AN ANALYSIS OF WIRELESS AND VALUE ADDED SERVICES ON THE REGIONAL DISPERSION OF TELECOM SERVICES IN DEVELOPING COUNTRIES

Boris Ramos
Ph.D. Candidate
Email: bramos@wpi.edu
bramos@espol.edu.ec

Khalid Saeed
Professor of Economics and System Dynamics
Email: saeed@wpi.edu

Oleg Pavlov
Assistant Professor of Economics
Email: opavlov@wpi.edu

Social Science and Policy Studies Department
Worcester Polytechnic Institute
100 Institute Road, 01609 USA
phone: (508) 831 5553
fax: (508) 831 5896

Abstract

Telecommunications in developing countries lack adequate planning and policies, so their telephone densities show the lowest values worldwide. The failure in considering the complexity of the regional telecommunication system in developing policies and technological strategies has increased the telecom gap between other regions and this particular sector of the world. We used a system dynamics modeling approach as a methodology that deals with the complexity of the system in order to evaluate existing access technologies and value added services in telecommunications that could improve the dispersion of regional telephone services in developing countries. The role of Wireless Local Loop and cellular systems, which have low deployment delays, was found to be crucial on the growth of telecom infrastructure. The voice mail and prepaid payphone service implementation improved the telephone access in developing countries.

Introduction

Over the past several decades in developing countries, telecommunications have often been seen as a luxury after other investments such as: food production, transportation, electricity, or irrigation projects, among others. For this reason, developing countries account for only twelve percent of the total number of telephone lines worldwide. The situation for rural areas of these countries is even worse, although more than fifty percent of the world population lives in these regions. In fact, the telephone densities are several times greater in the main cities than in rural areas of developing countries (Saunders *et al.* 1994).

There is, however, a growing recognition that telecommunications is essential for economic development and political and social integration of remote areas (Saunders *et al.* 1994). Linking remote villages to the outside world with telecommunications improves the quality of life of the local population (Hudson 1984). The realization that telecommunication networks are an essential component in the process of rural development, induces a search for better policies, technologies, and investment strategies that increase telephone penetration in non-urban areas in developing countries.

The deployment of rural telecommunications involves the advancement of the universal service policy. Universal service can be defined by the provision of “universal” availability of connections by individual households to public telecommunication networks, with non-discriminatory and affordable prices (Hank and McCarthy 2000). In practice, progress toward universal service has been measured by the percentage of households with telephone service (Cain and Macdonald 1991)

The current policies and technologies for increasing telecommunications deployment in rural areas are considered to be insufficient or unsuccessful, and the plans for expansion of local telephone networks are considered to be imprecise considering the scope of the investment (Malecki 2003; Melody 1999; Strover 2003; Calhoun 1992). It has been historically observed in developing countries the low level of adoption of new telecom technologies mainly because of lack of understanding of the impact of these technologies. Currently, the wireless systems and value added services (VAS) are considered to have the potential to increase urban and rural telecom access in developing countries. However, it is still not clear if they will be able to improve the regional telephone density of these countries after their implementation.

The access plant of the traditional telephone network, as opposed to the switches and backhaul connections, is extremely unproductive and underutilized, and shows fewer economies of scales since it is largely dedicated. The access plant is considered to be the largest asset of the telephone network, since this can account for more than half of the total assets of the company. The traditional access plant is wired, and is largely a function of the distance from the subscriber to central office or switching equipment. For this reason, the cost to provide a telephone line to a rural subscriber could be ten times the cost for an urban subscriber (Calhoun 1992).

Wireless technologies, such as cellular networks and Wireless Local Loop (WLL), are being seen as a way to increase telephone density in developing countries, due to its rapid deployment and lower cost (Noerpel 1997). It has been observed during previous years a rapid growth of cellular networks in developing countries especially in cities and other urban areas. The wireless technologies are less sensitive to distance than traditional wired technologies, which makes them more attractive for deployment in dispersed or scattered rural environments. However, there are still several questions regarding their viability in developing countries. For instance, the lack of electricity and of reliable power supply in developing regions has been considered the biggest challenge in deploying wireless systems in these areas (Rycroft 1998).

In some cases, the low level of telecom penetration in developing countries has been attributed to an outdated telecommunications system that prevents development of value added services, which are able to generate more revenue required for telecom investment (Fretes-Cibils *et al.* 2003). In some cases, the resources invested in value added services, or intelligent network platform, have been considered to be worthwhile after the revenue of the telecom company is increased, and better service to the subscribers is provided (Hamersma 1996). In spite of this, few studies have been developed in order to assess the impact that these innovative solutions have on increasing the connectivity of nations (Barandse 2004).

This research has analyzed the impact of wireless and value added services on the dispersion of regional telephone services in developing countries using System Dynamics modeling. System Dynamics is a holistic methodology that deals with the limitation of bounded rationality or linear cause-and-effect relationship commonly applied in strategy design and considers the main interactions and feedback effects between the different elements of the system. For this reason, System Dynamics is appropriate for evaluating long-term policies and strategies needed for increasing telephone penetration in developing countries.

In the past, it has been observed in developing countries the low level of implementation of WLL services. The principal reasons found were the considerably high cost of the subscriber equipment and quality problems presented during the initial stage of deployment (Robledo and Arathoon 2002). However, this investigation found that WLL could be a viable alternative, especially in low-density countries, where the cost of wired systems increases considerably and the large coverage and low deployment delay of WLL systems become determinant factors on the dispersion of telephone services.

Cellular systems are considered the best technology currently in the market that is able to accelerate the growth of telecom services in developing countries, especially in urban areas. However, it was found that in thinly populated countries WLL performs better than any other access technology including cellular systems. In this scenario, the cellular access network still performs better than the conventional wired telephone network.

It was found that some value added services were able to improve the telephone access in developing countries. The voice mail and prepaid payphone service implementation significantly improved the number of phones in rural areas of developing countries.

The Regional Telecommunications System

The model considers a case of government or privately owned telecom monopoly. Thus, the impact of competition is not considered in this analysis. In this scenario, the tariffs are fixed and regulated by the government and the quality of service is assumed to be the same among the wired and wireless services under analysis. Finally, the financial resources of the telecom company are assumed to be totally reinvested in the system.

The following sectors form the regional telecommunication system implemented in this model: 1) Telephone Demand, 2) Telephone Deployment, 3) Telephone Traffic, and 4) Financial Resources.

The model sectors and their interactions are shown in Figure 1. These sectors are grouped according to the functions they perform. The Telephone Demand sector represents the subscribers with telephone and the unmet demand, which is composed of subscribers in the waiting list and subscribers willing to subscribe. The subscribers in the waiting list are connected at a rate, which depends on the number of telephones ready to be connected.

The Telephone Deployment sector represents the process of deployment of new telephone lines, which is a function of the amount of economic resources available, the number of subscribers in the waiting list, the current number of telephones ready to be connected, and the number of telephone lines being deployed. On the other hand, the Telephone Traffic sector represents the level of usage of the telephone network in urban and rural areas, which is a function of the price, income per capita, and the regional telephone density. Finally, the Financial Resources sector accumulates the economic resources used in the expansion of telephone infrastructure in urban and rural areas. This sector depends on the number of subscribers, telephone traffic, telephone service price, operating costs, and the investment in telecom infrastructure.

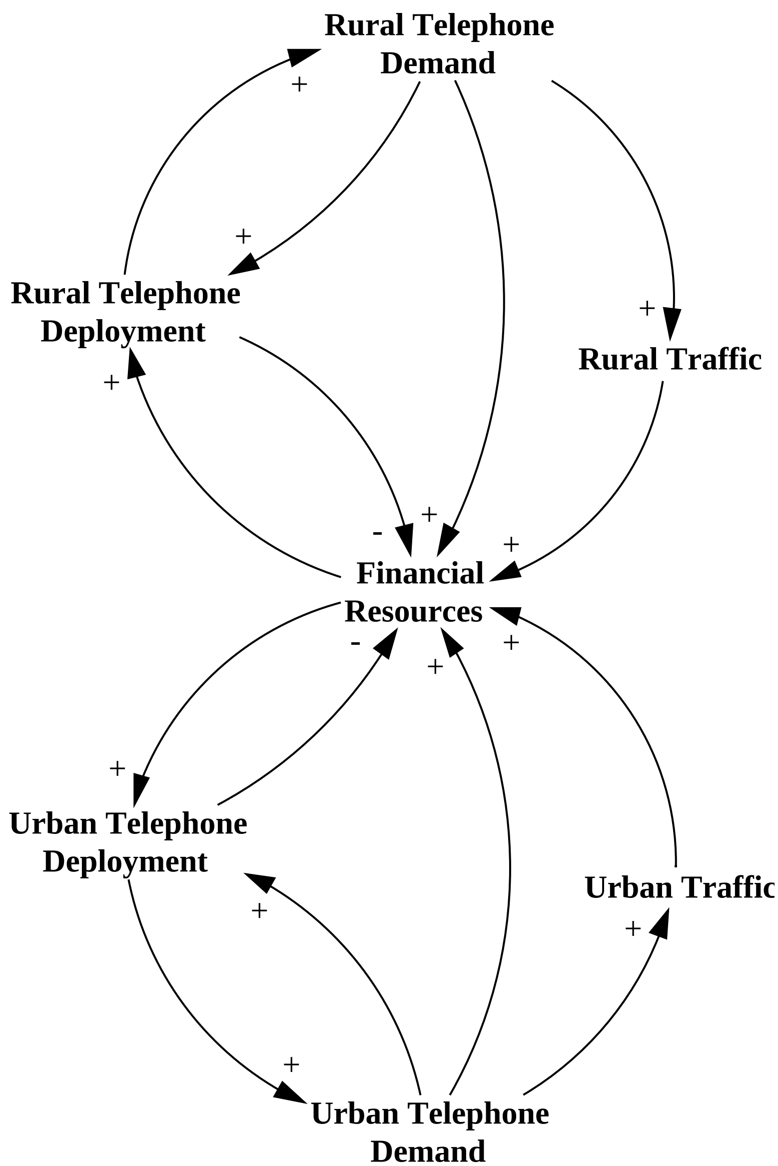

Figure 1. The Structure of the Regional Telecom System

Wired and Wireless Access Networks

The wired access plant is the largest component of a conventional telephone network, since the cost of the backhaul connections and switches are considered to be insignificant when compared with the cost of the access component (Webb 2000). Figure 2 shows a schematic of the wired telephone network, which includes the wired local loop, the switching office also known as central office or local exchange, and the backhaul connections. The wired local loop connects the switching office to the subscriber, and the backhaul connections interconnect the switching offices. The wired access plant, which goes from the switching office to the subscriber, includes the local loops associated with access and can account for more than fifty percent of the telephone company's book assets.

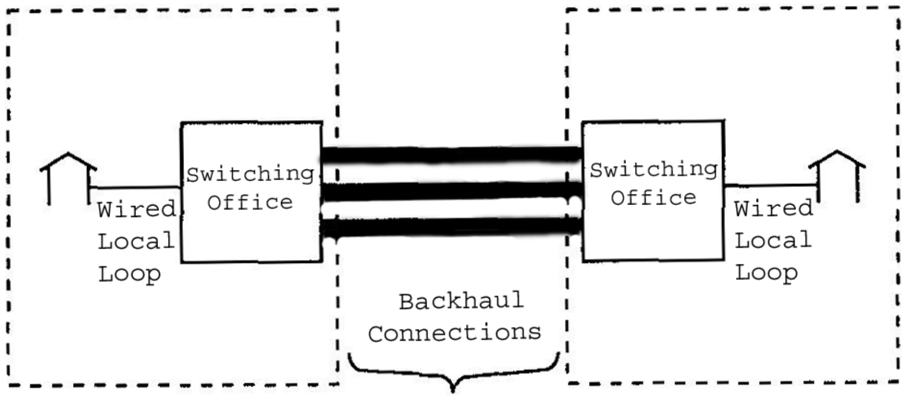

Figure 2. Schematic of a Wired Telephone Network

It has been established that the costs of wired local loops increases at a greater than linear rate as a function of the distance, and decreases as the subscriber density increases (Calhoun 1992; Mannisto and Tuisku 1994; Webb 2000). This situation occurs because longer wired loops require more cable, and incorporating additional loading coils and larger gauge cable. Historically, the telecom implementation has started in more dense urban areas, and then it has moved toward less dense suburban or rural areas, which have represented a transition to lower economies of scale, longer loop distances, and higher deployment costs (Saunders *et al.* 1994). In rural areas, where the population density is very low, the cost of the wired local loop could be more than ten times the cost in urban areas (Calhoun 1992).

The wireless technologies are being seen as an alternative to the access plant, which can replace the dedicated and underutilized copper wire with a shared and more efficient radio spectrum among subscribers (Duckworth 2004). Figure 3 shows the schematic of a telephone network with a wireless access plant, where the wired local loop of a conventional telephone network has been replaced with a wireless link, which can be fixed for the case of Wireless Local Loop systems or mobile for the case of cellular systems. The cost of wireless systems has less sensitivity to distance and subscriber density than wired systems, since it has little impact where and how the subscribers are located inside the area of coverage of the radio cell. However, it is important to emphasize that there could be some extra costs associated with very remote subscribers living in fringe coverage zones, where it may be necessary to install a higher subscriber antenna with higher gain (Calhoun 1992).

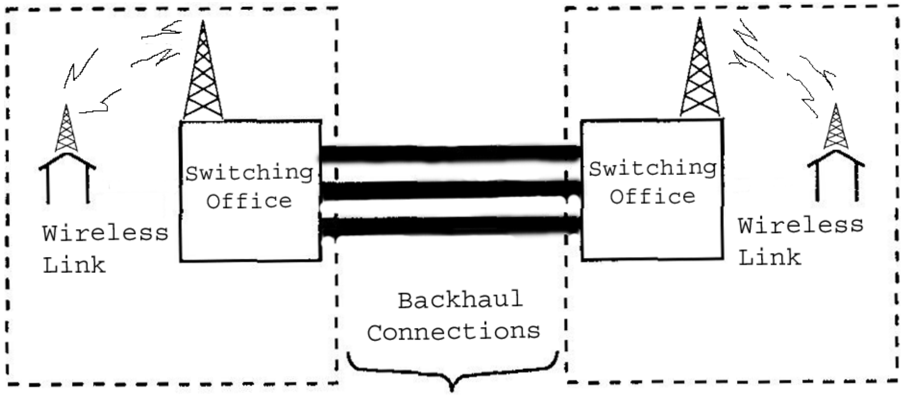

Figure 3. Schematic of a Telephone Network with Wireless Access Plant

The wireless technologies, such as cellular and WLL, have been considered to have the potential to increase telephone density in developing countries, because of its rapid deployment and lower implementation costs (Noerpel 1997; Hamersma 1996). In addition, wireless systems are supposed to reduce the relative cost difference between urban and rural deployment, so while rural access still remains more costly, the difference is not as big as the case of wireline technology. In spite of the potential advantages of wireless technologies, there are still several questions regarding their viability of implementation in developing countries. The lack of electricity and of reliable power supply in developing regions has been considered the biggest challenge in deploying wireless systems in these areas (Rycroft 1998).

The causal structures of wired and wireless access technologies in the regional telecommunications system are shown in Figures 4 and 5 respectively. In these figures, it can be observed that the cost of the access technology affects the provision of new telephones, which increases the total number of connected subscribers. The increase of connected subscribers improves the telephone density, which determines the population density of unserved areas or new connections. The higher the telephone density, the lower the population density of new connections, which become more remote or rural. In addition, the population density determines the average distance between households. This distance has a direct impact on the cost of a wired telephone line and also influences the deployment time, which affect the supply of new telephone lines as shown in Figure 4.

On the other hand, the causal structure of the wireless access technology is shown in Figure 5. The population density of new connections determines the area of the cell, which has a direct impact on the cost of the subscriber units as the distance from the subscriber to the base station increases and more expensive equipment is needed on the subscriber side. In addition, the access to electricity has an important impact on the cost of the subscriber unit, since additional power supplies, like solar panels, might be required. The population density determines the number of subscribers per base station, which influences the cost of a base station per subscriber. The higher the cost of the base station per subscriber and subscriber equipment, the higher the deployment cost of a wireless telephone in the system.

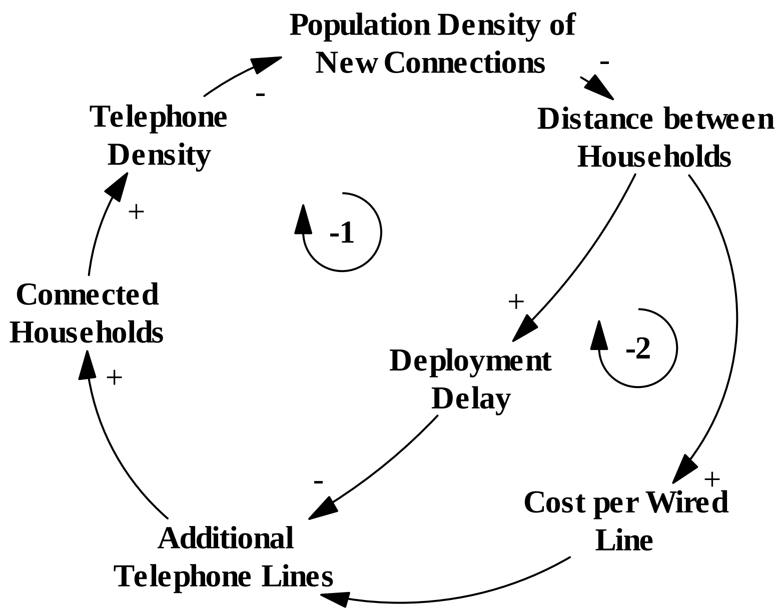

Figure 4. Causal Structure of Wired Technology in the Regional Telecommunications System

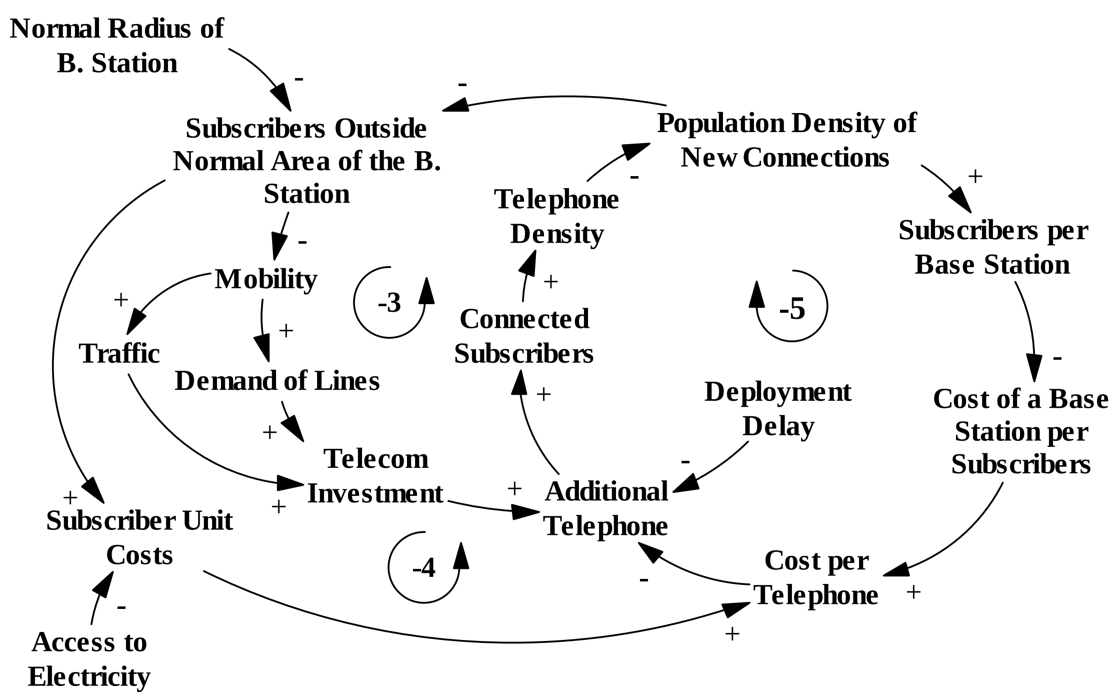

Figure 5. Causal Structure of Wireless Technologies in the Regional Telecommunications Systems

Value Added Services in Telecommunications

The provision of value added services, such as mail boxes, virtual telephony, and call answering, among others, represent an opportunity to improve the productivity or revenue from the local loops, and provide extra value or better service to the subscribers (Thorner 1994). It has been stated before that the local loop is extremely underutilized and unproductive so increasing the productivity of these loops would be essential to improve the financial resources, which are used for telephone expansion in developing countries.

The value added services have been found to improve the traffic and the call completion rate, which improve the revenue of the telephone network (Hamersma 1996; Thorner 1994). In some cases, the low level of telecom penetration in a country has been attributed to the fact that the telecommunications network is outdated, which prevents the deployment of value added services (Fretes-Cibils *et al.* 2003).

The implementation of value added service platforms, which are called intelligent networks (IN), involves improving this network and introducing new services on this platform (Thorner 1994). For instance, a low Dual Tone Multi Frequency penetration, which represents a high number of old electromechanical switches, is considered to have a low level of intelligence in the network (Hamersma 1996).

There is a management trend in developing countries to overlook or delay the provision of valued added services, since the focus has been to address the large number of waiting lists or outstanding demand in the system (Saunders *et al.*1994). The lack of financial resources makes difficult for telecom operators to expand their facilities to meet large unmet demands and replace old equipment at the same time. However, the cost of upgrading the switching system, which allows the provision of many value added services, is much lower than the cost to upgrade the local loop (Calhoun 1992).

The investment in value added services reduces the amount of investment available for telecom expansion but there is a potential to increase the financial resources of the telephone company in the long run. In addition, there is a believe in the telecom industry that investment in more advanced value added services from revenue generated in basic services, such as telephony, could divert the focus from the expansion of basic telecom infrastructure and universal service (Siochru 1996). For this reason, the investment cost of the valued added service platform needs to be trade-off against the potential increase of revenue and provision of better services to the subscribers (Hamersma 1996).

In spite of the potential benefits that value added services could provide to the expansion of telephone services in developing countries, there are few studies developed in order to assess the impact that these innovative solutions have on increasing telecom penetration in these nations (Barandse 2004). This research will study the impact of three different value added services: voice mail, virtual telephony, and prepaid payphone cards.

The voice mail service is offered to current telephone subscribers. This service requires the deployment of mailboxes. In addition, the prepaid payphone service is offered to all the population. This service requires the deployment of calling card numbers and public payphones. Finally, the virtual telephony service is offered to subscribers in the waiting list. This service is a combination of voice mail and prepaid payphone card services. Therefore, it requires the deployment of mailboxes, calling card numbers, and public payphones.

The causal structure of value added telephone services in developing countries is shown in Figure 6. It is observed that the investment in value added services increases the VAS infrastructure of the telephone company, which improves the availability of different VAS in the region. The higher the availability of these services in the country the higher the willingness to pay or demand for VAS. The increase in VAS demand improves the number of VAS users, which increase the economic resources to be used in future VAS and telephone investment. Finally, the higher the willingness to pay for value added services, such as virtual telephony and voice mail, the higher the demand for telephone services.

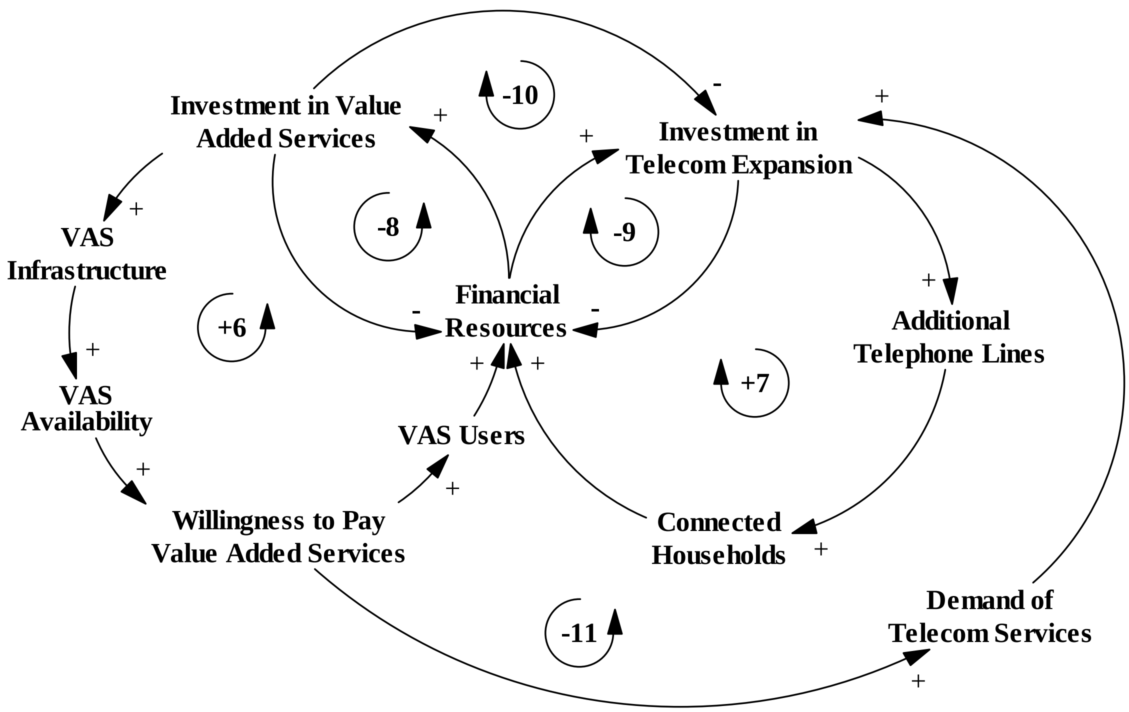

Figure 6. Impact of Value-Added Services on Telephone Expansion

Telecom Dispersion for Different Access Networks

In this section we simulate the historical and future behavior of the growth of the cellular and conventional wired telephone networks in Ecuador, which is shown in lines 1(cellular #1) and 2 (wired) of Figures 7, 8, 9, 10, 11, and 12 respectively. In addition, we simulated two hypothetical cases which consist on the implementation of Wireless Local Loop and cellular networks by the telephone operator as a replacement of the wired access network in year 1993, which is shown in lines 3 (WLL) and 4 (cellular #2) respectively.

The simulations are calibrated for the case of Ecuador, which has an urban income per capita of 1,708 dollars and a rural income per capita of 310 dollars. In addition, its urban population density is 284 people per kilometer squared and its rural population density is nineteen people per kilometer squared (World Development Indicators 2002). In

Figure 7, it is possible to observe the moment when the number of cellular phones surpassed the number of conventional telephone lines in year 2002. It is important to note that most of the implementation of the cellular network has been in urban regions.

The implementation of cellular systems in urban and rural areas involves the deployment of base stations that have a normal radius of coverage of five kilometers and an extended radius of coverage of thirty kilometers. The maximum number of subscribers supported by each base station is 5,000. The normal cost of each cellular base station is 150,000 dollars. In addition, the cost of a normal subscriber unit is fifty dollars, and the cost of a special subscriber unit, which is used outside the normal coverage of the base station, is 400 dollars. The normal subscriber unit is mobile since it can move inside the normal area covered by a base station, but the especial subscriber unit is fixed since it requires an especial antenna attached to the wall of the house in order to communicate with the base station. The access to electricity in urban areas is ninety eight percent and in rural areas is fifty percent of the population. The cost of a solar panel, which is used to supply with electricity the subscriber equipment in each house where there is not electricity, is 500 dollars. The license fee for cellular systems is assumed to be 50,000,000 dollars for a license period of fifteen years.

The implementation of WLL is similar to the cellular implementation. It considers the same level of access to electricity and the use of the same solar panels as the cellular case. It involves the deployment of base stations, which have a normal radius of coverage of fifteen kilometers and an extended coverage of thirty five kilometers. The maximum number of users supported by each base station is 5,000 households. The normal cost of each base station is 150,000 dollars; the cost of a normal subscriber unit is 400 dollars, and the cost of a special subscriber unit, which is used outside the normal coverage of the base station, is 600 dollars. The license fee for Wireless Local Loop has been set to 5,000,000 dollars for a license period of fifteen years.

The deployment of the cellular network produced the fastest growth of telephones in urban and rural areas. It is observed in line 1 of Figure 7 that the cellular network increased exponentially in urban areas, which represents the historical behavior observed in past years. The number of cellular subscribers keeps increasing exponentially until they achieve steady state growth, which is indicated by a linear growth. This situation is also observed in the hypothetical case in urban areas when the telecom operator decides to replace the wired access network by a cellular access network, as shown in line 4 of Figure 7. However, the cellular implementation does not produce the same exponential growth in rural areas; it produces a linear growth because the income per capita of the rural population is too low to afford several cellular phones per family. The rural households can afford only one cellular phone per family.

The number of urban and rural telephones is considerably improved by the implementation of the cellular network because it has the lowest cost per telephone in urban areas and the lowest deployment delay in both regions, as observed in lines 1 and 4 of Figures 9, 11, and 12. It is important to observe that the number of rural phones is still improved by the cellular network in spite of its higher cost per telephone in rural areas with respect to the wired network. This happens because the cellular network implementation delay is much lower than the implementation time of the wired telephone network. The lack of electricity in rural areas increases the cost of the cellular subscriber equipment due to the need of solar panels. In addition, the low rural population density requires the use of more expensive subscriber equipment which is fixed to each house. Therefore, the improvement in the implementation delay observed in cellular networks increases considerably the supply of urban and rural telephones, which increase the revenue and financial resources of the telecom company.

When the cellular system is implemented in the regional telecom system, the cellular subscribers increase the telephone density of the region. The higher the telephone density the lower the population density of the new connected subscribers as shown by negative feedback loop 5 in Figure 5. The reduction of the population density of the new connected subscribers because of the growth of the telephone density increases the number of subscribers outside the normal area covered by a cellular base station, as shown by negative feedback loop 4 in Figure 5. This determines a higher number of subscribers requiring fixed antennas and especial equipment in order to connect to the base stations from home, which represents higher costs for the subscriber units. In addition, the low access to electricity in developing countries is a major factor influencing the cost of the subscriber unit, which increases the cost of deploying a phone in the system.

The higher the number of subscribers with fixed antennas located outside the normal area covered by the base stations, the lower the number of subscribers with mobility in the cellular network, as shown by negative feedback loop 3 in Figure 5. The mobility is a characteristic of the cellular network that improves the attractiveness and demand of the telephone service. The improvement on demand increases the investment in cellular lines when there are enough financial resources available. In addition, the mobility and portability of the cellular system tends to increase the traffic of the network since the willingness to pay and usefulness of a telephone has been improved.

It is observed in line 3 of Figure 7 and 8 that the hypothetical implementation of WLL is able to improve the number of rural and urban telephone lines in the long run with respect to the conventional wired access network which is shown in line 2. This situation occurs in spite of the higher cost per telephone of the WLL system with respect to conventional wired network, as observed in lines 2 and 3 of Figures 9 and 10. The lower deployment delay of the WLL system with respect to the conventional wired system, which is shown in lines 2 and 3 of Figures 11 and 12, is able to improve the supply of telephones in spite of its higher cost.

When the WLL technology is implemented in the regional telecom system, the new WLL subscribers or connected households increase the telephone density of the region. The higher the telephone density the lower the population density of the new subscribers being connected as shown by negative feedback loop 5 in Figure 5. In addition, the low access to electricity in developing countries is a major factor influencing the cost of the subscriber unit, as shown in negative feedback loop 4 of Figure 5. The higher the subscriber cost the higher the cost of a WLL telephone line, as shown in negative feedback loop 3.

The growth of telephone lines in the conventional wired network also reduces the population density of the new connected subscribers as the telephone density of the region increases. This situation increases the distance between households as shown by negative feedback loop 1 in Figure 4, which considerably increases the deployment delay and the cost of the wired telephone line. The relatively high deployment delay and cost of a wired telephone line reduces the supply of new telephone lines and the number of connected households, as shown by negative feedback loops 1 and 2 in Figure 4.

Sensitivity Analysis of Different Access Technologies

The preceding section showed how cellular technologies were able to considerably improve the number of telephones in urban and rural areas of Ecuador. We conducted additional experiments to test the sensitivity of the cellular system and other access technologies to changes in population densities. The population densities were reduced from 284 people per kilometer squared to seventeen people per kilometer squared in urban areas, and from nineteen people per kilometer squared to two people per kilometer squared in rural areas. The simulation results of the sensitivity analysis are shown in Table 1.

It is observed that a lower population density reduces the impact of the cellular technology in the regional telecom system, but this technology is still able to increase the number of phones in urban and rural areas when compared with the conventional wired technology. This situation is observed in the hypothetical case when the cellular access network is implemented as a replacement of the wired external plant, which is indicated by technologies one and four in Table 1. However, it is observed that WLL provides the best performance in urban and rural regions under this new scenario. This happens due to the larger coverage of the WLL cell with respect to the cellular cell, which reduces the cost. The larger radio of coverage per base station requires a lower number of special and more expensive equipment required to connect the subscriber with the base station in areas outside the normal coverage. It is also observed that WLL achieves steady state growth sooner than any other technology in urban areas.

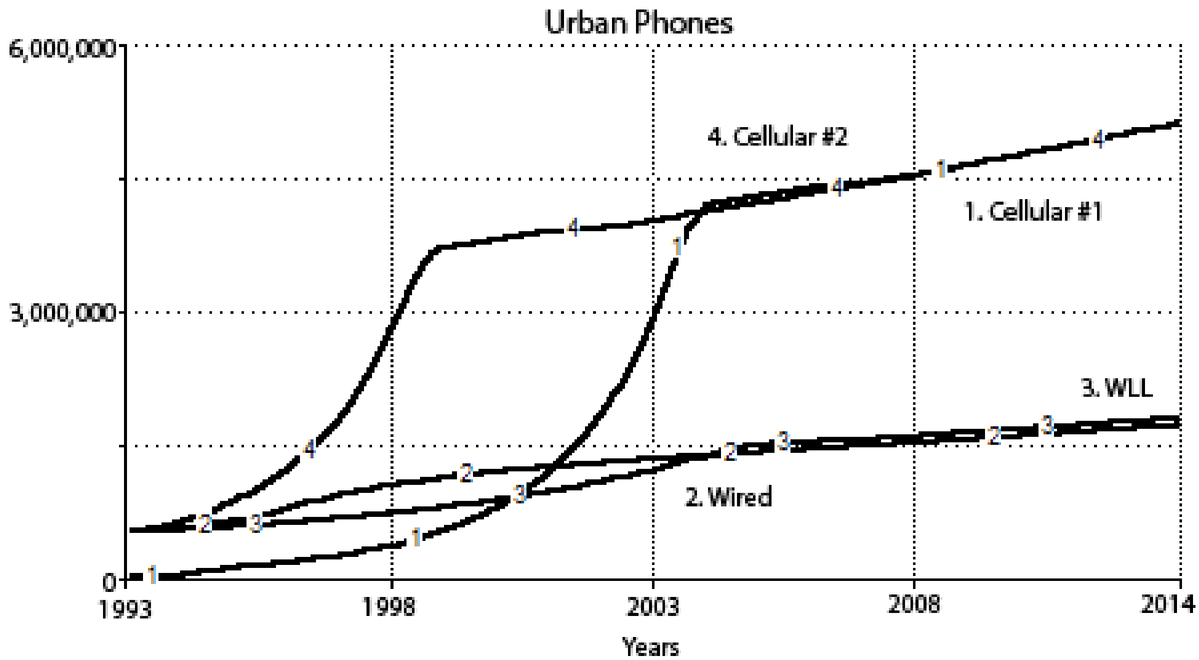

Figure 7. Urban Phones for Different Access Networks

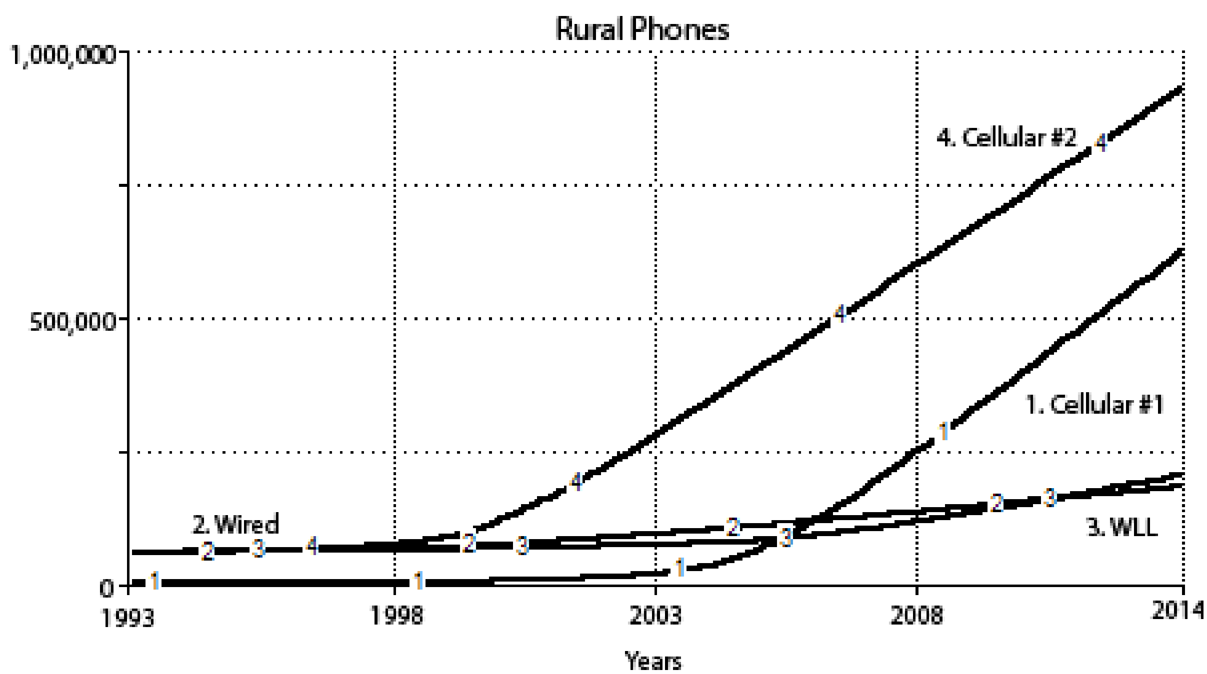

Figure 8. Rural Phones for Different Access Networks

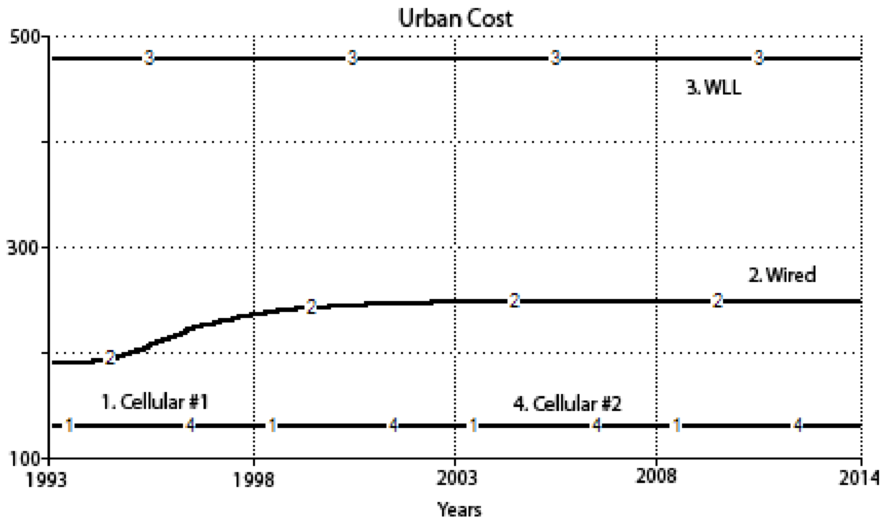

Figure 9. Urban Cost for Different Access Networks

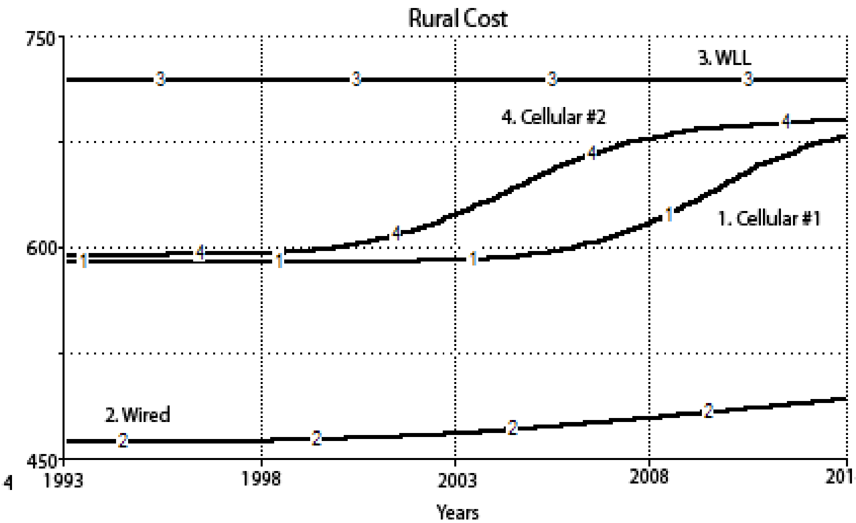

Figure 10. Rural Cost for Different Access Networks

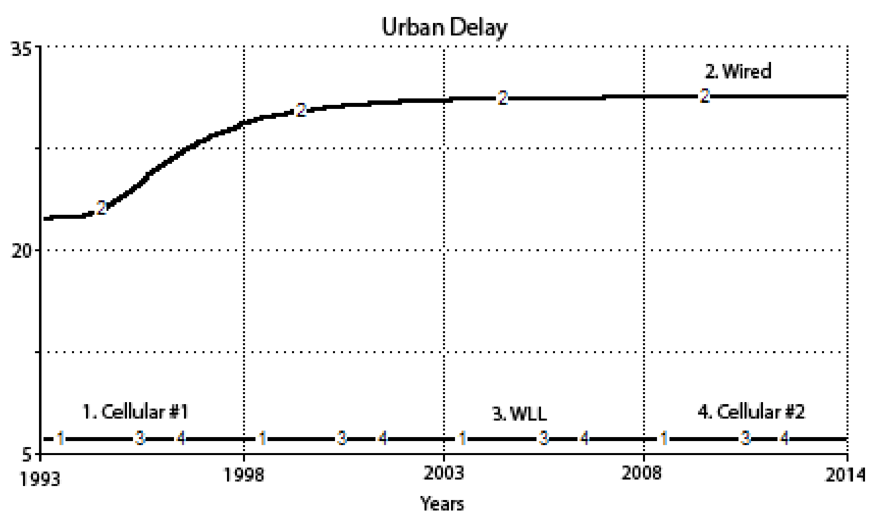

Figure 11. Urban Delay for Different Access Networks

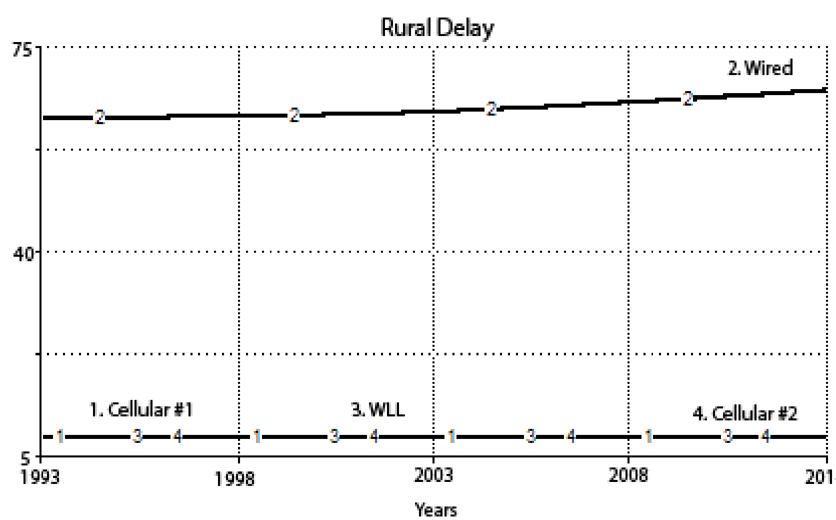

Figure 12. Rural Delay for Different Access Networks

		Years				
Technology	Telecom Indicators	1993	1998	2003	2008	2014
1. Cellular #1	Urban Phones	0	86.675	111.651	162.828	276.715
	Rural Phones	0	965	1.231	1.777	2.999
	Urban Cost	246	249	249	250	252
	Rural Cost	706	706	706	706	706
	Urban Delay	6	6	6	6	6
	Rural Delay	8	8	8	8	8
2. Wired	Urban Phones	538.458	548.448	548.784	548.940	549.013
	Rural Phones	59.829	56.236	46.142	33.420	21.671
	Urban Cost	648	606	569	546	530
	Rural Cost	1.338	1.335	1.329	1.322	1.316
	Urban Delay	91	85	78	76	74
	Rural Delay	195	194	193	192	191
3. WLL	Urban Phones	538.458	776.121	1.307.627	1.602.804	1.809.448
	Rural Phones	59.829	63.860	73.048	112.214	181.203
	Urban Cost	480	480	519	531	531
	Rural Cost	853	853	854	856	862
	Urban Delay	6	6	6	6	6
	Rural Delay	8	8	8	8	8
4. Cellular #2	Urban Phones	538.458	733.486	1.011.228	1.543.091	2.586.728
	Rural Phones	59.829	62.128	65.512	72.481	88.396
	Urban Cost	272	280	295	329	387
	Rural Cost	707	707	707	707	707
	Urban Delay	6	6	6	6	6
	Rural Delay	8	8	8	8	8

Table 1. Performance of Different Access Technologies for a Thinly Populated Country

Impact of Value Added Services on Telecom Expansion

The impact of the implementation of different value added services in the regional telecommunications system is observed in Figures 13, 14, and 15. The value added services implemented are voice mail, virtual telephony, and prepaid payphone services. It is important to note that each VAS is simulated individually and the investment in each of them is assumed two percent of the total investment budget, which is subtracted from urban telephone investment. The initial telephone density in year1993 is twenty six telephones per 100 households or about seven telephones per 100 inhabitants.

The regional distribution of voice mail investment is fifty percent in mailboxes in both rural and urban areas and the cost of each mailbox number is ten dollars. The investment in prepaid payphone services is thirty five percent in payphone implementation in both urban and rural areas, and fifteen percent in calling card numbers in both regions. The cost of payphone implementation includes the cost of each payphone device, which is

500 dollars, and the cost of a telephone line. The cost of each calling card number, which is implemented in the intelligent network platform of the telecom operator, is five dollars. Finally, the investment in virtual telephony is ten percent in mailbox numbers in both urban and rural areas, thirty percent in payphone implementation in both regions, and ten percent in calling card numbers in both regions.

It can be observed in lines 2 and 4 of Figures 14 and 15 that the implementation of voice mail and prepaid payphone services improve the number of rural telephones and financial resources respectively. The improvement of financial resources increases the rural telecom investment and the number of rural phones. On the other hand, the implementation of virtual telephony is not good enough to improve the financial resources of the telecom company and the number of rural phones. Finally, the implementation of these value added services do not have a major impact on the expansion of telephones in urban areas. This situation occurs because urban phones achieve steady state growth in the short term, which means that demand of phones equals supply of phones in urban areas.

The investment in voice mail and payphone services increases the voice mail and prepaid payphone infrastructure and availability, which improve the willingness to pay or demand for voice mail and payphone services, as observed in positive feedback loop 6 of Figure 6. The improvement in willingness to pay increases the number of users, which improve the revenue from voice mail service fees and prepaid payphone card usage. In addition, the increase in the number of voice mail users improves the revenue from telephone traffic, since more telephone calls are completed. This situation improves the financial resources of the company, which increase the investment in telephone expansion, as shown by positive feedback loop 7. The improvement in telephone expansion investment increases the number of rural telephones and subscribers. The deployment of voice mail services in urban and rural areas also improves the demand and investment of telephones in urban and rural areas as shown by negative feedback loop 11 in Figure 6.

Sensitivity Analysis of Different Value Added Services

The preceding section showed how voice mail and prepaid payphone services improved the number of rural telephones in Ecuador. We conducted additional experiments to test the sensitivity these value added services to changes in the telephone density. The initial telephone density was reduced from twenty six telephones per 100 households to three telephones per 100 households. The simulation results of the sensitivity analysis are shown in Table 2.

It is observed that voice mail and prepaid payphone services still are able to improve the number of rural phones in a developing country with a very low telephone density. This situation occurs because prepaid payphone and voice mail services considerably improve the financial resources of the telecom company, which are used for investment in telephone expansion. On the other hand, virtual telephony also improves the financial resources of the telecom company but is not able to increase the number of rural phones.

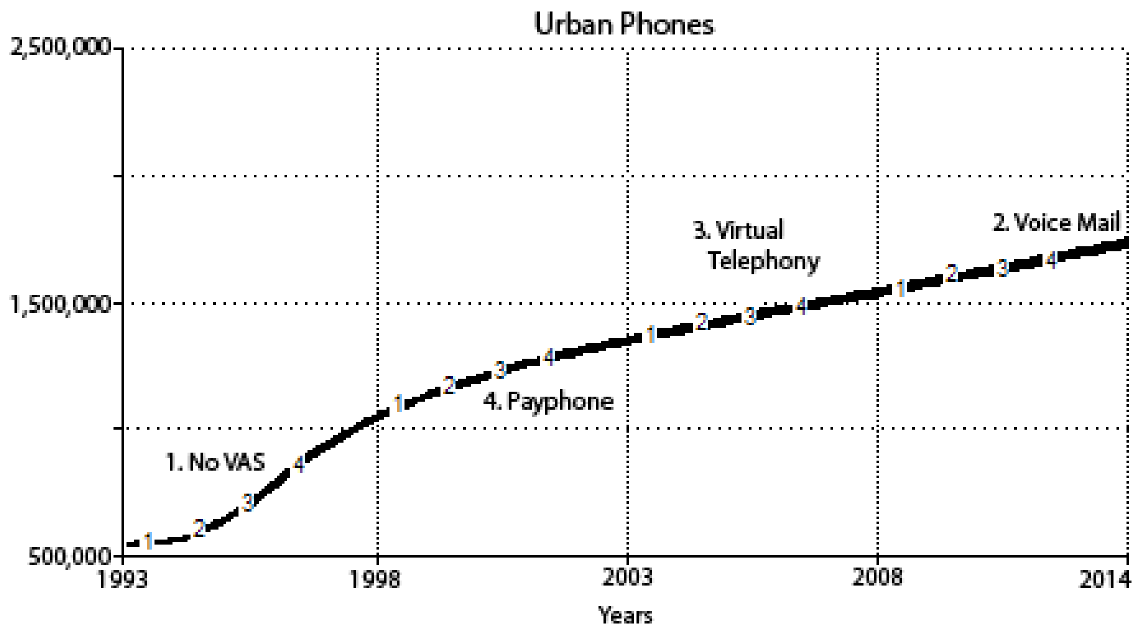

Figure 13. Urban Phones for Different VAS Implementation

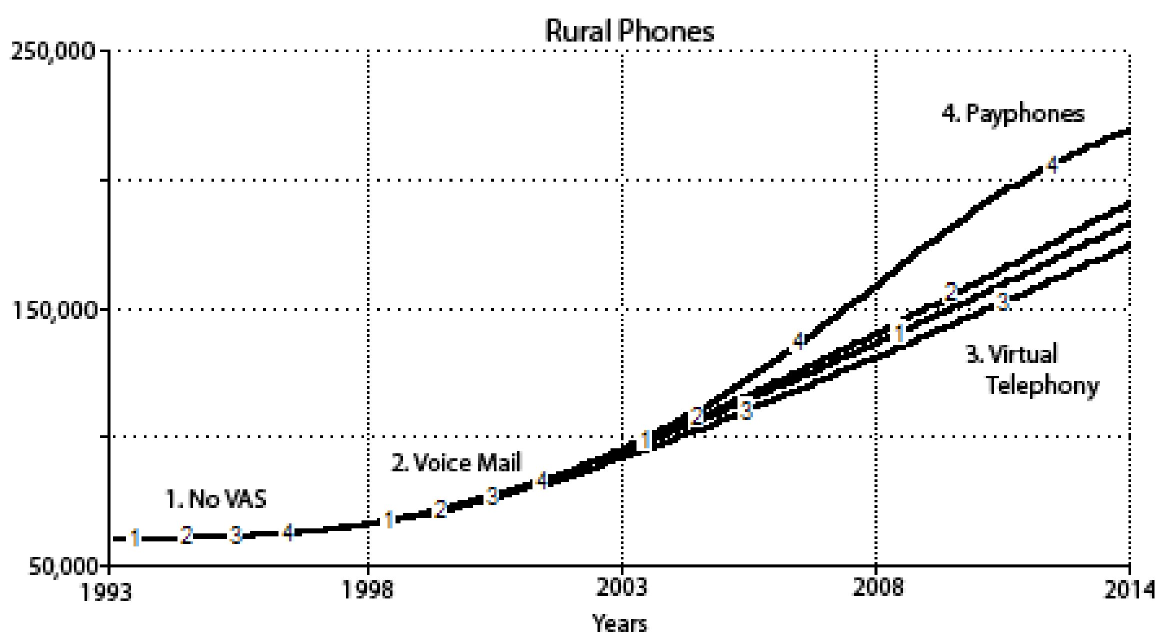

Figure 14. Rural Phones for Different VAS Implementation

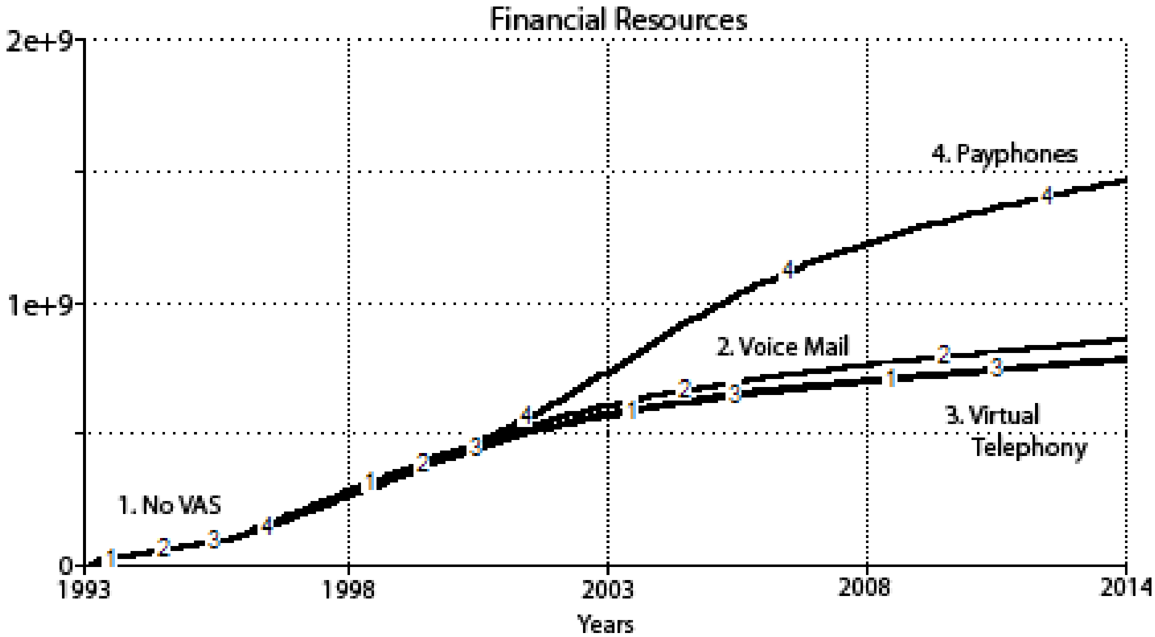

Figure 15. Financial Resources for Different VAS Implementation

		Years				
VAS	Telecom Indicators	1993	1998	2003	2008	2014
1. No VAS	Urban Phones	538.458	2.028.494	9.855.138	14.961.082	17.297.645
	Rural Phones	59.829	65.290	109.785	385.060	875.788
	Financial Resources	0	0.023e+10	0.19e+10	0.61e+10	0.8e+10
2. Voice Mail	Urban Phones	538.458	1.982.066	9.708.127	15.087.406	17.492.470
	Rural Phones	59.829	65.229	108.008	384.531	909.475
	Financial Resources	0	0.023e+10	0.18e+10	0.64e+10	0.87e+10
3. Virtual Telephony	Urban Phones	538.458	1.954.774	9.417.366	14.941.756	17.329.789
	Rural Phones	59.829	65.128	104.431	346.556	802.678
	Financial Resources	0	0.022e+10	0.16e+10	0.62e+10	0.82e+10
4. Payphones	Urban Phones	538.458	1.954.935	9.440.000	14.901.898	17.290.851
	Rural Phones	59.829	65.130	104.819	371.089	1.055.719
	Financial Resources	0	0.022e+10	0.16e+10	0.72e+10	1.35e+10

Table 2. Performance of Different Value-Added Services for Lower Telephone Density

Conclusions

This paper realized an investigation of three different access technologies: wired access networks, Wireless Local Loop, and cellular systems, and three value added services: voice mail, virtual telephony, and prepaid payphone services. The wireless technologies and voice mail and prepaid payphone services were able to considerably improve the regional dispersion of telephone services.

Additionally, it is important to note that there is not specific access technology that provides the best performance for every type of environment. For instance, Wireless Local Loop was found to be the best technology for improving the number of urban and rural telephones in a thinly populated country. On the other hand, the cellular system implementation showed the best performance for the specific case of Ecuador.

It is important to note that developing countries have had a low level of implementation of Wireless Local Loop services in past years. However, this investigation found that WLL could be a viable alternative in spite of its relative high cost, especially in low density countries, where the cost of wired systems increases and the low deployment delay and relatively large coverage of WLL systems become crucial factors in the dispersion of telephone services.

An important aspect observed in the analysis of this investigation was the impact of deployment delay on the dispersion of telephone services. It was determined as a very important factor for increasing the number of telephone lines in developing countries. For instance, it was found that in certain settings the cost of a wireless technology was higher than the cost of a wired system, but because of the lower deployment delay the performance of the wireless system was better than that of the wired one.

The voice mail and prepaid payphone services implementation were found to have a positive impact on the expansion of telephone services. They were able to improve the financial resources of the telecom company and the number of rural telephones.

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