980	3,524.1	8.85	120.4	0.8
Uruguay	3.1	17	3,155	492.1	15.72	84.1	2.2
Upper Middle Income total 43 countries	638.3	16	3,520	86,113.5	13.49	86,113.5	6.3

Country	Population millions	Density per sq.km.	GDP per capita	Main Lines thousands	Main Lines per 100	Waiting list, thousands	Waiting list,years
Australia	17.5	2	17,050	8,257.0	47.10	4.3	-
Hongkong	5.8	5,461	14,155	2,819.8	48.62	3.8	-
Italy	57.8	192	19,975	23,709.0	41.03	45.0	0.1
Japan	123.4	334	27,005	57,652.3	46.03	-	-
Kuwait	2.0	81	...	345.6	17.54	2.8	0.3
Sweden	8.7	19	27,510	5,919.0	68.10	-	-
Taiwan	20.8	577	8,890	7,418.3	35.75	-	-
U.S.A	255	27	22,450	144,057.7	56.49	-	-
High Income total 39 countries	826.9	25	21,005	406,315.0	49.14	1,443.4	0.1

Table 1 (cont'd).

	Population millions	Density per sq.km.	GDP per capita	Main Lines thousands	Main Lines per 100	Waiting list, thousands	Waiting list,years
WORLD	5,472.4	41	3,980	573,933.6	10.49	46,444.0	1.7
Africa	684.3	23	605	10,076.1	1.47	3,732.4	5.3
Americas	743.3	19	9,970	193,458.2	26.03	4,440.2	0.7
Asia	3,165.7	119	1,685	122,186.9	3.86	11,758.2	1.4
Europe	559.0	75	13,310	197,648.9	35.36	9,454.0	1.0
Oceania	27.3	3	12,725	10,027.5	36.79	21.2	0.1
ex.USSR	292.8	13	2,835	40,536.0	13.84	17,038.0	8.6

Note. Selected countries. From World Telecommunication Development Report (1994). Geneva: International Telecommunications Union.

countries is 2.5 years, where in lower middle income countries it is 4.7 years, and in upper middle income countries it is 6.3 years (World Telecommunications Development Report, 1994). Given the fact that the demand for telecommunications among developing economies is higher in more developed countries and these countries have higher economic growth, it is appropriate to note that these countries will be able to generate more internal revenues for network modernization. In addition, the economy of these countries could support a competition, and more telecommunications services could be introduced and be operated on the costs basis and fewer services would need to be subsidized. This issue will be addressed in more detail later in this paper.

Problems of Telecommunications Modernization

Interesting analysis has been done by Pierce and Jequier (1985) based on the study undertaken by Hardy and Hudson (1980). The study covered 15 industrialized countries and 37 developing countries over a fourteen-year period. The purpose of Hardy's research was to test by means of cross-sectional time-series regression analyses a number of basic hypotheses about the role of telecommunications in the development process. Hardy clearly distinguished the residential and business telephones as well as developed and developing nations.

The findings brought some unexpected results. The common beliefs that business telephones lead clearly to economic development was not supported by the data collected, and the same appears to be true about the hypothesis that economic development leads directly to the development of business telephones. But what is particularly interesting for my research is that Hardy found that business telephone leads development in industrialized countries, and it is the residential telephone which leads development in the developing countries. This theory is definitely very important, as it could lead to more accurate planning for national telecommunications infrastructure modernization.

Another study, by Jonscher (1987), also showed the benefits of residential telephone service. The research was conducted by utilizing macro- and micro-level analysis of benefits to individual sectors, in terms of revenue gains and cost savings. The results were compared with the amortized costs of the investment and operation expenses. Studies of the Philippines and Costa Rica showed the 5:1 benefit/cost ratio for residential service, which is high enough to justify the investment.

That particular study by Jonscher (1987) measured the immediate benefits of residential telephone service on economic development, and given the same measurement, business users will probably benefit even more. However, what we do have to keep in mind is the long term benefits of telecommunications services for the whole national economy.

Gille (1986, p.43) argues that "the development of the communication network provides for a decentralization of the economic system necessary to achieve growth." Gille also implies that the developing countries should focus their telecommunications infrastructure development in those sectors which are most important for national survival, and this, in most cases, means agriculture. Telecommunications for agriculture, on the other hand, means rural coverage and long-distance connection to small agricultural villages across the country.

Many developing countries turned to telecommunications modernization because of the growing pressure of businesses, where the "universal service" obligation has been somewhat left behind. The most common excuse for that, is the economical disadvantage of residential service, especially in the rural areas, compared to urban and business services. Westerveld and Prasad (1994) note than "a small proportion of the total amount of subscribers [in rural areas] can be a large burden on the back of public telecommunications operator" (p.70-71).

The main problem that developing countries are facing now is how to finance the needed investment, given the fact that the number of resources is limited. New technological development in switching and transmission can reduce the total cost of providing telephone services. For rural communications, small-to-medium sized switches can reduce the required investment for subscriber connections -- quoting

a break-even figure of less than US$1000 per line, compared with US$1000 to US$1500 which is the typical price currently being paid (Telecommunications in Central, 1993, p. 129-130). Wireless/cellular technology is also aimed at cutting cost up to 30-40 percent (p. 130). Another, very important factor is time, telephones are needed and are needed now.

Wireless/Cellular Systems as a Technical Solution

The use of wireless technology goes back to the beginning of 1900's. Among the first to deploy that technology were ships at sea. By the 1940's the United States Federal Communication Committee made available additional frequencies in 30 to 40 MHz as the idea of using wireless communication had become more appealing. The technology improved and other users, including private companies, such as taxi, trucking, and construction started to use wireless systems. Public agencies such as police, fire, and emergency medical help started to operate their own radio systems (An Overview, 1986).

The use of radio for communication is very broad, it ranges from VHF-UHF radio to satellite and personal communication network. Within this paper, I will only address three particular wireless technologies. Point-to-multipoint (PMP) radio communications which was originally designed for police and medical emergency use. The PMP system, such as InterDigital UltraPhone, is a central station

network system serving subscribers omni-directionally at distances of up to a 40-mile radius (Personal communication, August, 1994, and InterDigital prospects). The cost per subscriber has come down to approximately US$ 2,000. PMP systems are used in Eastern and Central Europe and Latin America. These systems are designed not only for local access in remote areas, but also for local loop access in semi-urban areas (Westerveld and Prasad, 1994, p.72).

Cellular communication, developed in 1947 at Bell Laboratories, uses the principle of subdividing a large geographical area into smaller sections, or "cells," and by permitting the assignment of the same channels to multiple, nonadjacent cells (a "frequency reuse" concept), traffic capacity on channels could be significantly increased (An Overview of Cellular, 1986, p.104)

What is it about wireless/cellular systems which makes, or would make it attractive for telecommunication modernization in developing countries? The explosion in wireless systems is rapidly decreasing equipment and infrastructure costs. When first introduced in the US, terminals alone cost US$3,000. In 1992-1993, the first digital GSM network in Europe reported start-up cost, combined infrastructure and terminal equipment cost, of US$3,300 per subscriber. Today, Motorola quotes a small, two-base-station analog AMPS cellular system at US$1,200 per subscriber. Future systems promise even lower costs. Qualcomm is asserting that CDMA digital cellular (or PCN)

system will cost just US$600 per subscriber, and with the world-wide expansion even US$400 per subscriber (Swensrud and Friedman, 1994). All of these systems costs assume a certain number of subscribers per cell site. For the AMPS system, the optimal number of subscribers is around 1000-1200 (Mr. Buckland, Regional Manager of Motorola, Personal communications, August, 1994). CDMA technology, designed for personal communications and to be used mostly in urban areas, has a capacity up to 20 times analog. An investment in the cellular network, utilizing that technology, is much lower due to fewer cells, lower planning costs, and support of a much higher number of subscribers (Crawford, 1994, p. 19-20).

The fast pace of cellular network deployment also is one of the big attractions of wireless technology. The small system can be introduced in a matter of a few months, and the nationwide coverage of such country like Hungary was possible within several years of deployment.

In addition to being reliable, cellular communication is becoming more sophisticated in supporting not only voice, but also data, and very possibly - video (CDMA technology). For many developing countries, especially those from the former communist regime, even more sophisticated wireless technologies became available with the dismantling of the former Coordinating Committee for Multilateral Export Control (COCOM) organization, which restricted high-tech technology transfer to these countries (a few restrictions are still remain in place).

Many different standards and systems have been introduced in the last several years, some are designed better for business urban areas, others -- for residential rural areas. I will address the different wireless/cellular systems, including satellite and personal communication network technologies, in a later chapter.

The use of low earth satellites for personal communication is very interesting and promising. Worldwide coverage would immediately resolve the universal coverage constraints all developing countries face. However the cost of satellite-based communication may be too high for most developing nations. The actual implementation of satellite communication systems is only possible in the beginning of the next century, and probably only then could an accurate analysis and implementation for developing countries be made.

The main argument of this paper is to show that in order to pursue national development, telecommunications infrastructure need to be modernized. New technologies, and in particular wireless/cellular systems, can support such modernization plans more efficiently and faster. However, the implementation of these new technologies often faces the local government bureaucracy and lack of knowledge from service providers and policy makers.

Chapter 1 will focus on the telecommunications infrastructure and national development. It will describe the existing infrastructure in developing countries, major obstacles to telecom modernization, and recent trends

undertaken by the governments in the telecom modernization process. Chapter 2 will describe wireless technologies in more detail and present the case for cellular systems as a possible solution for telecommunications infrastructure development in developing countries. It will include a cost-based analysis of wire-line connections vs. cellular. Chapter 3 will describe political economics in developing countries. It will look at why the recent liberalization and privatization processes have taken their particular shapes, what the role of multinational organizations has been and how cellular technology fits into this scenario. Chapter 4 will summarize the conclusions of the analysis, and will include policy and technology recommendations for incorporating technologies as a key component of telecommunications network modernization.

Telecommunications and National Development

It took the governments of developing countries many years to understand the role of telecommunications for national development. According to the World Telecommunication Development Report (1994), the benefits of telecommunications were recognized only by an elite group, and the telephone had the image of a luxury good, not the tool for successful operation. The chairman of the Advisory Board of the Center for Telecommunications Development of the ITU cited three reasons why telecommunications development was not always a high priority (Kerver, 1987).

First, the governments did not recognize the benefits of telecommunications as visible and proven. Second, telecommunications had to "compete" with other priorities such as health, food, and education. Third, there was a widespread presumption that telecommunications projects should be funded through grants. Grants usually came from foreign sources, such as International Telecommunication Union, World Bank, EC's PHARE Program, and regional banking organizations. These organizations acted not only as a source of funds, but they also stimulate other sources of funding through co-financing arrangements (Telecommunications in Central, 1993, p.124).

At today's stage of worldwide economic development there are few doubts left that telecommunications links production activities with exchange activities involving the circulation

of goods and information activities that coordinate the whole economic system. Gille (1986) in his study of economic growth and telecommunications, points out that without telecommunications, the organization, management and coordination necessary between the specialized units within an increasingly diverse economic system are not possible.

Wellenius (1989) summarizes the studies conducted in the 1970's and early 1980's to research the relationship between basic telecommunications services and development. Telecommunications, serving well in places with other forms of communications, such as the postal service and travel, is often more efficient in terms of time, energy, materials and quality of the environment. Telecommunications weakens the physical constraints on organizational communication and therefore increases productivity. With improved communications, markets gain efficiency and responsiveness, and information becomes available from villages, towns, cities, countries and the world. "Telecommunications contributes to the well-being of the family, providing rapid access to services needed to preserve life, health and property, and enhancing contact with kin, friends and special interest groups" (Wellenius, 1989, p.4).

Business users in urban areas can benefit from improved telecommunications directly and immediately, where rural benefits are harder to see and measure. The most obvious advantage of the use of telecommunications in distant rural areas is the information link with urban centers.

Telecommunications can overcome distance barriers and support better agriculture, industry, shipping, education, health and social services.

Hudson (1989) shows that, during the past decade, several studies sponsored by the ITU in collaboration with the Organization for Economic Cooperation and Development (Pierce and Jequier, 1983; Information, Telecommunications, 1986), and by the World Bank (Saunders, 1983) as well other development agencies, have tested the extent to which telecommunications contributes particularly to rural development. These studies show benefit-to-cost ratios ranging from 5:1 to more than 100:1 because of "improved efficiency in the managing of rural enterprises, time savings in ordering spare parts, and savings in travel costs and time" (p.8).

Pierce and Jequier (1985) provide some explanation of why residential telephones are important for national development. The most obvious, they say, is that residential telephones are available 24 hours a day, contrary to eight hours use of business telephones or four-five hours of public village telephones. Another explanation, based on permanent availability of residential telephones, is that these telephones are "... able to capture what we might call the 'ephemeral' benefits of the telephones, i.e. the benefits of 'once-in-a-life' uses in cases of emergency."

Other studies, besides those, mentioned earlier Hardy and Hudson (1980) and Jonscher (1987), concerned with the

role of rural telecommunications for national development include the Parker (1981) study on benefits of rural telecommunications in the United States and the Clarke and Laufenberg (1981) study on telecommunications in rural Africa. The Parker (1981) study emphasizes the enormous benefits of investment in rural telecommunications. Parker calculates that the virtual reduction in the total stock of US telephones resulting from the absence of the Rural Electrification Administration (REA) Telephone Loan Programs would have caused a loss in GDP of 0.001 percent. In other words, the loss in GDP in 1980 would have been about US$ 283 million. Furthermore, these loans have indirectly helped to stimulate economic activities in the rural areas, and hence bring in additional tax revenues. In fact, Parker states, that there is good reason to believe that the REA Telephone Loan Programs are a net contributor to the federal treasury. Clarke and Laufenberg (1981) in their study of rural communications in Africa conclude that telecommunications has a very strong multiplier effect on economic growth and plays the role of a catalyst in national development.

Hudson (1984) emphasizes that rural communications can facilitate the development process in three major ways by improving efficiency, or the ratio of output to cost; effectiveness, or the quality of products and of services such as education and health care; and equity, or the distribution of benefits throughout the society. For example, producers such as farmers and fishermen can compare

prices in various markets, which can eliminate dependency on local middlemen, enhance mobility of their products and increase responsiveness to market changes. Telephone service can facilitate timely ordering of spare parts for tractors, pumps, and generators. Telecommunications also allows fast contact between producers, suppliers, and shippers, and substitutes part of the travel which results in significant savings in personnel time and travel cost. Timely access to relevant information such as weather reports and prices and availability of necessary inputs (seeds, fertilizers, tools, credit, etc.) should make rural agriculture enterprise more efficient. "The telephone system can be a vital tool to enable people to participate in their own development" writes Hudson (1984, p.31).

Hudson (1984) analyzes the use of telephones in rural areas. The findings show that rural residents tend to use telecommunications more heavily and spend more of their disposable income on telephone conversation than do people in the city. For example, in Alaska and northern Canada, the growth in telephone use has forced telecommunications authorities to activate more circuits than anticipated. The number of long-distance calls in some Indian villages in northern Canada increased by as much as 800 per cent (p.8). In Alaska, the introduction of small earth stations in villages spurted the long-distance by 350 per cent (p.8). Hudson came to the conclusion that economical benefits of telecommunications are related to distance, and benefits per

telephone are likely to be greatest where telephone density is lower (p.8).

Hornik (1980) refers to the impact of telecommunications as complementary: "Communication technology works best as a complement -- to a commitment to social change, to changing resources, to good instructional design, to other channels of communication, and to detailed knowledge about its users."

Existing Infrastructure in Developing Countries

The importance of telecommunications for national development is already proven. Realizing that, developing countries started actively seeking a way to improve their communication infrastructure. In order to link their needs, ability, and goals to the use of cellular/wireless systems in network modernization let us look at what stage of development telecommunications infrastructure exists and what are the main elements of that infrastructure.

Table 1 showed the differences that exist in telephone lines penetrations among different countries of different economies. It can be added that in the developing countries there are about 43 million telephone connections in service, but more than 17 million outstanding applications (Wellenius, 1989). The number of potential users is probably much higher, given the fact that in many countries due to slow telecommunications expansion such a list is not up-to-date, and people don't request service simply because they

see it is unlikely that they will get it. Many more potential customers will be "generated" when the service is available and the benefits of the telephone will become more obvious. In addition, more advanced telecommunications services, such as data, facsimile, and mobile services just started to be introduced.

The demand for telephones is increasing far faster than governments had expected. For instance, by 1989, the Czech Republic had about five percent unmet demand which according to the World Telecommunication Development Report (1994) statistics rose to more than 20 percent in the year 1992. Wellenius (1994) gives a more realistic estimate of current unmet demands for basic service in developing countries, which is one-half of what is already in place.

The infrastructure is still very limited even in most middle-income countries, such as Brazil, Mexico, Russia, etc. The fact that Brazil and Mexico have their own domestic satellites still does not show big expansion of telephones. These countries have an average of seven telephones per 100 people and rural areas have even smaller numbers of telephones. The other middle-income countries, including the twenty-two members of the Arabsat regional satellite system and south-east Asian users of Indonesia's Palapa satellite have even smaller penetration rates (Hudson, 1989).

By the end of 1989, due to constant under investment policy, the Czech Republic, with a total population of 10 million people, had a waiting list nearing half a million,

and in Hungary there were only 1 million phone lines for 11 million people. In Russia, it is estimated that only four per cent of international phone calls are completed on its circuits (Pundyk, 1992, p.13).

In lesser developed countries the situation is much worse. India, the second most populated nation in the world, where nearly 75 per cent of the people live in 575,000 villages, has less than 10 million telephones, of which 90 per cent are in the urban zones (Ravi, 1992). This means that most of the rural population has no access to telephone facilities. If national development depends on a modern telecommunications infrastructure, it is necessary to introduce telephone services for residential users which are scattered in rural areas (Westerveld and Prasad, 1994, p.70). The telecommunications system should be designed in such a way that it puts a minimum financial burden on government and on the telecommunications enterprise. Considering this point, cellular communications could be the best technology for telecommunications infrastructure expansion in rural India.

What are the basic elements of a telecommunications infrastructure? In general it consists of several levels of switching hierarchies, from the first, for local call routing, to the last, for international connection. End-user is connected to its local switch which in turn is connected to another switch which transfers the call in necessary direction. For international calls, an international gateway

is used. The quality and capacity of the switch determines the quality of the connection and the number of calls in any given period of time.

The medium used for physical connection to the end-user and between switches differs from country to country. In local connections, for most cases, it is copper wire. Intermediate switch connections usually requires a much bigger capacity, where coaxial cable is used most often. Fiber is getting very popular due to its very high capacity and much better technical specifications.

Wireless technology has developed a large range of communication media, which are being implemented in many types of telecommunication connections -- cellular for the local loop end-users, microwave for higher capacity, usually switch-to-switch connections, and satellite for nationwide or large distances coverage and international interconnection.

In developing countries, practically all aspects of telecommunications infrastructure are underdeveloped. In many cases the most advanced satellite communication has been in the hands of military, not for personal communications use. In the least developed nations, international direct dialing is the only well established telecommunications link which obviously is for use by government and elite business communications. Even in middle-income countries like Russia and Latvia, simple long-distance direct dialing is available only for limited number of users, usually in capitals and big urban centers. International direct dialing has only

recently been introduced and is also available on a very limited basis. Switching equipment is old and needs replacement. Digitalization is a big step forward many developing countries try to implement in their efforts of network modernization. Local connection is also very poor, and practically nonexistent in rural areas (Bauer and Straubhaar, 1993).

Trends in Telecom Sector Modernization

Given the poor status of the telecommunications infrastructure in developing countries and the increased reliance on telecommunications and information related services for national development, many governments have imposed rather radical changes in telecommunications policy.

Privatization and liberalization are two big words which started to shape the telecommunications industry in many developing countries. In order to attract private capital, new telecommunications policies have been introduced or are to be introduced in the near future. Many developing countries accepted foreign ownership in what for so long had been seen as natural government monopoly. Practically in almost all developing countries which followed a modernization process, foreign ownership and operation were introduced in new services -- usually cellular mobile communications.

Many foreign companies started joint-ventures with local manufacturers or service providers in developing countries. The purpose was to manufacture telecommunications equipment or provide telecommunications services in existing or newly established infrastructures.

Unfortunately, telecommunications reforms in many developing countries were being driven more by myopic fiscal and debt management concerns than by considerations of strategic development (Watkins, 1994). So far, the poor governments of the developing countries are selling shares in telecommunications operator companies, and licensing foreign companies in cellular systems as the way to satisfy urgent business users' needs, and to generate some income in budget. Foreign operators with foreign equipment are cream-skimming the most profitable markets in those countries, business subscribers. Some portion of the profit goes into government pockets, and it seems that everybody is happy. Governments end up having the sales money and more money is generated through operation. Foreign investors are happy also. Revenues have covered expenses in three or less years, and now it is clear profit. Business users are also happy with the access to a modern telecommunications infrastructure, and they are willing to pay the higher tariffs. Several researchers recognized the use of power, nationally and internationally (Roger and Singhal, 1989; Schiller, 1975). Hamelink (1986) suggests that we examine who are the real beneficiaries of the present status of industrialized and

developing countries relationships?

Telecommunications development, backed by foreign investment and operators, is concerned about instant profits, not long term investment plans which would lead to national development. However, the advantages of new technologies could probably break the strong dependence on foreign investment, and make local telecommunications entities more efficient and customer oriented.

The use of satellite can dramatically reduce the cost of providing information to small and scattered users. Satellite can provide basic telephony as well as radio and television. The cost of different kinds of services and information can be spread over a large number of users. Big countries, like India, China, Brazil, and Russia would be at a great advantage to use domestic satellite for scattered users nationwide.

To summarize, wireless systems can compete with conventional copper wire links on the following grounds: initial cost, installation time, flexibility, adaptability to terrain, reusability of equipment, and maintenance cost.

One of the most important factors is installation time. The long waiting list for telephone service in many developing countries could mean potential losses for businesses by not having access to fast communication and for governments by not collecting taxes and operating revenues. The delay in telecommunications infrastructure expansion may delay the whole national development process in a country and

be an obstacle for full integration into the global economy.

Another aspect of telecommunications infrastructure modernization for universal coverage is the employment of public telephones or Coin Operated Telephones (COT). By utilizing wireless technology, the telephone services could be introduced on a nation-wide basis much faster, less costly, and, by cross-subsidy process, be priced more affordable for residential users. In addition, traffic generated through public telephones and COT, in general, is much higher than the average residential user, and therefore in some cases such service might be even profitable. The problem with the public phones is that they are available only for 3 to 5 hours a day (Hudson, 1984, p.64) which results in inconvenience to the users. The introduction of COT could be much easier in more developed economies where there is a limited number of COT already in place (e.g. Central and Eastern Europe).

The following chapter looks at wireless technologies as a very advanced and cost-effective substitute for traditional copper-wire connections. It examines what the most influential parameters are which determine the most appropriate choice of technology. In most cases it is the combination of wireless and wireline technologies that makes the most cost-effective telecommunications infrastructure. The analysis of different parameters including terrain, population density, distances and power supplies will result in the most appropriate network configuration.

Wireless/Cellular Communications

Because cost is one of the main factors in accepting new technology, it would be very useful to look at the relative investment cost of wireline network access versus the cost of wireless access as a function of subscriber density. This chapter compares the costs of providing local loop connection per subscriber/main line, utilizing both, wire-line and wireless technologies. In addition, it looks at different wireless technologies as they can be implemented differently for specific coverage configurations and for their potential market in the local loop. The use of satellite for personal communications and how it is appropriate for developing countries will also be considered.

Diaz-Hernandez (1993) makes an interesting analysis of different radio technologies for rural communications. He analyzed the impact of fixed cellular systems, point-to-multipoint (PMP) systems, and low earth-orbit (LEO) satellite systems in three different time frames: 1992-93, 1996-97, and 2000. The 1992-93 and 1996-97 scenarios both consider cellular (GSM) and PMP technologies. The scenario year 2000 also includes LEO. The results are as follows: for the first two scenarios, GSM is more favorable, considering costs where the subscriber densities are higher than 0.02 subscribers/sq. km. The scenario for the year 2000 positions LEO between GSM and PMP. LEO will provide cost advantage for densities lower than 0.02 subscribers/sq. km. According to

that study (Diaz-Hernandes, 1993), the trend will be that for rural areas with a low grouping factor (number of subscribers per point of communication link), below 16, GSM and LEO technologies will grow. The PMP technology will continue to offer the most cost-effective service within rural areas that have moderate to higher grouping factors, 16 and higher.

Along with such parameters as subscriber densities and grouping factors, other important considerations need to be analyzed. Even if the cost of a single land-line telephone is less expensive than wireless for the same traffic capacity, in an operating environment, the balance can swing in favor of wireless. This was the case in Indonesia, according to Ratelindo Director Mr. Kamarga (Personal communication, August, 1994). Ratelindo is a joint venture between Indonesia's state-owned telecom operator and the private company, Bakrie Electronics.

There is interesting and cost-effective approach which has been proposed by Westerveld and Prasad (1994). Even though they do not provide the estimated cost of the system, it is clear that such a system could be very efficient. They propose to use the existing cellular mobile telecommunications systems for fixed rural subscribers. The main advantage is the sharing of cost of installation, operation and maintenance. In this way, the relatively prosperous mobile subscriber will subsidize the indigent rural subscriber, by providing the incentives for investment. Initial users, depending on needs, could be emergency

services, gas stations and public call offices (PCO) or coin box telephones.

Fixed cellular systems can have a cell radius coverage of 100 km. or more, depending on the terrains. Cellular capacity is normally enough to support average rural traffic (developed world) of 0.25 E/sq. km. (Farrimond, 1990).

Westerveld and Prasad (1994, p. 75-77) show the potential implementation of such a system in rural India. Because of the limited financial capacity of most Indian villages, most initial subscribers will be government/police posts, small medical posts/hospitals, store owners, and some pay phones/PCO. Thus it is expected that the initial demand will be four to eight subscribers per village. The design of a village telephone system has to be cost effective for such a small amount of subscribers. Westerveld and Prasad (1994) propose a concept that relies on modern but simple digital switching technology for the small "village exchange" and the use of fixed cellular technology for the connection to the outside world. The system consists basically of a small local switching node which supports all local traffic, and connection to the national network is done by one or two fixed cellular connections which are used as trunks. Local connections utilize copper wire.

Another consideration includes the kind of communication which is going to be supported: is it plain voice communication or high-volume and high-security-required data which would be much better supported by wire-line connection.

In addition, if a government is planning to implement a multi-media information system which could combine high volume cable transmission and interactive communication of telephone services, then high-capacity fiber links would be the most appropriate. However, such a plan is far beyond the current needs and abilities of governments in developing countries.

Local Loop in Telecommunications Infrastructure

The major task, and the most expensive, in building telephone networks, is the construction of links between the local exchange and the subscribers. According to World Bank statistics (Ashutosh and Kazeminejad, 1992) the high cost of "wiring and rewiring" service areas has been the major reason for low penetration of telecommunication networks in rural areas. Adding the low usage of telecommunication services by rural customers, rural service can be a big burden on the backs of public telecommunications operators. The access network or "local loop", until recently, has been utilizing wireline connection as the only means of connecting the end-users. This means that the investment cost of an access network strongly depends on the distance between subscribers and the exchange. Generally, the lower the subscriber density, the higher the investment cost per subscriber for the access network. The cost can be many times higher for very sparsely populated areas than for urban areas.

A new approach for building access network is emerging: Wireless Local Loop (WLL) or Radio Access Local Loop (RALL). The technology is based on wireless radio connections between subscribers and the local exchange.

As many developing countries turn to modernization of their telecom infrastructures, the choice of technology became the hot discussion for policy makers. World Telecommunication Development Report (1994) statistics show (see Table 2) how much a new traditional telephone line costs. The costs are calculated based on data collected per main line added in the period from 1990-1992 in selected low economy countries. Figure 1 gives another look at investment per line in developing economies.

The average cost per line added ranges from $1,200 in Eastern Europe to $6,200 in Sub-Saharan Africa, while for individual countries, the low is $215 in Madagascar and the high is $59,757 in Malawi. Even though there is some danger of using these figures, due to different disparities in economies (labor, equipment price, tariffs, transport, etc.), they still show how costly it is to lay a new line, especially in sparsely populated ares. It is also very important to note that, in developing countries, telephone expansion was aimed primary at capitals and urban cities, and most often for international traffic modernization.

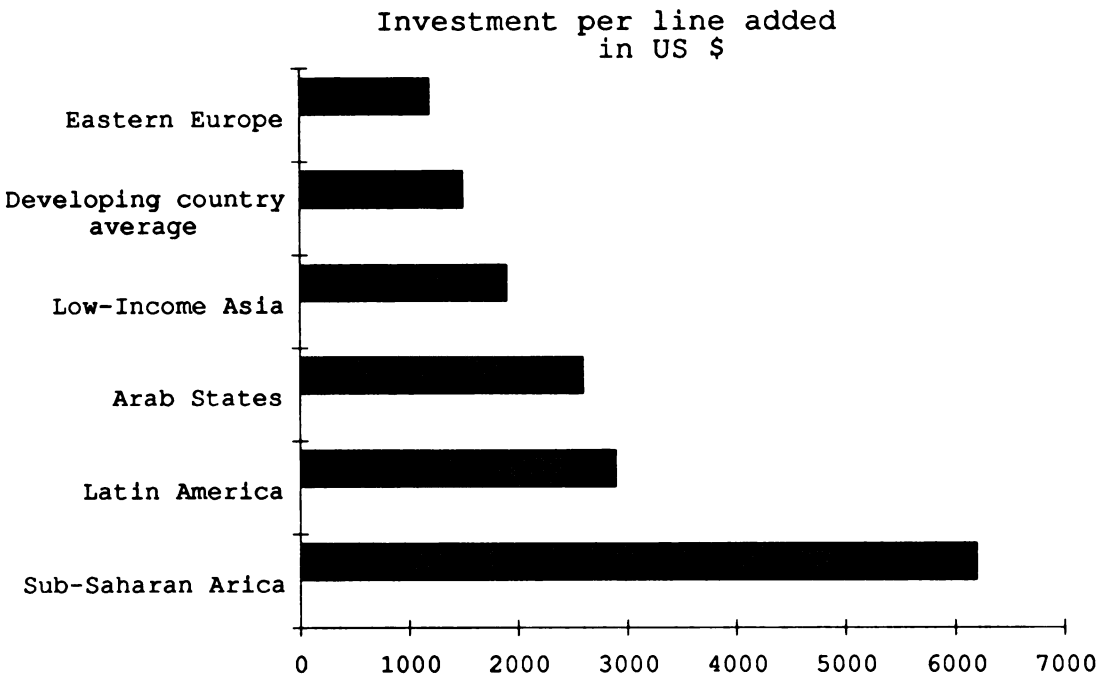
In addition, the cost of copper telephone line shows no signs of decreasing. On the contrary, the cost is rising, for both equipment and labor. All this will play a crucial role

Table 2 Investment per Telephone Line Added, Selected Low Income Countries, 1990-92.

Category	Country	Investment (US$ mil.)	New main lines added in year	Investment per main line added (US$)
High investment per line countries	Malawi (90)	12.5	210	59,757
	Zimbabwe (92)	55.2	1,000	55,963
	Mali (92)	14.6	373	39,206
	Benin (90)	21.2	700	28,282
Average low inncome	43 countries (90-92)	6,715.5	4,537,000	1,480
Low investment per line countries	China (92)	2,946.7	3,018,500	976
	Ethiopia (92)	7.2	7,400	971
	Sierra Leone (90)	0.2	420	410
	Burundi (92)	0.8	2,800	295
	Madagascar (91)	1.0	4,800	215

Note. Investment per main line added is calculated by dividing total investmetn by new lines added during the year. The average obtained (US$ 1,480) is close to the estimate cost of a new line (US$ 1,500) used in this paper. The low income countries are thouse with annual Gross Domestic Product per capita below US$ 600. Source: ITU/BDT Telecommunication Indicator Database. From World Telecommunication Development Report (1994). Geneva: ITU.

Figure 1 Investment Per Line Added.



Note. Source: World Telecommunication Development Report, ITU (1994).

in decision making for wireless technologies, which will be explained later.

Even while there have been other, higher capacity, physical connections, such as coaxial and fiber, with the price being competitive to copper, it still doesn't solve the problem for local loop connections. Fiber is very useful for high-volume transmission, and it would be advantageous to have such connections between major communications hubs. However, in the local loop, where hundreds or thousands of local subscribers usually require just plain telephone connections, it would be a waste of time and resources, especially if these subscribers were scattered over a large area.

The average cost of a cellular wireless connection is around US$1,000 - US$1,500 per subscriber (almost the same as the average cost of a new mainline added in developing countries - US$1,500). According to Mr.Dale Louis, Inter Digital executive in Moscow, the cost of a cellular system depends on the system configuration, and fixed cellular can be installed as cheap as $200-$300 in urban areas, such as Moscow (Personal communication, August, 1995). The major difference is that the cost of cellular wireless systems depends not so much on the distance from the switching center to the subscriber as on system capacity and mobility factor. In wireline connections, distances from subscribers to switches are the most influential factor. In addition, systems can be configurated differently to address different

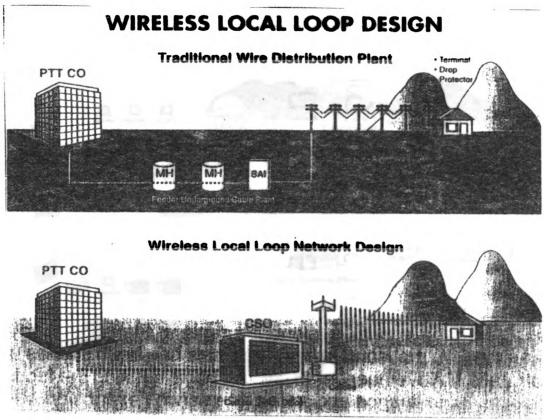
circumstances, such as highly populated versus sparsely populated areas.

Wireless Local Loop Design

By using existing cellular technology, basic telephone services, such as voice data and facsimile can be provided quickly and cost-effectively. The original approach of WLL is fixed cellular network, where radio connection is between fixed terminals and the Cellular Switching Office. Figure 2 gives a basic configuration of the wireless local loop design. The main components of the system are the Cellular Switch Office and Cellsite with the antenna (Ford, 1994). Connection to the PSTN switching usually is done by cable. In this case, the WLL system is part of whole telephone network. In some instances, the cellular network can be optimized by bypassing the connection to the nearest central switching and running its own microwave connection for those distant switches. A typical fixed cellular network design is shown in Figure 3.

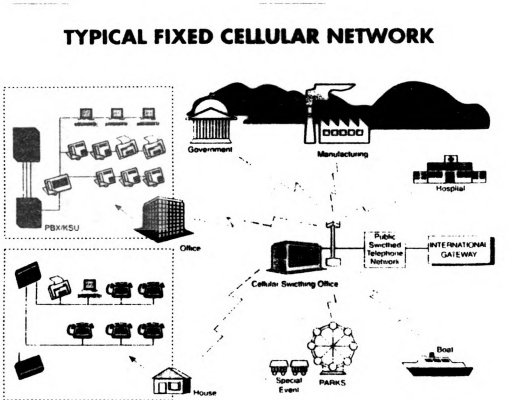
Fixed WLL systems as a solution for basic telephone service have been employed by government telephone companies in Germany, Sweden, Spain, Malaysia, Indonesia, South Africa, Argentina, Brazil, Venezuela and elsewhere (Wickman, 1994). In addition, it is interesting to note that many users of WLL networks, developed by private companies for mobile usage, ended up using them for a fixed service. This was the case

Figure 2 Wireless Local Loop Design.



Note. Source: Ford (1994).

Figure 3 Typical Fixed Cellular Network.



Note. Source: Ford (1994).

in Eastern Europe (e.g. Moscow) where no other alternative network was available for business users. These examples can give some insight to cellular network planners in constructing the cellular system more efficiently.

Many different standards have been introduced, and there is a great deal of negotiation for development and acceptance of a worldwide standard for Personal Communication Network (PCN) and Global Communication Network.

Satellite communication could also be considered as cellular technology, where the cell site is not on the ground, but in space. In this instance, the coverage of one cell increases significantly. However, in the present stage of development these systems will be much more complex and costly. The use of satellite for personal communication is significantly different from terrestrial cellular systems.

Ford (1994) points out that cellular technology has found its way into many everyday communications solutions. The range of applications which can be served varies as widely as the customers who implement them. Virtually every major industry segment has begun using cellular technology for some aspect or another of its business.

To make a cost-benefit analysis of WLL or cellular technology you must find out if wireless technology is an economically viable alternative to the traditional fixed network. Several questions need to be answered:

- what are the adoption criteria for the WLL solution?

- what are the criteria and priorities from the economic point of view?
- what are the different technical approaches?
- is there a potential market for WLL?
- what about universal service?

The main adoption criteria to be considered for WLL are:

- subscriber density and penetration;
- service level and quality;
- speed of roll-out;
- degree of mobility required.

Typical residential subscriber densities range from about 5 per square km. in rural areas to 2,000 per square km. in dense urban areas, while business subscriber densities may be two to three times this figure within the most dense areas. A particular technology within a particular spectrum and cell size can service a specific number of subscribers. Such technologies as Cordless Telephone 2 (CT2) and Digital European Cordless Telephone (DECT) have a range of a few hundreds meters. Others, such as Nordic Mobile Telephone (NMT) can cover a radius up to 100 km (Parker, 1994).

According to PA Consulting Group (Schonenberger, 1994, p. 17), first generation of WLL reached the cost of about $1000-$1500/line. The system utilizes analog technology and has been designed as a fixed cellular system. Second generation WLL, using currently available technologies, is targeted on $400/line (without user terminal), and the next generation WLL, digital, using high volume integrated

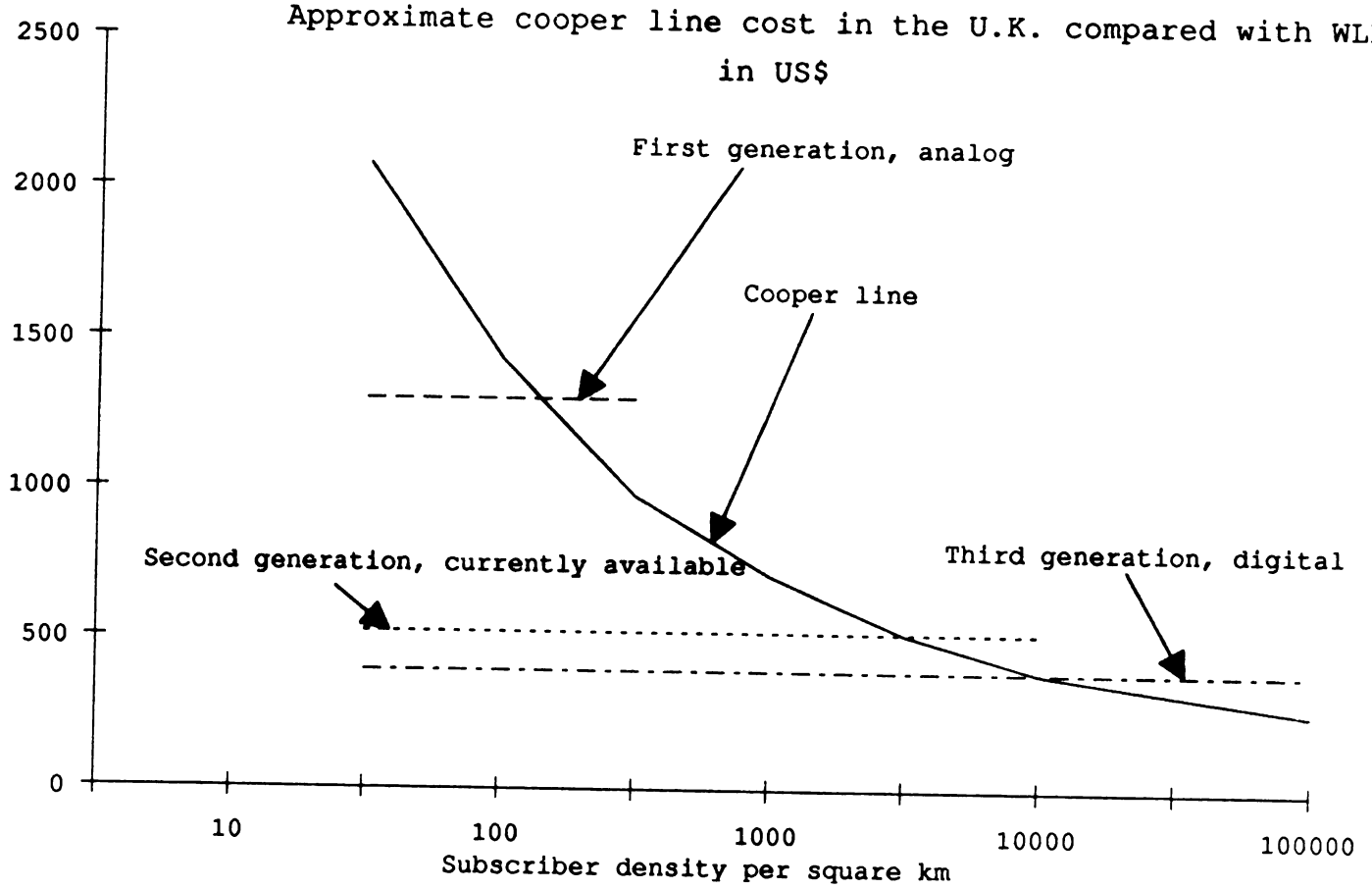
components (DCS1800, DECT, etc.) is projected to cost $300/line (without user terminal) (see Figure 4).

The conclusion, that WLL is more cost-effective in less urban areas, has been shown by many researchers, including Parker, J. (1994), Wickman, J. (1994), and Nokia Wireless (1994). The differences in cost per subscriber ranges from $600 to $1700, depending on system design, technology, and mobility factor. Figure 5 represents the range in cost of cellular systems compared to wire-line as a factor of the distance from the Central Office.

Whatever the service, speech quality, and reliability are the key success factors when WLL is compared with wireline. Modern telephone networks based on digital switching provide both very high reliability and a quality that few radio systems are able to meet. Digital radio systems can provide very high speech quality as demonstrated by CT2 and DECT, but require relatively wide channel bandwidths. Group Special Mobile (GSM) standard, using Time Division Multiplex Access (TDMA) technology, is designed with the emphasis on spectrum efficiency, but has lower voice quality. In an analog system, delay is not a problem; however, the speech is highly variable and conversations may be overheard.

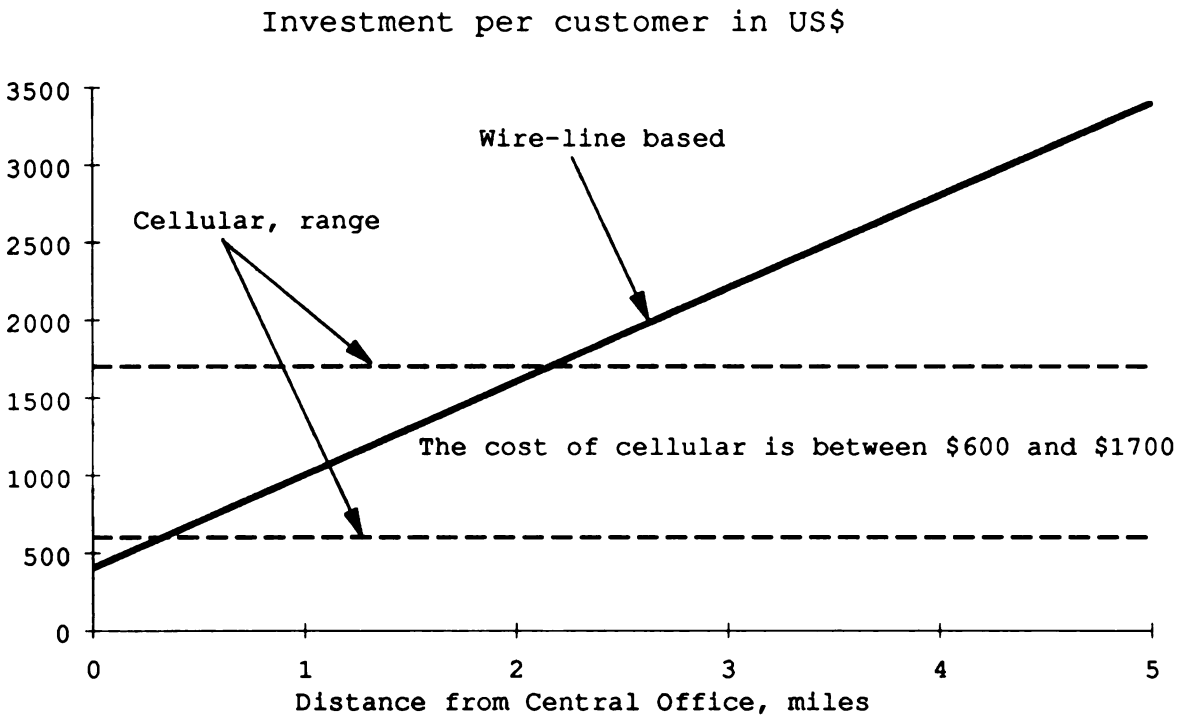
As for services, technology has been developed to accommodate a variety of services, including simple voice and facsimile, and moving towards the most sophisticated digital techniques to provide data, and even video, in the future.

Figure 4 WLL Compared with Wireline, Instalation Cost.



Note. Source: PA Consulting Group, Schonenberger and Rowe (1994).

Figure 5 Investment Per Subscriber.



Note. Combined sources from Parker (1994), Wickman (1994), and Personal Communications.

With the introduction of digital techniques privacy has been improved, and many enhanced features have become available.

WLL service has a unique advantage over all other access technologies with the respect to speed of roll-out. Small scale cellular systems can be established within several weeks. Nationwide coverage can be accomplished in a few years. Westel, the joint cellular venture between Hungary's telecommunications authority and US West, says its NMT 450 network achieved nation-wide coverage, at a cost of US$82 million, by the end of 1994 -- within three years of start up (Eastern Europe, 1994). However, the number of users is limited due to system configuration and limited capacity.

Mobility is another factor in the hands of the operator. Cellular systems can be designed from fixed to limited mobility to full mobility with roaming capability across a number of operators using a variety of systems. The same system can be used for fixed and mobile users. The difference would be in the range of coverage and the number of subscribers. For example, a GSM cellular system in fixed mode will cover up to 100 km. and GSM in mobile mode -- only up to 35 km.

From the economic standpoint, in most cases, a combination of wireless with traditional network may be the most efficient method of modernizing the network. The government or operator, having specific plans for the expected penetration, revenues and investment profile, has to design a system accordingly. There are marketing requirements

such as speed of roll-out (usually business pressure), universal service obligation (usually political pressure), and customer demand (service quality and security). There are also technical constraints such as subscriber density, present network situation, topography, regulatory, etc.

Many developing countries have established historic districts which will be very vulnerable to the installation of physical cable, not to mention jeopardizing traffic and destroying overall esthetics. Wireless technology can be the perfect solution for them. Also, with the greater flexibility of wireless, it can be expanded and reconfigured practically simultaneously.

If cellular technology is potentially cheaper in lower density areas, the "uneconomic cost of access" argument will be a weaker defense for operators which have universal service obligations. Existing and new operators need to see the possible advantage of using WLL compared with traditional wire-line connections. In addition, cellular systems can be used as a way of differentiating services between competing operators where competition exists.

Several analog cellular systems are already in use for cellular application. They provide a good communication range and penetration into buildings. Some of their advantages are good channel transparency, low delay, and up to 4.8 kbit/s voice-band data. Disadvantages are speech quality that can vary greatly, limited security, and the fact that they cannot support Integrated Services Digital Network

(ISDN) or higher data rates. Analog cellular systems also have many advantages from the operators' point of view. It is a mature technology, equipment has low complexity, and its straightforward interface with the fixed network results in low cost.

According to Mr.Arnamo, Marketing Director in Ericsson Radio System (Personal communication, August, 1994), the Ericsson's NMT-450 system can cover up to 150 km in the fixed mode and 20-30 km in the mobile, given the same maximum number of subscribers of 15,000-25,000. The minimum radius of coverage is about 1 km, which is the limit for supporting high density areas. The future attractiveness of NMT is seen in migration of its present (business) users to GSM.

According to Nokia Telecommunication's NMT 450 System Description (Nokia Wireless, 1994), the optimal system size is from 300 to 1920 subscriber interfaces and from 16 to 96 base station channels. Typically, to one BD 34 base station with 20 channels, hundreds of subscribers could be connected. An urban example of the system implementation serving up to 28,600 subscribers can be achieved with the following assumptions:

City:

- radius 15 km, area 700 sq. km
- 40 subscribers per sq. km
- average traffic per subscriber 50 mErl.

Network parameters:

- average cell size 7 sq. km

- frequency reuse pattern 9
- blocking rate 5 per cent

In the case of greater subscriber density, the micro cell with about 0.8 sq. km can support 350 subscribers per sq. km. In a rural implementation, the coverage of one cell can be extended almost to 600 sq. km with the average 0.5 subscriber per sq. km density. As Mr. Alexander Lambeek, Nokia Export Manager in Central and Eastern Europe, mentioned that the NMT 450 system in the turn-key project costs around $600 per subscriber (personal communication, August, 1994).

Digital mobile GSM and DCS 1800, apart from the difference in range (up to 35 km for GSM and 10 km for DCS 1800) and frequencies (GSM -900 MHZ and DCS 1800 - 1,8 GHz), will perform similarly when used for WLL. Advantages include consistent speech and service quality, security through better encryption, and an existence of a comprehensive set of standardized telecommunications services. Disadvantages are speech quality and delay which do not meet fixed network standards. These standards are not transparent to voice band data, signaling tones, etc., preventing the use of standard telephone products. But, probably, the main disadvantage is that GSM does not provide a straight interface to the PSTN local exchange, which, in most cases, is analog. This results in increased cost of GSM and a poor add-on standard to a fixed network (Parker, 1994).

In fact, GSM and DCS 1800 can support much higher subscriber densities and be implemented in WLL off an

existing cellular network. According to Mr. McCann, Marketing Manager for Northern Telecom, the cost of GSM in WLL has been in the range of $500 -$800 per subscriber in a major system with more than 15-20 cell sites (Personal communication, August, 1994). Mr. McCann pointed out that with an increase in the number of cell sites, the cost per subscriber decreases. Telecom Finland will operate Northern Telecom's WLL in early 1995. The cost per subscriber is expected to be $500-$800 (Personal communication, August, 1994).

There are other standards implemented or designed for WLL. One more standard worth mentioning is Code Division Multiple Access (CDMA) which has been widely studied for possible use in cellular systems. CDMA, developed by Qualcom is considered by many as a superior technology to digital TDMA. In short, CDMA achieves greater quality, higher capacity and greater flexibility than TDMA. CDMA, given the same 12.5 MHz operating bandwidth, achieves a capacity increase of up to 20 times the analog AMPS and seven times the digital TDMA, using universal reuse of frequency. It is proposed that CDMA based cellular networks will be able to carry video signals. Having earned international recognition, CDMA technology is not yet commercially available and this is the main reason for the widely accepted TDMA based GSM standard worldwide (Crawford, 1994). Even though CDMA technology seems to be more technologically advanced, the real question is not about technology, it is

about economics. Analog AMPS and digital TDMA are technologies which satisfy current needs, are proven, and most important, are available today.

The potential market and projected penetration of WLL as a portion of local loop varies. PA Consulting Group (Schonenberger, 1994) assumes a 10 percent share of the total local loop market in developed and developing markets. Table 3 shows that a 10 per cent worldwide penetration will generate US$27.6 billion annually, of which US$9.8 billion would be generated in developing countries alone.

A ten percent penetration in developed countries might seem reasonable, because those countries have reached rather high penetration of telephones and the demand is met by traditional connection. Wireless connections are being implemented only for new customers and primarily in more distant places. The penetration of cellular systems in developing countries, on the other hand, might reach a much higher number. According to the World Telecommunication Development Report (1994) statistics, the unsatisfied demand for telephone service was around 20-30 percent, on average, in developing countries in 1992. Given the assumption that cellular systems will be included as an appropriate technology for network modernization in developing countries, the total penetration can easily reach the 20 percent mark. In addition, many countries in Latin America, Asia-Pacific, Africa, and Eastern and Central Europe have very poor fixed networks which could be replaced by WLL as a fast and cost-

Table 3 The Long-Term Market for WLL.

Region	Europe	USA	Other developed countries	Rest of the World	Total
WLL share of Local Loop	10%	10%	10%	10%	
Average proportion of income spent on telecom.	1.3%	1.3%	1.3%	1.3%	
Telephony penetration (lines/100)	50	50	40	40	
Average annual income (US$)	25,000	25,000	25,000	10,000	
Population (Bn)	0.45	0.25	0.5	4	4.2
Annual WLL revenues (BnUS$)	7.3	4.1	6.5	9.8	27.6

Note. Calculations are based on PA Consulting Group assumption that WLL achives a 10 per cent share of total Local Loop market, and 1.3 per cent of average annual income spent on telecommunications. From Schonenberger, J. and Rowe, J. (1994, May) PA Consulting Group, Paper presented at IIR Conference, Budapest, Hungary.

effective solution for providing basic telephone services. In some instances, in the long run, WLL could probably reach half of the total local loop market. Meanwhile, other factors, such as market structure and the buying power, will also influence the penetration of WLL.

Many terrestrial cellular networks are designed to support voice and data via cell-divided geographic areas, where low and middle Earth-orbiting satellite projects, like the Motorola-led Iridium, TRW's Odyssey, Loral/Qualcomm's Globalstar, and Inmarsat's Project 21, promise to make communication without any boundaries. These projects include the launch of between 12 and 66 non-geostationary orbiting satellites with the coverage of the entire globe (Pelton, 1993).

The concept of Global Personal Communication Services extends the reach of terrestrial PCS islands by overlaying satellite systems, like the American Mobile Satellite Corporation and its global counterpart, the International Maritime Satellite Organization (Inmarsat). With Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) systems, the PCN terminal can operate with much lower power, which results in smaller sizes. However, the idea of flexible communications without geographical limitation raises many regulatory challenges not to mention technical and economical questions. While users are quite interested, regulators have a variety of concerns.

The problems, such as how wide-spread use of wireless systems might undermine conventional wireline services financially, how the connection to the PSTN could be controlled and regulated, and how social policies like underpriced local exchange services through cross-subsidies would be achieved (e.g., higher than cost-based access charges to mobile radio carriers.), would even put more pressure on local telecom service providers in developing countries. Even though the first satellite of the most advanced Iridium project is expected to be launched next year and the initial service will start in 1998, there is little hope that such service would be appropriate for solving problems in developing countries because of its cost. Today's satellite communication via Inmarsat costs US$7 per minute where the Iridium's is considered to be around US$3 per minute plus the added local connection charges, taxes, etc. In this situation global PCN is more like premium service and not a competitor to the existing, much cheaper, terrestrial options, including cellular radio and PMP systems (Frieden, 1993). However, as it was mentioned earlier, in some instances LEO can be the most appropriate technology (Diaz-Hernandes, 1993). This was the case for very low subscriber densities (less than 0.02 subscribers/sq. km., but not less than 0.0002 subscribers/sq. km.) and low grouping factors of less than 16.

One of the recent attempts to analyze the use of satellite for rural communication had been made in Peru with

the assistance of the U.S. government (Mayo, 1992). The Rural Communications Services Project (RCSP) was a satellite-based communication system to provide communication to seven concentrated rural communities and huge jungle area. The initial cost of the system was US$2 million and operating costs per year ware US$150,000. The average cost per call was US$4, however it was too high for rural customers, and the actual charges were only US$1.15 per call. Even with subsidized tariffs, there were 111,000 calls, and system revenue was only US$130,000 (in 1985).

This particular experiment shows that satellite system could be employed very successfully for communication purposed in rural area, however, the cost of such a system is still rather high to generate enough traffic to recover the initial investment and operation costs. In addition, due to developing countries debt problems, investment is usually more costly. It will be very interesting to follow the introduction of new, LEO-based satellite communication systems, as they could reduce the costs of telephone coverage.

As of yet, no standard has emerged as the clear favorite for radio local loop use. This is due in part to the fact that all standards considered have advantages and disadvantages. Another reason is that there have been no commonly agreed upon specifications for the performance that a WLL system must provide. Meanwhile, the current developments in cellular telephony give a clear advantage of

that technology over traditional wire-line connections in scarcely populated areas for plain voice telephone service. The main advantages are its costs, speed of roll-out service, and its flexibility. Even in urban centers, wireless technology can provide the cost-efficient solution to introduce basic service for customers. Satellite-based wireless coverage is very promising for developing countries, however due to its high cost, it will be used only by big businesses.

The cellular systems in developing countries is being introduced fast and is popular. The users for that new service, in most cases, introduced through joint ventures, are businesses which have no other choice and are willing to pay much higher tariffs. Why is cellular telephony not being implemented as a part of natural expansion of the modernization process? To answer that question, an analysis of contextual forces needs to be done.

To summarize the discussion about the cost-effectiveness of wireless communication, let us look at the example of Central and Eastern Europe. Demand for telephone services is growing exceptionally fast in suburban areas, because many new joint ventures and joint stock companies have been established outside metropolitan areas. This development has challenged local telephone companies and new operators: how can they provide high quality speech and data transmission services in a fast and cost-effective way even to remote locations? Fortunately, opportunities have also appeared for

local telephone operators to differentiate pricing of services depending on customers' economic status, which improves operators' financial possibilities.

The main question is how to improve the quality and efficiency of existing network and how to serve additional customers despite the limited finance. What would be the optimum network technology? Holmberg (1994) compares wire-line connections with NMT-based wireless network solution based on the function of subscriber density.

The most obvious advantages of wireless technology are the following: installation is faster, it is more flexible and cost-effective. The service can be offered without the delay caused by line construction, giving the network operator earlier access to revenues. Also, the maintenance cost of wireless connections is decreasing compared with copper connections, especially in rural areas. The construction, modification or expansion of the wireless network is flexible, as the exact locations of the subscribers do not have to be known, only a sufficient capacity must be offered in the application area.

The most cost effective way of the interconnection is where the WLL system is connected to existing PSTN local exchange with open 2 Mbit/s subscriber interface. In this case, there is no need for separate mobile switching or external signaling converter for PSTN interfacing (Holmberg, 1994). The basic idea is to offer the WLL customers all of the PSTN services like voice, fax, and data services.

However, limitations imposed by the radio interface and NMT signaling exists, e.g., fax and dial up modem speeds up to 4.8 kbit/s are supported (Holmberg, 1994).

There are many engineering considerations and different study methods (see Holmberg, 1994), but let us look at the findings. The network implementations were modeled on a study area that consisted of eight different sub-areas including urban, suburban, and rural area types. The most important variable was subscriber density, that varied between the areas in the range of 0.1 to 1200 subscribers/sq. km. There also were differences in types of housing in the areas, and in the distance between the sub-areas and the local exchange.

The costs included in this study (Holmberg, 1994) covered the following:

- exchange and the associated remote site equipment;
- transmission equipment;
- infrastructure for equipment sites;
- in-house cabling;
- terminal equipment (including telephone sets and radio terminals)

and the following labor costs:

- equipment installation;
- civil works.

According to the results, the optimum network architecture would consist of three different network

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architectures. In areas where subscriber density is high and which are not too far from the local exchange, -- the best alternative seems to be direct cooper lines. In areas where the subscriber density is medium, i.e. corresponds to the population density of typical suburban and more densely populated rural ares, the optimum is the architecture based on concentrators and copper lines. If the subscriber density is even lower, the lowest cost will be obtained by using the concept based on wireless access nodes and the NMT base station network.

The break-even area between the concentrators and wireless architecture is in the range of 20 to 40 subscribers per square km. However, the exact cost level of each architecture, and thus the exact break-even points between wireline and wireless, are subject to many assumptions behind the network models (Holmberg, 1994).

It should be noted that the NMT system has 4.5 MHz frequency bandwidth (compared to 10 MHz for GSM) and has limitations to traffic capacity. The GSM system for WLL could support higher traffic and, therefore, could be more appropriate for more dense areas and higher traffic.

A further example of the cost-effectiveness of cellular technology is Motorola's predicted potential payback of 0.84 years (Table 4). Because potential payback is one of the factors which influence the decision making in the choice of technology, it is no wonder that so many ventures are going cellular. On the average, the investment can be recovered

Table 4 Wireless Local Loop - Potential Payback.

Assumed Tariffs and Charges	
Instalation fee:	
PBX line	117 units
Residential Line	117 units
Business Line	117 units
Montly fee:	
Residential	23 units
PBX	37 units
Line use (Average Rates)	
Peak (5 min.)	0.3 units
Off Peak (3 min.)	0.1 units

Capital Investment per Subscriber	
Residential	1,000 units
Business	1,000 units
Payphone	1,000 units
PBX	1,000 units
Total	4,000 units

Potential Generated Cell Revenue		Average Potential Montly Revenues per User	
Average Monthly Usage (#of local calls)		Residential	28 units
Residential	50 calls	Business	97 units
Business	200 calls	Payphone	15 units
Payphone	150 calls	PBX	127 units
PBX	300 calls	Total	267 units per month
			3,204 units per year

Overall Predicted Payback	0,84 years per subscriber

Note. "Figures are for example only and will vary according to type, size and location of the relevant market" - Motorola. "Units" are used instead of currency because in different countries "units" might vary, and in the calculation are selfsubtracted and used only to show the number of years to break even. From Motorola Cellular Infrastructure Division (1994, May). Paper presented at IIR Conference, Budapest, Hungary.

within three years, which is definitely a very attractive way to invest in that particular service. This scenario is developed based on business subscribers, and cellular being a higher-priced service. For residential users the payback could be extended to, lets say, ten years, providing more affordable pricing, but leapfrogging the time.

At this point, the obvious question should be asked: If wireless technology is so advanced and appropriate for network modernization, why is it implemented so rarely, or to be more specific, only on a limited basis for business subscribers? Generally, governments in developing countries appear to be mainly concerned with instant business growth. Universal service obligations, or at least expansion of services in rural areas, even though often stated in modernization process plans, are put aside. The following discussion will answer whether telecommunications is seen as a commercial only service or as a national development tool. The whole process of telecommunications modernization has been researched and promoted to help nations to develop. One key aspect of such "promotion" is relatively hidden: the role and influence of multinational corporations and organizations in this process.

Cellular Popularity in Developing Countries

To a reader, unfamiliar with recent changes in the telecommunications sector in developing countries, my concern and research may be slightly unclear, because cellular technology is booming in developing countries. Before we go any further, let us look at cellular popularity in developing countries.

Cellular technology is becoming the only available technology in developing countries where the demand for better communications is growing tremendously. Cellular markets in Eastern and Central Europe, including the former Soviet Union, Latin America and Asia-Pacific, are booming. Businesses are willing to pay extra for cellular service, which, once again, can be deployed fast and is proven to be reliable.

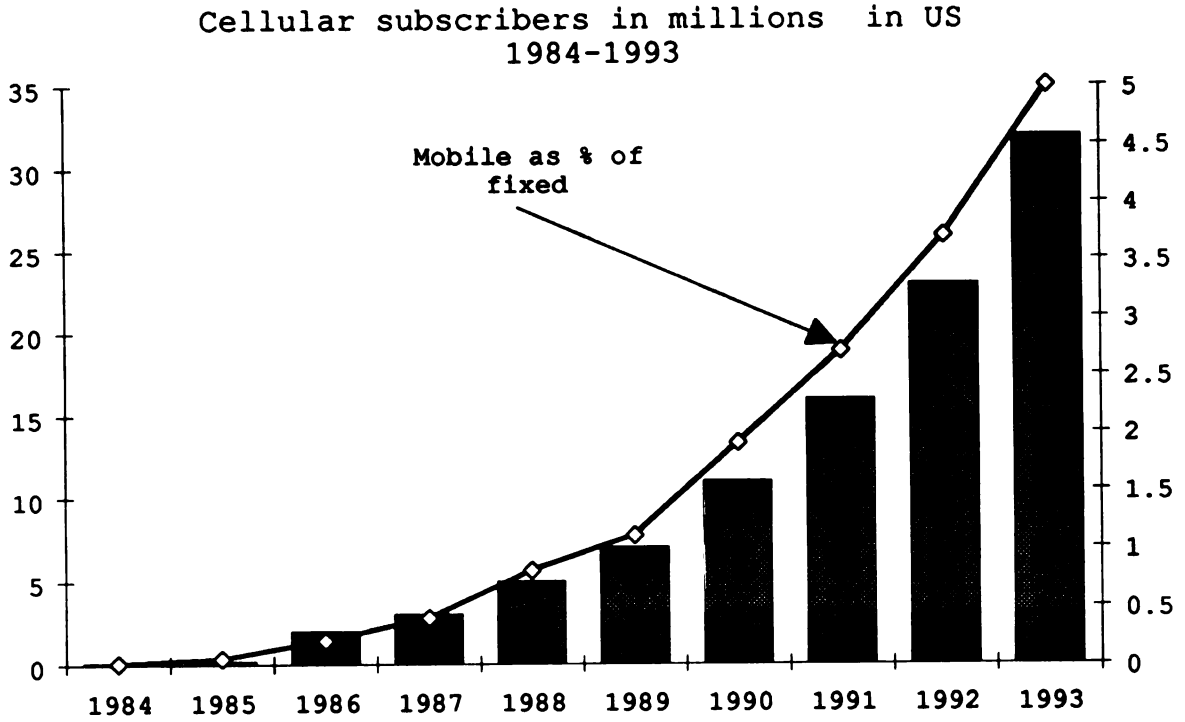
Kanzawa (1994), points out the major reason for the popularity of cellular technology in Southeast Asia: "Construction of telephone lines cannot keep up with the rapid pace of economic development" (p.24). In Thailand the number of mobile subscribers increased more than twofold in 1993, compared to 1992, and now exceeds 400,000. According to World Telecommunication Development Report (1994), mobile telephones will outnumber fixed units by 1994 in the Philippines and Thailand. In Mexico, the waiting list of several months for wire-line telephones has been challenged by cellular connections which allow telephone service to be established within hours. Hungary, where the number of cellular subscribers surpassed predictions twenty fold (!), is planning to have nationwide coverage by 1995 (Titch, 1991). In Russia, the potential of cellular technology contributed to development of the modernization plan to cover eighty percent of Russia by 2010.

These are only some of many examples of cellular technology "conquering" the market in different parts of the

world. However, the growth of the industry has been uneven. Over 50 percent of total subscribers are in the Americas, mostly in the United States (11.3 million), Canada (1.0 million) and Mexico (267,000). Europe provides 25 percent; Asia, 15 percent; and Oceania, 2.4 percent. Cellular technology in Africa has found its way only into ten countries, with the total number of subscribers at 30,000 (World Telecommunication Development Report, 1994). The major growth of cellular systems is expected to be in the Asia-Pacific region. The Organization for Economic Cooperation and Development predicts that this region's share of 25 percent in 1990 will increase to 33 percent in 2010, and 50 percent in 2040 (Williamson, 1994).

Two major indicators of the level of cellular development, density (mobile subscribers per 100 population) and substitution (mobile subscribers per 100 fixed-link subscribers), can be very helpful in analyzing current markets and markets' trends for particular services. The most advanced cellular systems are in Scandinavia, as well as, in more developed economies. As far as second indicator, the leaders are again Scandinavian countries and the countries which have a high demand for mobility (e.g. oil-rich Brunei, Bahrain, and the United Arab Emirates), or which have poorly developed traditional network and long waiting lists (most noticeably Thailand, and fast-growing Latin America, Asia, and Central and Eastern Europe). Mobile penetration worldwide is presented in Figure 6. Figure 6

Figure 6 Cellular Subscribers in Million and as a Per Cent of Fixed Lines, 1984-1993.



Note. Source: ITU/DBT Telecommunications Indicator Database, World Telecommunication Development Report, ITU (1994).

also shows penetration of mobile service as a percent of fixed lines. Overall, the penetration of cellular is one for every 244 inhabitants (World Telecommunication Development Report, 1994).

Business Demands Reliable Communication Fast

Understandably, local businesses, which are in need of telephone services, started to pressure authorities in order to meet their demands. In most cases local businesses are represented in governments and have a lot of influential power. This whole process was fueled by globalization of world markets, and the failing of restricted trade barriers (most noticeably, in the former communist-regime countries). The local markets became available for imported goods, which for a long time were "forbidden fruits" of capitalism. On the other hand, natural resources found export markets in developed countries through private entrepreneurs. For expansion of that trade, communications links need to be established.

At this point, it is clear that some radical steps in the telecommunications industry need to be made. While governments are correct to recognize that businesses need telephone service in order to compete, there may be better ways for them to pursue their plans. The direction of telecommunications modernization plans need to be oriented not solely on urban business subscribers, but also on

residential customers and on coverage of rural areas.

The Role of Multinational Corporations

Banks, as well as multinational corporations (MNCs), are playing a big role in the whole process of national economic restructuring, including telecommunications infrastructure modernization. MNCs are demanding good communications facilities in order to be present in given countries. Because many developing countries are depending on MNCs' production facilities for national employment, they follow the rule of expanding business communications. At the same time, MNCs, through government negotiations and inter government organizations, are pressing developing countries to liberalize and privatize the telecommunications industry.

Two major international banking institutions, World Bank (WB) and International Monetary Fund (IMF), are very powerful, because practically every developing country is depending on some kind of financial help from these institutions. In promoting a market economy, WB developed specific changes developing countries have to make in order to meet criteria for financial help. For the telecommunications industry, WB is heavily promoting liberalization, and competition. In theory, this might be the right approach, which is clearly seen in the U.K. and U.S.A., as a way for better service and lower costs for users. Schiller (1976) and Hamelink (1986) present the point

that transnational corporations are the predominant force in the global capitalist systems. Schiller (1976) argues that the historically, particular national development process must be put into the context of the evolution of capitalism, and its local or national manifestation.

Meanwhile, WB also says that telecommunications services need to be provided on its cost-basis, meaning no cross-subsidy among profitable and non-profitable services. The relationship, developing countries are facing with banking institutions, can be seen as a great contradiction. In order to accelerate national development telecommunications facilities need to reach rural areas and be accessible nationwide. To do that, they have to borrow money from the WB, which says that you have to price the service according to its costs, which we have seen are very high. Business users can afford these high tariffs, but residential, probably not. Giant information technology transnational corporations have become principal actors in promoting modernization, argue Mattelart and Schmucler (1985).

Evans (1985) has conducted vigorous research on the role and relative autonomy of the Third World. His argument is based on the past decades' experience of Third World states taking over the mining and manufacturing industries established by transnational corporations in their countries. He concludes that the transnational corporations remain in power and rule national development in the Third World.

For a multinational companies, acquiring controlling share in telecommunications enterprises in developing countries, mean to implement long-term development strategies and establish regional or global market presence. In the process of privatization, there are different objectives from both sides. From the national development point of view, financial objectives are the most important. Privatization revenues can be considerable, for example, in Argentina, the sales of ENTel in 1990 helped the government reduce its foreign debt by US$5 billion. There are also economic objectives to improve efficiency and performance, and developmental objectives to enhance the domestic capital markets and encourage widespread company ownership among the public at large (Grossas, 1994, p.412).

Prospective investors look at privatization from a number of view-points. The crucial consideration is the likely returns on investment. As Grossas (1994, p. 413) mentions that "most telecommunications companies are potentially attractive investment." Because the industry is treated as utility it usually retains monopoly and with appropriate tariffs, returns could be above the average for investments of comparable risk (Grossas, 1994).

There are substantial differences in return on investment for national development and profit return on investment for operator or private capital. While the profit return is mainly concerned with immediate return on investment (such as by introducing wireless systems), the

national development return is a long-run process. How to combine privatization process pursuing national development policies and, at the same time, make it attractive to private capital? To reach the equilibrium in this question, careful negotiations and compromises need to be considered. While the certain profit return on investment must be applied by certain tariffs, the overall expansion of the system in rural areas must to be considered in the agreement. It should be allowed to the operator to earn extra profit from most profitable operation in order to reinvest in rural and residential areas. Project appraisal criteria which is based solely on financial profitability and rates of return on investment and not more on economic and social impact discourages rural investment.

Telecommunications: Commercial Service or National Development Tool

The process of telecommunications modernization is not just a question of technology and its cost. Often politics prevail over what seems more reasonable and proven technologically and economically. The role and influence of multinational corporations is becoming increasingly important in shaping the global economy.

So far, the global market has realized the role of wireless technologies in telecommunications infrastructure. It is clear that the fastest element of the telecom industry,

wireless communications, has helped business communities in developing and developed countries, making their operations more efficient. However, the question of universal coverage at affordable prices remains unanswered. Even if national coverage can be achieved using wireless technology, it doesn't mean that the service will be affordable for every user.

Telecommunications, and especially telephone service in rural areas and universal coverage, should be considered as a national development tool. As with education, the results might not be seen immediately. Unfortunately, at today's stage of modernization, telecommunications is considered only as a commercial service. While the business role is clear, the future and potential benefits of residential telephone service are hard to recognize, or maybe even hard to admit (Westerveld and Prasad, 1994).

Why? That is not an easy question, especially in fast changing governments and government policies in developing countries, currency fluctuations, and overall instability. I have experienced much of these changes in the former USSR and in today's independent Republic of Latvia. What is generally presumed, that new changes in government structure (free elected government) will lead to government policies aimed at national development and the well-being of its residence, is sometimes misleading. When I worked for the U.S. Agency for International Development (AID) in Riga, Latvia, Mr. Richard J. Peters, at that time the AID representative, mentioned

that it will take three to five government elections to reach some kind of positive attitude towards national development. At that time it seemed interesting, now I couldn't agree more.

I have been following the telecommunications modernization process in the Republic of Latvia, and have come to the conclusion that the modernization process in that particular country is the way for government to cash-in fast. The local telecommunications company has been sold to a foreign company (49 percent), all the promises of expanding telephones in rural areas and replacing telephone lines in urban areas were just promises, (for now), almost two years after signing the contract. A foreign investor (a consortium of Cable and Wireless and Telecom Finland) planned to use wireless technology on a wide basis for rural telephony. In addition, they made a commitment to install two fiber links with western countries and constructed only one. A new digital switch, also promised within the first year of joint operation, is not yet deployed. These are just some examples of how plans for the telecom modernization process turn out differently in the implementation.

On the other hand, two cellular standards have been introduced in Latvia, also by a joint venture with foreign partners. NMT-450 plans to have country-wide coverage very soon, and GSM has started in the capital city. Even though there are two different standards, no real competition is expected, because they both are provided by the same company,

which, of course, has no obligation to rural service at affordable prices. By the way, services and end-user equipment of that cellular systems are several times costly than in the US and other countries, where competition is in place.

Why doesn't the government change this scenario, either by introducing competition, or price regulation? Why should it? Government in this case, is also a partial participant in the joint-venture, and by keeping higher tariffs it can generate more revenues, and by providing a monopoly licenses, the licenses can be priced much higher. The shortcoming of this solution is that government is trying to squeeze out as much revenue as possible, not admitting that these higher costs are, in turn, a burden for business, and a barrier for small entrepreneurs, not to mention residential users.

The situation might be different in developing countries, where the level of foreign investment is restricted, or even more important, is controlled by the government. Very explicit regulations need to be imposed on foreign participants. Other considerations, such as the use of new technologies and coverage obligations need to be taken into account.

Nulty (1994, p.345) points out that new entrants, either in cellular or traditional telephony, seek only the most profitable markets and prefer not to worry about the others. At the same time, these new entrants are undermining the profits of local service providers which it need in order to

provide service to rural areas.

The telecommunications sector is one of the few services provided by most governments in developing countries that can be expected to pay for itself, and turn a profit as well. The indirect benefit of telecommunications is often overlooked and is very difficult to predict and to qualify. Telecommunications in rural areas must be looked at the same way as roads, water supply, electricity, etc., which are widely considered to be necessary for development and generally are not expected to be profitable.

To summarize, it can be seen that governments in many developing countries opened up the telecommunications industry for private capital and foreign firms, in order to satisfy the increasing business demand for telephone connections. New cellular telephony is becoming very popular with business users, and also is fast to install. In the meantime, the rush for modernization, resulted in unclear policies due to pressure from multinational corporations and organizations. Often, it is thought that only business customers and not residential are in need of communication services. The main mistake that many governments make is that they consider telecommunications as only commercial service and not as a tool for national development.

Another argument is concerned with viability of competition. Different income levels in developing countries would probably support different sides of this argument. Low income level in addition to low demand for telephone services

would argue for a monopoly service provider, whereas the income level is higher and enormous waiting lists for telephone services exist, it is quite possible to introduce competition. Furthermore, competition is more likely to result in a faster provision of the service, and in more competitive pricing. The following compares the monopolistic cellular service charges in the Czech Republic with the charges in Denmark, where competition exists.

> In the Czech Republic, monopolistic NMT operator charges the connection fee in a range of $416-$656, where in Denmark - $61.50, monthly business rental - $60 and $7.03 respectively, mobile call charge - $0.27-$0.30 and $0.25-peak, 0.125-off-peak respectively, and an average annual expenditure for mobile business user is $2500.00 and $736.00 respectively. In Denmark, there are two cellular operators, one on NMT, the other -- GSM (Doyle, 1993).

The differences in economic development among developing countries result not only in economical viability of establishing competition, but also in the whole process of introducing new technology (e.g. cellular). For upper-middle income (GDP per capita) countries, such as Argentina, Brazil, Mexico, Greece, Russia, etc. it could be much easier to introduce mobile cellular systems for two reasons. First, is that the income in those countries are higher (average GDP

per capita US$3,520), and more people can more support costs and tariffs of the cellular service. Second, is that the waiting lists are much longer and there is higher demand for telephone services. On the other side, lower-income countries, such as China, India, Egypt, Nicaragua, etc. have less income in GDP per capita (average US$310), and cellular service in those countries could be only profitably introduced for small number of users (World Telecommunications, 1994). The cellular service, as it is introduced by private capital, is only available to business users and small elite.

In next chapter, to conclude the on-going discussion about the role of wireless in telecommunications infrastructure modernization in developing countries, I will formulate some important rules, that might be incorporated into policy regulation. My main emphasis is to look at telecommunications infrastructure as a national development tool, where wireless technologies can help to reduce the financial burden of infrastructure modernization. The use of wireless technologies should be considered not only as a fast supplement for regular telephony for business users, but also as a regular element of telecommunications infrastructure expansion in residential and rural ares where it could be more cost-effective to utilize wireless connections.

Conclusions and Policy Recommendations

Since the invention of the telephone, never has the unmet demand for basic telephone services been more acute. The recent initiatives by the renaissance Eastern Europe and other developing countries to accelerate establishing free market economies further exacerbates the worldwide shortfall in telephones per capita.

Modern telecommunications systems have become a very important element in promoting economic development. The ability to use information technology effectively will be among the determining factors in separating leaders from laggards in global economy. The output of transnational corporations and international trade has been growing at more than twice the rate of world output (Wellenius, 1994).

As business is becoming global, it requires a worldwide communication network, based on reliable and a modern telecommunications infrastructure. International business, by gaining global market share, is growing larger and is becoming more complex. Business is recognizing telecommunications as a major driving force in development, leading into the global market, global competition, and global market strategies.

Developing countries face a dilemma. They have to provide high-quality basic service to large parts of their population, while many are strapped by foreign debt problems that make public financing difficult. At the same time, they

have multinational firms and domestic enterprises demanding even more sophisticated services on new commercial terms. These two different challenges could require different telecommunications architectures to be employed. "The right choice [of technology] from the viewpoint of large business customers may not be the best choice for the welfare of the country as a whole" writes Cowhey (1994, p. 548). All that puts a lot of pressure on public policy. However, national policy makers have a chance to choose mix and match of different approaches and technologies in order to achieve desired goals.

Why Use Wireless/Cellular Technologies

A major question is how to improve telecommunications service with minimum investment, fast and up-to-date. The answer to that, in part, came with the development of wireless communication. In particular, three different technologies, point-to-multipoint, cellular, and satellite, already in use in some aspects of telecommunications, could be considered by developing countries for broader use. Let us look at three different scenarios very familiar to many developing countries.

Scenario One: A national telecommunications operator is in the process of a broad network modernization scheme to get phone service to residential and commercial users. Investment capital is limited. The waiting list of

subscribers is long. Potential business opportunity remains unexplored for lack of a sound communications infrastructure. There is under immense pressure to provide an immediate, cost-effective solution.

Scenario Two: A network operator is providing service to densely populated urban centers as well as sparsely settled rural regions. They have licensing requirements obligating them to provide telephone service to all at a fair price. Their network planners have demonstrated the exorbitantly high cost of getting single lines to farms and rural villages, with land and right-of-way acquisition, cabling, installation and attendant equipment. Yet, they are confronted with the task to bring down this cost while meeting their universal service obligation.

Scenario Three: The telecommunications environment has been opened up to competition. The local phone company has become more commercially oriented. They are presently operating fixed network service and perhaps even a cellular network. There is unused capacity in their cellular frequency allocation, yet fixed network demands from growing suburban areas have exceeded the existing wireline capacity. Now, they must rationalize both cellular and fixed networks, meet new growth but squeeze more profitability out of their operations, shortening the return period on their investment. What to do?

These three scenarios, and many others, are typical for many developing countries, which seek a solution to their

network modernization. Competitive and regulatory pressures in telecommunications environments are bringing about exciting new solutions that are flexible and cost-efficient. One such solution, well-suited for the above mentioned scenarios, has already been tested by respected national operators and private companies, and relies on many technologies with open interfaces for broad network compatibility.

This Wireless Local Loop concept is a logical way to provide low-cost, immediate and sophisticated . telecommunications services using proven cellular mobile radio techniques rather than a fixed line connection. No cables, no digging, forget expensive land acquisition. Cellular technology, for the business-minded, is not just voice service, but also fax and data, and with advances in digital -- security and more enhanced services.

Cellular is not the only right technology for modernization plans. Cellular, along with other wireless technologies, such as PMP and satellite, is only an integrated part of telecommunications network infrastructure development. Depending on the market demand, topography and priorities, the right system utilizing any cost-efficient technologies should be considered including optical fiber, cooper wires, microwave radio, and perhaps even coaxial cable.

After having installed the equipment, operation and maintenance costs have to be calculated. In most cases these

costs can be passed on to business subscribers, which can afford high tariffs. What about residential users? That depends on many different factors related to the buying power (GDP per capita) of people, local government or operator policy, e.g., cross subsidization policy, loan or grants conditions by international institutions, the way the investment is used and the depreciation rate, existing infrastructure, etc.

As for the design of any telecommunications network, one has to find a balance between cost, capacity, and grade of service. To determine the grade of service that can be provided at a reasonable cost it is also necessary to have proper data on subscriber behavior. For many other developing countries, these data are not readily available, but, for example, based on research from India (Westerveld and Prasad, 1994, p.75) the system (fixed wireless connection to the already existing cellular network, described in Chapter 2) with two outgoing lines can support an outgoing traffic from a village of up to eight subscribers rather satisfactory.

Places that until recently have had very poor communications are rapidly acquiring state-of-the-art telecommunications that will let them foster both internal and foreign investment. It may take a decade for many countries in Asia, Latin America, and Eastern Europe to unlock bottlenecks in transportation and power supplies, but by installing optical fiber, digital switches, and the

latest wireless radio systems, urban and rural areas from Beijing to Budapest are stepping into the Information Age.

The combined wireline and wireless access solution provides a new innovative and cost effective approach for building fixed telecommunications networks, whether it is a question of providing basic telephone service to increase telephone density or a new competitive business approach is considered. It seems that for any operator thinking of utilizing the new standards in its PSTN network, serious consideration should also be given to the benefits of combining the wireline access approach with a wireless approach. These approaches clearly complement each other, and when used together, provide a very cost competitive solution.

The main benefit of using the combined wireline/wireless access are:

- faster service provision and earlier revenues due to wireless option. This in turn will result in a shorter investment payback period;
- easier to plan and manage growth than in a 100 percent cable network which typically has significantly longer planning lead time requirement;
- lower overall costs due to lower costs in the long local loop via wireless;
- lower cost due to use of open multi vendor

interface standards;

- local mobility within one cell for fixed cellular and full mobility as an enhanced service in a mobile cellular system.

The following conclusions can be made:

- There always seems to exist a high density break-even point after which a wireline approach becomes less expensive per subscriber than a wireless approach. This is due to the sharing of cabling costs with more subscribers and rising costs of high capacity wireless coverage.
- There always seems to exist a low density break-even point beyond which a wireless approach becomes less expensive per subscriber than a wireline approach. This is due to the high costs of cabling isolated subscribers and to the low costs of wide area wireless coverage.
- There always are other considerations which influence the choice of technology. Whether there is the need to establish a network fast or whether there is a particular demand for mobile communication. At the same time, there may be a need for very high traffic capacity, security, and reliability. Local factors, such as engineering, training, and manufacturing can also influence the decision.

Considerations for Network Modernization

Let us look at what kind of questions are on todays agenda in a developing country which has decided to modernize its telecommunications infrastructure. Once the decision to modernize the telecommunications system has been made, questions of needs, priorities, ability, and feasibility need to be evaluated.

Market requirements: business and customer, business with its power is demanding a good and reliable telecommunications infrastructure, customers which might not be such a powerful force (as they don't realize all the potentials of telecommunications) still posses some power for political pressure and demand "universal access." Today, the potential market is only seen for business subscribers, and the residential and rural users are neglected.

Financial feasibility of the modernization plan is probably the most important, as in any investment. Telecommunications is proven to be a very good income-revenue source in any economy. Most striking is that the revenue is going into the general budget and the telecommunications operator is dependent on the same general budget, and has to "compete" with seemingly more urgent investments, such as health, agriculture, etc. Financing can be internal and external, and usually is combined. Internal revenue is very important and is very effective, especially in a well-run telecommunications network. In general, the lesser developed

the economy is, the less likely that internal sources would be adequate to finance the costly modernization project. External sources are very broad, from loans to foreign direct investment. The last one, has become very popular in recent "telecommunications deals".

Technological constraints. The choice of technology relates directly to financing, as somebody has to pay for the installation of the network, and with marketing requirements, as different technologies can support different applications and users more efficiently. That choice is based on a variety of factors. One was already mentioned -- cost, others are geography/topography, subscriber density, regulatory constraints, quality, availability and connectability to local networks, standards, and environmental restrictions. These are the most obvious, clear technical decisions, however no less important are local personnel, its training, and local engineering for the purposes of having an ability to build, maintain, operate telecommunications network, and even manufacture telecom equipment.

In the meantime, there are additional forces which influence the technology to be deployed, such as, foreign companies and interest groups, as they are very much active in promoting their technologies, which in some cases might not be the most appropriate. Governmental loans usually come with, if not exact technology restrictions, then with the restriction of technology originations, which again might not

be the best scenario, especially if domestic manufacturing is planned to be developed . National governments, often do not have strong negotiation power, due to lack of technical knowledge and ability to predict the outcomes of adoption of specific technology. All the factors influence the choice of technology. Some more, other less. I just wanted to stress that no single factor is going to make that decision.

Chasia (1976) points out that technology transfer is a social process which involves adjustments of a society's institutions to the technology. He distinguishes three levels in the transfer process:

- ability to use the technology;
- ability to operate and maintain the technology;
- ability to invent and make the technology.

Clearly, any technology transfer must include the first level. The second level is crucial if the country or region is planning not to be completely dependent on outside expertise. The third level could be separated from sophisticated research and development to a simple manufacturing. Telecommunications planners must consider these technology transfer factors in planning the system for national development, including the feasibility of each of the level of technology transfer.

There is also a need for more trained personnel who can design systems for the specific needs of their home countries, analyze current new technologies, and its potential implementation. Opportunities to learn about new

technologies and planning tools from industrialized countries and share experience with other developing countries would also stimulate innovations and lead to the better design of telecommunications systems, both cost-effective and customer-oriented.

Policy Recommendations

The urgent modernization process of the telecommunications infrastructure raised a dilemma for operators and governments. What is the priority for universal coverage? Should countries with limited resources focus on universal service to the detriment of the revenue-earning business sector? Pekka Tarjanne, Director General of the ITU has said that the development of rural areas should not be just looked at in the context of telecommunications but in a broader economic context. According to Tarjanne, an ITU study shows that for every US$1 invested in rural telecommunications, US$1 is generated in indirect benefits per year (Swensrud, 1992, p.2).

Thus, this and other studies described in Chapter 1, recommend that governments should focus on residential and rural telecom modernization, along with business and urban, since the residential and rural telephony have potential for big returns for national development. Telecommunications infrastructure needs to be looked on as a promotional tool for national development not just as a simple commercial

service, based on direct payment. Government, and telecom service providers need to generate demand from residential and rural users, in order to make the information flow freely and promote democracy.

Telecommunications infrastructure modernization is a costly project. A very cautious approach needs to be used for finding the financial source of the modernization project. It leads to the second recommendation, that internal financing and national private capital need to be the primary sources of financing in order to prevent the out sourcing of the capital. Financing through foreign banks and direct foreign investment need to be negotiated more in favor of the local network development and coverage increase, for business and especially residential users. If the internal financing is not feasible, than a country would probably be dependent solely on foreign investment through grants and foreign private capital.

Third, following the approach of the European Union, this study agrees that regulation of any telecommunications entity needs to come from a third party, in no way financially dependent on the service provider, and be represented by the end-user interest groups. In cases where government is one of the participants of a joint-venture, I would impose a mandatory financing of a regulatory body by that joint-venture, clearly stated in the license agreement.

In cases of monopoly operation, a price regulation needs to be imposed. The rationale for imposing price-cap

regulations for monopolistic providers was shown in the comparison of the Czech Republic and Denmark in Chapter 5.

It could be argued that income level in many developing countries cannot support competition in mobile telephone service. To establish competition, at least two independent networks must be installed, and that means roughly twice the investment. However, the enormous waiting lists, especially among potential business subscribers, suggest that demand may well be high enough to support an early introduction of competition. Furthermore, international experience suggests that service quality and customers typically benefit with the introduction of competition, or even a pending threat of competition (Scherer, 1994, p. 75). Hungary demonstrated that competition is desirable and feasible when in 1992 it tendered two GSM digital mobile licenses. However, in less developed economies, competition could be inappropriate, and regulation would need to be imposed on the operator.

The tremendous shortage and the poor quality of the existing fixed telecommunications network means that there is a critical role to be played by wireless technologies. Whereas in developing countries cellular telephony has largely been a complement to existing fixed lines, in developing countries it will, for many years be a substitute for direct exchange lines. Although a cellular telephone is typically more expensive to operate than a traditional connection, many potential users in developing countries can obtain connections almost immediately by subscribing to

mobile (Doyle, 1993, p.333). The availability of cellular services will serve to decrease waiting lists for telephone service, reducing the externalities associated with waiting and thus benefit the economies.

A fourth recommendation relates to technology. Wireless technologies need to be considered and implemented more aggressively, and especially to be used in rural areas for achieving universal coverage. Where it is cellular communications, point-to-multipoint, or satellite, it could be advantageous to consider them instead of wire-line connections. So far, cellular systems have been implemented mostly for business needs and is supported by higher tariffs and connection charges. Hundreds of cellular licenses have been issued to private companies to operate both in analog and digital standards. Business customers, willing to pay more, will get their desired telephone service. However, what about residential users and even small businesses? As government realizes the role of telecommunications for residential users, and the idea of having universal access is supported by some kind of financing (like from the sales of shares or from sales of licenses, or loans), wireless cellular is becoming the best choice of technology.

The main question in regards to telecommunications in rural areas is whether the network can be cost effectively covered, given the fact that there is low business revenue and low usage from residential customers. Wireless communications, again, is helping to solve that problem. The

cost of wire-based network is high because every single pair of copper needs to be laid down to connect either urban business or residential customers or a pay phones. Wireless cellular connections, even with a single line (one call in a given time) can be used by a number of users, given the low usage rate and a given blockage rate. The system can be easily expanded as the usage increase. More lines can be added without laying new copper lines, such as in the case of wireline connections.

One obvious problem is that cellular systems requires batteries or electricity, which might be a problem in some areas, however, with the boom in cellular technology, the battery industry also advances its capabilities very fast.

A new, very attractive way of utilizing cellular technology in rural areas is via pay phones. One analog cell with a radius of 100-150 km. can support up to 25,000 connections, and that would be enough for local businesses and pay phones in every covered village, which, in turn, could generate enough revenue to at least cover the expenses. In India, on the average, there are about 100 inhabitants per village. If the cost of that one connection is US$1000 (Ericsson's RASS 1000 system, described in Chapter 2) plus operation cost, the pay phone connection in a village would cost $10 per villager. Over a period of ten years it would come to $1 per villager per year. Operation costs of the system could be covered by tariffs (which in this scenario could be very affordable), or could be subsidized by the most

profitable business and long distance users.

Of course, it is not that simple and many factors need to be considered, but the main point is that fixed cellular technology can be deployed much cheaper and the former government excuse of "uneconomic cost of access" is becoming a weaker defense for these operators. One very important aspect in WLL connection is that regular telephone sets can be connected to the system, and there is no need to import telephone sets if local production is available.

In addition, a tariff differentiation can be introduced. The weekends and evenings hours can be assigned much lower tariffs, so residential customers can make phone calls, if not from their own hand-held telephones, then from pay phones, which could be installed easily within the area of coverage without any physical damage to the environment.

Despite the government's sanctioning a monopoly in mobile telecommunications and allowing the incumbent state enterprise to have majority control, little though was given to dealing with possible abuses of this position. On the example of the Czech Republic (the case of cellular monopoly, described in Chapter 3), the absence of effective regulation and of direct competition are tempting the operator to engage in monopoly pricing. Monopoly pricing is not necessarily inefficient, but often imperfect information about customers valuations of the service results in welfare costs.

It is recommended that government should regulate monopoly mobile operators on a price-cap basis. The

following statement made by the OECD adds force to the argument for regulation: "The most expensive tariffs for mobile services are found in those countries which have retained monopolistic service structures for analog cellular radio" (Mobile and PSTN, 1992). Following entry, price regulation should be maintained to prevent any predatory pricing by the new operator, but with the established competition those regulation can be removed.

Technological progress is changing the way telecommunications has been traditionally viewed. One of the key technological changes, which has been influencing the structure of the telecommunications industry is wireless cellular communications. With the changes in technology, changes in the government's role in telecommunications also occurred. The options for organizational and structural changes in telecommunications cannot be considered in isolation from changes in other sectors of national economy. There are tradeoffs between efficiency and economies of scale, as well as effectiveness of regulations and the status of telecommunications infrastructure and a country's attractiveness to foreign capital.

There are two main ideas in the role of wireless/cellular technologies for telecommunications network modernization in developing countries. One is that the development of radio techniques and its decreasing costs has made that particular technology available for developing countries. Foreign companies and service providers,

realizing the advantages of cellular technologies, are rushing into the big market of unmet demand in developing economies. Second is that, in order to pursue a national development telecommunications infrastructure, besides being commercially oriented needs to be emphasized on the coverage of rural and residential customers. For that particular area of coverage, wireless technologies, in combination with wireline connections, can provide the most cost-effective solution.

Policies need to be concerned not only with overall expansion of the system, they must be specifically oriented towards nation-wide coverage at affordable price, assuring the strong control over monopolistic service providers and encouraging real competition. Even though such policies are hard to reach in order to balance between businesses demand and universal coverage, the right technology with appropriate system configuration and tariffing policy could facilitate both, business needs satisfaction and the overall system expansion nationwide as an infrastructure. New ways to provide basic telephone services, such as by utilizing wireless technologies, can also reduce the financial burden of modernization process.

Finally, a difficult equilibrium must be achieved between the protection of foreign capital invested in telecommunications and national development goals, which should include efficiency, competition, economic reforms, and expansion of services in rural areas. To find out what the

mutually accepted decision is, more detailed research needs to be conducted. To some degree, future development in developing countries will answer that question. In addition, the innovations and trends in telecommunications and information related areas might change the current approach to telecommunications infrastructure and modernization plans.

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