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ORIGINAL

Via Hand Delivery

November 13, 1998

Ms. Blanca Bayo
Director, Division of Records and Reporting
Florida Public Service Commission
2540 Shumard Oak Blvd.
Tallahassee, FL 32399-0850

Re: In re: Fair and Reasonable Residential Basic Local Telecommunications Rates
Special Project No. 980000A-SP, Docket No. 980733-TL (Discovery)

Dear Ms. Bayo:

Enclosed for filing in the above-captioned matter is an original and fifteen copies of the American Association of Retired Persons ("AARP")'s final written comments in this proceeding.

Please acknowledge receipt of these documents by date stamping the extra copy of this letter and returning the same to me.

If you have any questions regarding this matter, please feel free to contact me. Thank you for your assistance processing this filing.

Very truly yours,

David M. Frank

encls: as stated

cc: parties of record (reg. mail)

PRESERVING JUST, REASONABLE AND AFFORDABLE BASIC SERVICE RATES

Prepared by Dr. Mark N. Cooper
On Behalf of the American Association of Retired Persons
Before the Florida Public Service Commission
Undocketed Special Project 980000A-SP

November 13, 1998

INTRODUCTION

AARP's initial testimony in this proceeding shows that there are no economic, legal, technological, competitive, social or public policy reasons to raise basic service rates. These final comments present detailed empirical analyses that support AARP's recommendation that basic service rates not be increased.

The most fundamental reason that there is no justification for basic service rate increases is that the loop is a facility shared by many services including basic local service, vertical services, intraLATA long distance, interLATA long distance and data. Services that share the loop have always contributed to the recovery of its costs. This is a principle that has been applied to the telecommunications network for its entire history. It was upheld by the Supreme Court in 1930 and has been used by the Federal Communications Commission (FCC) and virtually all state public utility commissions, including the Florida Public Service Commission (the Commission) since then. The FCC has reaffirmed the principle several times since the passage of the Telecommunications Act of 1996 (the '96 Act).

We see no reason to stop recovering costs for a facility from all the services that use that facility. There should be no free rides. We believe that ensuring that each of the growing array of services that will likely be provided over the telecommunications network pays a fair share of all common costs will result in rates for basic service becoming more and more affordable.

IT IS ECONOMICALLY CORRECT TO REQUIRE SHARING OF LOOP COSTS

Telephone companies say: Access to the network is a separate product whose costs must be recovered separately and sold as local measured service, while people pay for the mere right to place long distance calls.

AARP responds: Consumers want actual service such as local and long distance calls, not just access, and the companies that use the loop to sell services should pay for the inputs necessary to produce those services.

- **Use of the loop is a necessary condition for the sale of these services.**
- **Access only service (incoming calls only) could not be sold for very much because it has little value.**
- **Local measured service is not very popular, where it is sold as an option, precisely because it severs the natural link between access and use.**
- **Vertical services are supported by the network and are strong complements of basic service.**
- **Long distance calls use the network exactly the same way local calls do.**
- **New services, like high-speed data (xDSL), utilize the loop and other facilities just like local calls.**

The telephone company argument rests on a very simple and fundamentally incorrect assumption. It is based on the belief that people are willing to pay for access regardless of the use to which the loop is put. We believe it is much more appropriate to say that use determines the value of access. Consumers want actual services, such as local and long distance, not just access.

The kind of language used by the telephone companies to make this argument is worth some attention.

'When a consumer expresses a need for a particular service and offers to pay for it, the supplier of the service must expend productive resources in order to meet the need... A price must reflect a cost and, in particular, the (demand) activity that gives rise to it. It does not matter what subsequent use the service may be put to.'

This view simply assumes a need that is separate from any use. We believe it is a better description of human motivation to say that

'Use meets needs and creates a willingness to pay for service. Use is the activity that gives rise to demand. Services that have no use would not fill any need and no one would be willing to pay for them.'

Looking at services that are actually sold reinforces this conclusion. Selling an access-only service would be a difficult proposition. Most people would not buy such a service because use is what they want. Those few people who would buy access-only would not pay a great deal for it because it does not have a lot of value. It is fundamentally incorrect to separate use from value when it comes to something like the telecommunications network.

Another example is local measured service (billing for local calls on a per call or per minute basis). It is not very popular where it is actually sold, even when many people could be shown to have a lower bill. People do not buy it because it severs that natural link between use and value.

Vertical services are similar. They cannot be separated easily from the basic service with which they are sold. They are very strong complements of basic service. That is, if someone sells basic service to a customer, there is almost no chance that a different person is going to sell call waiting to that consumer.

A second error that telephone companies make is to assume that basic service takes precedence in a fictitious hierarchy of cost causation. The kind of language the telephone companies use to state their argument is again worth quoting

'It so happens that setting a consumer up to have basic service offers a variety of capabilities right away.'

We believe that it is just as true to say the following.

'It so happens that setting a consumer up to have long distance service offers a variety of capabilities right away.'

Both statements are equally true. In fact, it actually turns out that historically long distance over the loop did not "so happen." At the turn of the century when the telephone network was being deployed, local and long distance were separate. Callers had to go downtown to a central office to make a long distance call. The telephone company decided to integrate those two services. It was a conscious marketing and economic decision to bring local and long distance onto the one network and sell them together. This was not just an accident. Local did not cause the network and long distance just to happen along. In fact, at that time, to make loops support long distance, they had to be enhanced. Long distance caused the cost of the loop to rise dramatically. Attachment A is a study commission by AARP of the historical pattern of cost causation and allocation between premium services and basic service that documents the process.

Thus, for almost a century the network has been designed and deployed and sold as an integrated product that includes both long distance and local. It is pure sophistry to declare basic service as the cost causer.

A third set of erroneous arguments is that this is somehow the only way these costs can be recovered in a competitive market. In defending the telephone company preference for measured service and the desire to charge for access separately in basic service, the telephone companies offer arguments along the following lines:

'Charges for access alone are common in many competitive markets (e.g. clubs, credit cards, on-line computer services, long distance telephone service, etc.).'

We believe that it is probably more accurate to say

'Charges for access alone are absent from most competitive markets (e.g. supermarkets, shopping malls, drug stores, hardware stores, on-line computer services, theme parks, like Disney World, etc.).'

Thus, historically and contemporaneously it makes no sense to claim that the loop is caused by local service, while long distance and other services get a free ride.

IT IS LEGAL TO REQUIRE OTHER SERVICES TO PAY A SHARE OF LOOPS COSTS

Telephone companies say: The Telecommunications Act of 1996 requires subsidies to be explicit and therefore basic service rates should rise to cover 100 percent of the loop costs.

AARP responds: The 1996 Act recognized the shared nature of the network and intended for that sharing to be leveraged to make basic service affordable.

- Section 2545 (k) of the Act requires basic service to bear no more than a reasonable share of joint and common costs and it may bear less.
- Advanced services and basic service are repeatedly linked.
- Competitive services cannot be subsidized by non-competitive services.
- Rate rebalancing is not required or even mentioned in the Act.
- When the loop is treated as a shared cost, basic rates are not subsidized.
- Rates fall well within a range established by reasonable sharing rules.

Telephone company efforts to interpret the Telecommunications Act of 1996 to require basic rates to rise to recover loop costs are at odds with much of the explicit language in the

Act. The shared nature of the network is repeatedly recognized in the Act. Section 254(k) says that basic service should bear no more than a reasonable share of joint and common costs for facilities used by competitive services. The Conference Report (p. 129) actually says basic service could bear less than a reasonable share of those joint and common costs.

Throughout the Act, the fact that the network will deliver advanced and basic service is repeatedly recognized (e.g. the preamble, sections 254 (a) and (c)). The Act understood that there would be an array of services on the network and intended to protect basic service rates.

The words rate rebalancing do not appear in the Act. In fact, the desire to have subsidies made explicit is not the paramount policy in the Act. The Conference Report (p. 131) states that only "to the extent possible... support mechanisms continued or created under new section 254 should be explicit rather than implicit."

Given this policy context, it is important to recognize that once the loop is treated as a shared cost, basic service rates are not subsidized and are quite reasonable, even using the companies' own estimates of costs, which we frequently think are overstated.

For instance, once the loop is treated as a shared cost, it is clear that basic service covers its total service long-run incremental cost. Sprint's own number for incremental cost is $3.21. BellSouth's and GTE's numbers are similar. Basic service rates cover these costs. Our analysis of the BellSouth numbers reaches the same conclusion. They are clearly below stand-alone costs. According to the rigorous definition of subsidy, basic service is neither the source nor the recipient of a subsidy, once the loop is treated as a shared cost.

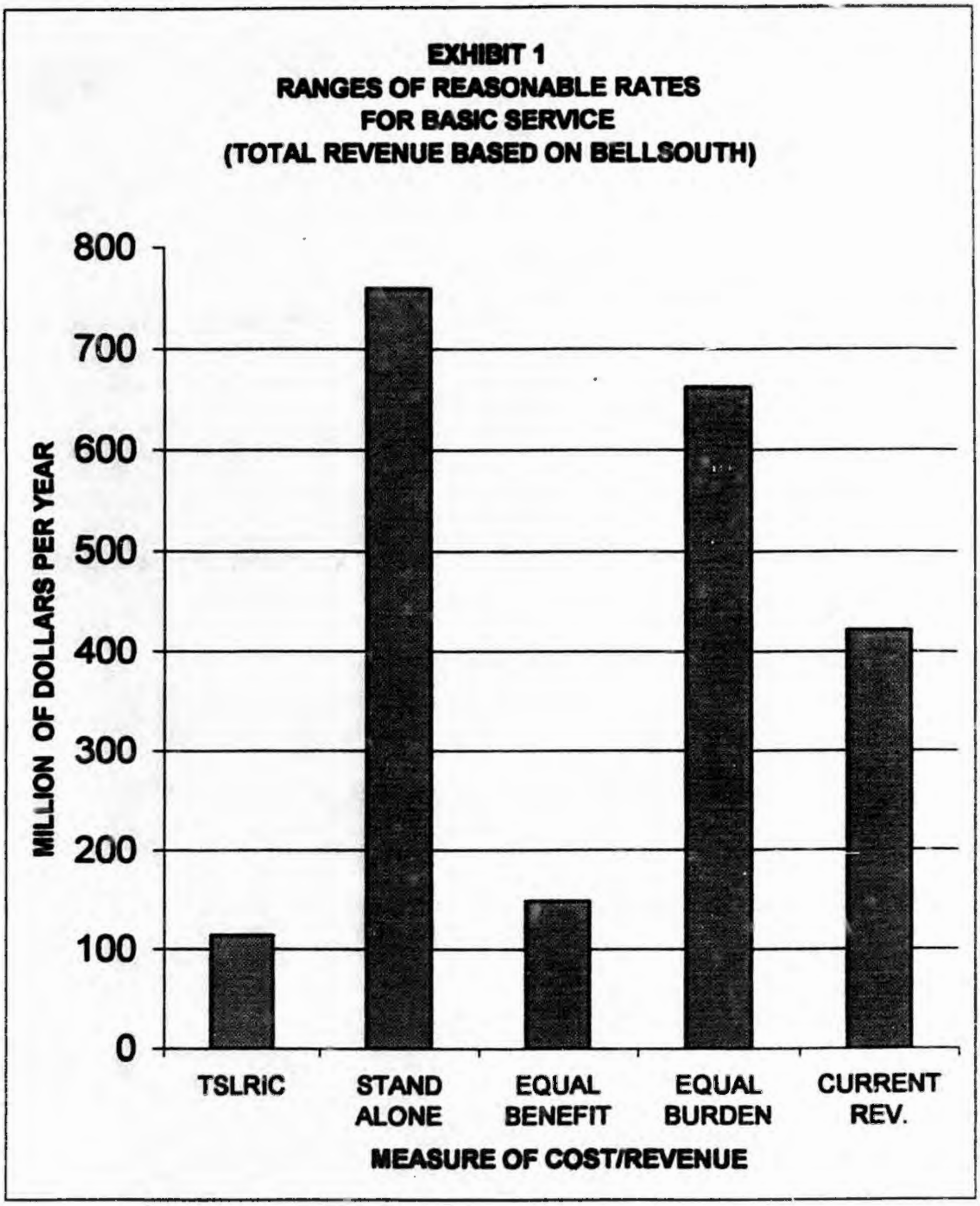
Having established the absence of a subsidy, the question of how shared costs should be recovered from all services arises. There are a variety of rules that can be applied.

One rule is an equal benefit rule. The telecommunications industry enjoys the benefit of economies of scale and scope. That is, by selling more than one product and selling larger quantities, it becomes less and less expensive to sell products on a per unit basis. The equal benefit rule marks each service down proportionately. Each service gets an equal mark down (benefit) from the stand-alone cost of the individual service.

Another rule is an equal burden rule. That is, identify the total service long-run incremental cost of each service and mark it up sufficiently to cover the total cost of the operation.

Applying these two rules we find that basic service falls within the range of reasonable prices. Exhibit 1 shows the results for BellSouth, since these numbers have been made available on a detailed basis in a non-proprietary manner. The results for other companies are similar.

Basic service is above the price set by the equal benefit rule and below the price set by the equal burden rule. Basic service bears a lower margin than other services, but that is the point of public policy. That is why the Act said no more than a reasonable share, and the conference report said perhaps even less than a reasonable share of common cost could be allocated to basic service.



Source: BELL SOUTH CONTRIBUTION ANALYSIS, Response to FPSC Staff 1st Data Request, Item No. 1, assumes loop costs equal 85% of basic service costs

FAIR RATES

Telephone companies say: It would be fair to raise rates because local service has become so valuable over the last 15 years.

AARP responds: Rates are fair today. Some household commodities have performed better than telephone service in the past 15 years, some worse. Such comparisons are not a basis for changing rates.

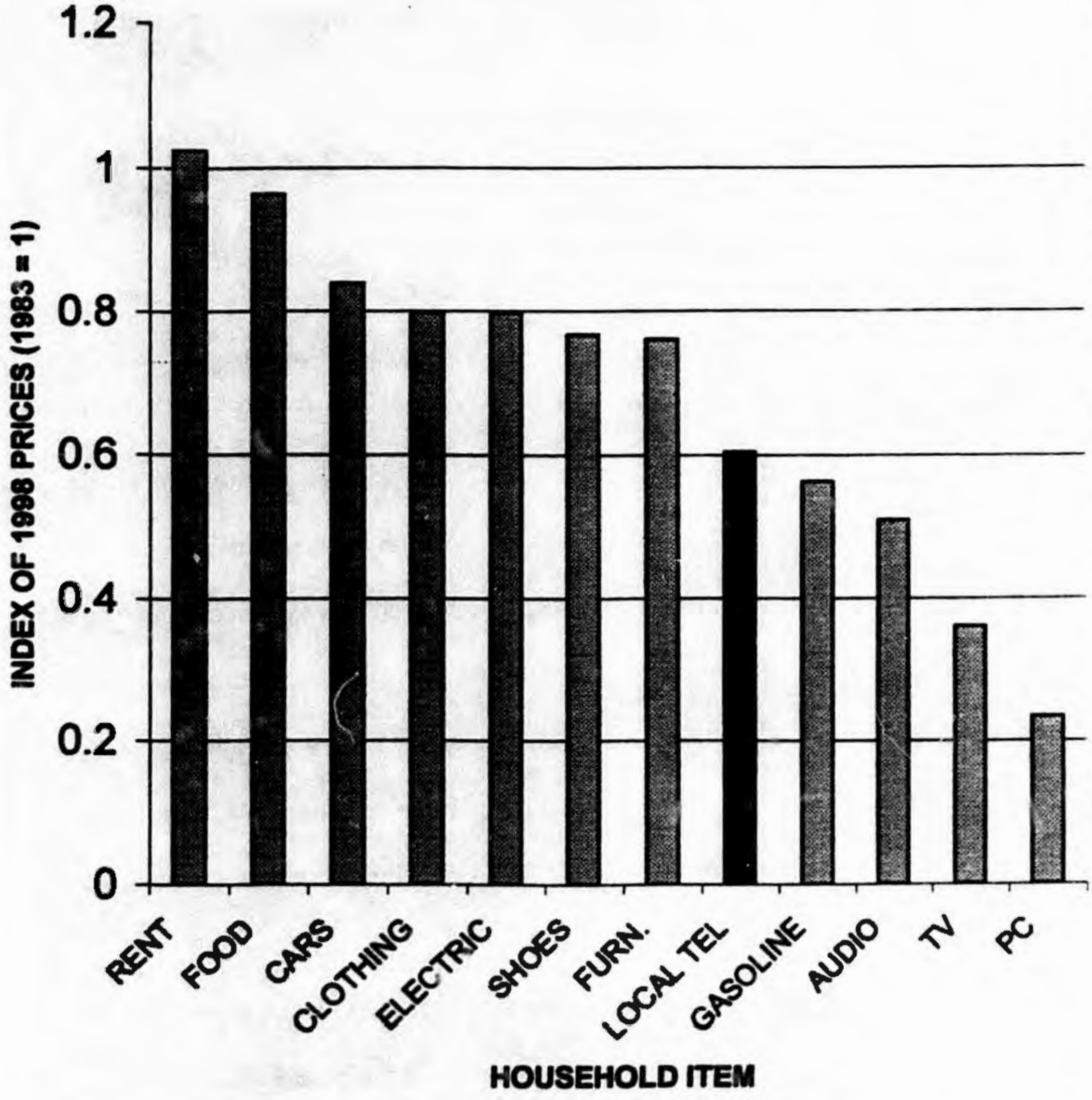
- **The increases proposed would make local service one of the worst performers in the household budget in the past 15 years.**
- **Comparing telephone rates to cable TV rates only underscores how unfair it would be to allow telephone prices to increase as unregulated monopoly cable TV rates have.**
- **Florida should not follow the anti-consumer policies of other states.**

Unlike other states, Florida requires the Commission to inquire as to whether rates are fair. This is new territory. Fairness is rarely raised as an explicit consideration in ratemaking. Because it is new, the Commission should not be mislead by erroneous comparisons.

The Commission is being told that because telephone service has become so valuable over the last 15 years, it can raise rates dramatically and they would still be "fair." It turns out that the performance of telephone rates in the last 15 years is only a little bit better than other things in the household budget (see Exhibit 2). A number of commodities frequently used by households have done better.

Personal Computers (PCs) have done much better. Other things like TVs and audio equipment have done better. Consumers have received the benefits of a technology revolution in PCs, television, audio, telephone

EXHIBIT 2
AT TODAY'S PRICES, CURRENT LOCAL RATES ARE JUST "FAIR"
(CONSUMER PRICE INDEX v. LOCAL RATES)



Source: CONSUMER PRICE INDEX; REPORT ON RESIDENTIAL TELEPHONE SERVICE IN FLORIDA, Robert G. Harris service, and other electronically based and computer driven industries. Companies in those industries have had strong financial growth, including telephone companies. It would be unfair to deny consumers a share of those gains.

Gasoline has come way down in price as well. That has to do with the ending of a monopoly.

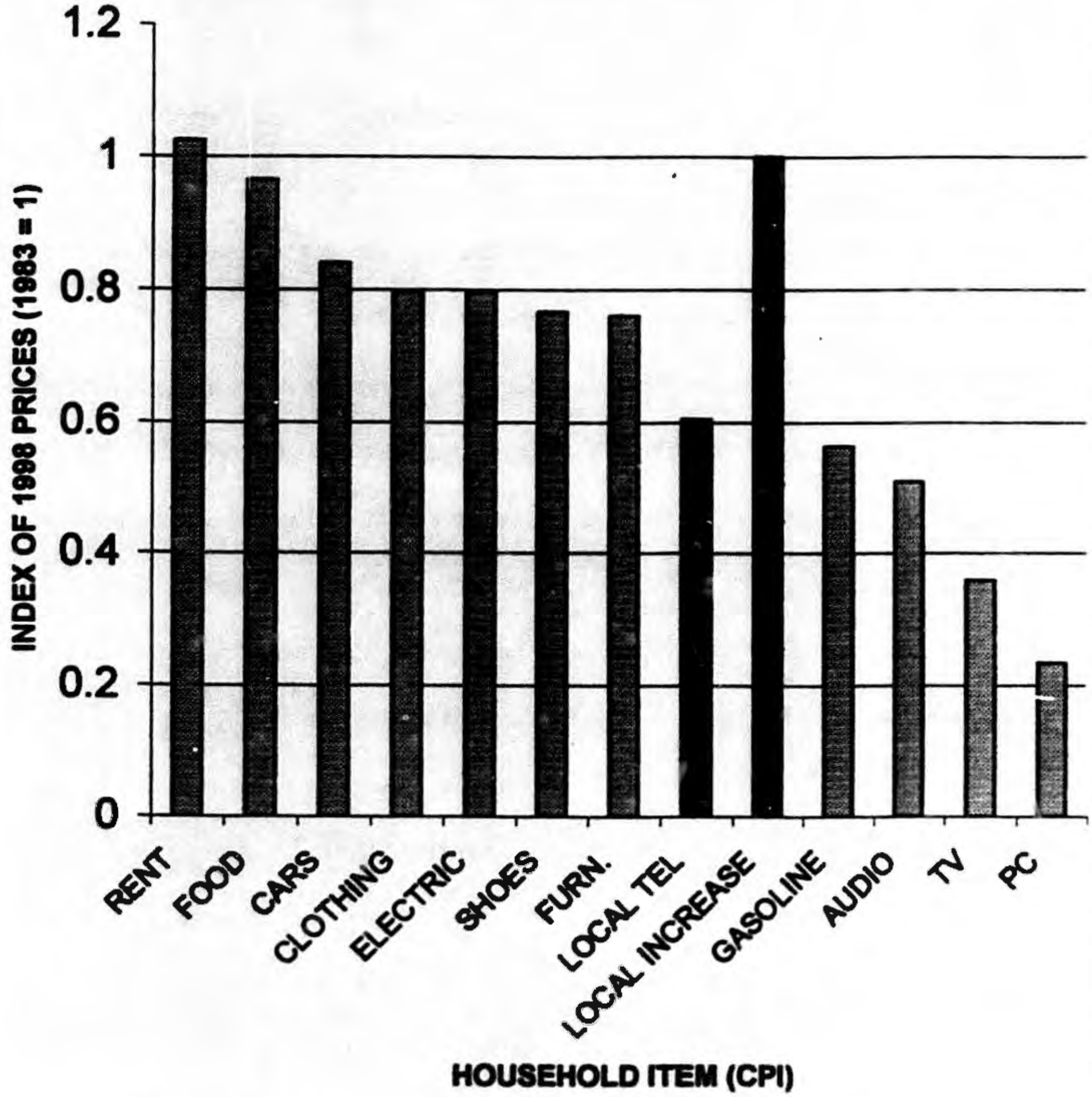
Furniture, shoes, and apparel have also come down in price. Simply put, things have gotten better in the United States. This comparison between telephone service, which has gotten cheaper and more valuable, and other commodities does not provide a basis for concluding that it would be fair to raise basic service prices.

It is interesting to consider the prospect of increasing telephone rates to their quality price adjusted 1983 level, as the telephone companies have suggested (see Exhibit 3). That would make telephone service one of the worst performers in the household budget because it would put it back to 1983 levels. If people were charged $23 for telephone service, keeping it constant in real terms, it would be a terrible deal, worse than virtually every other item in the household budget. There is no fairness in such a proposal.

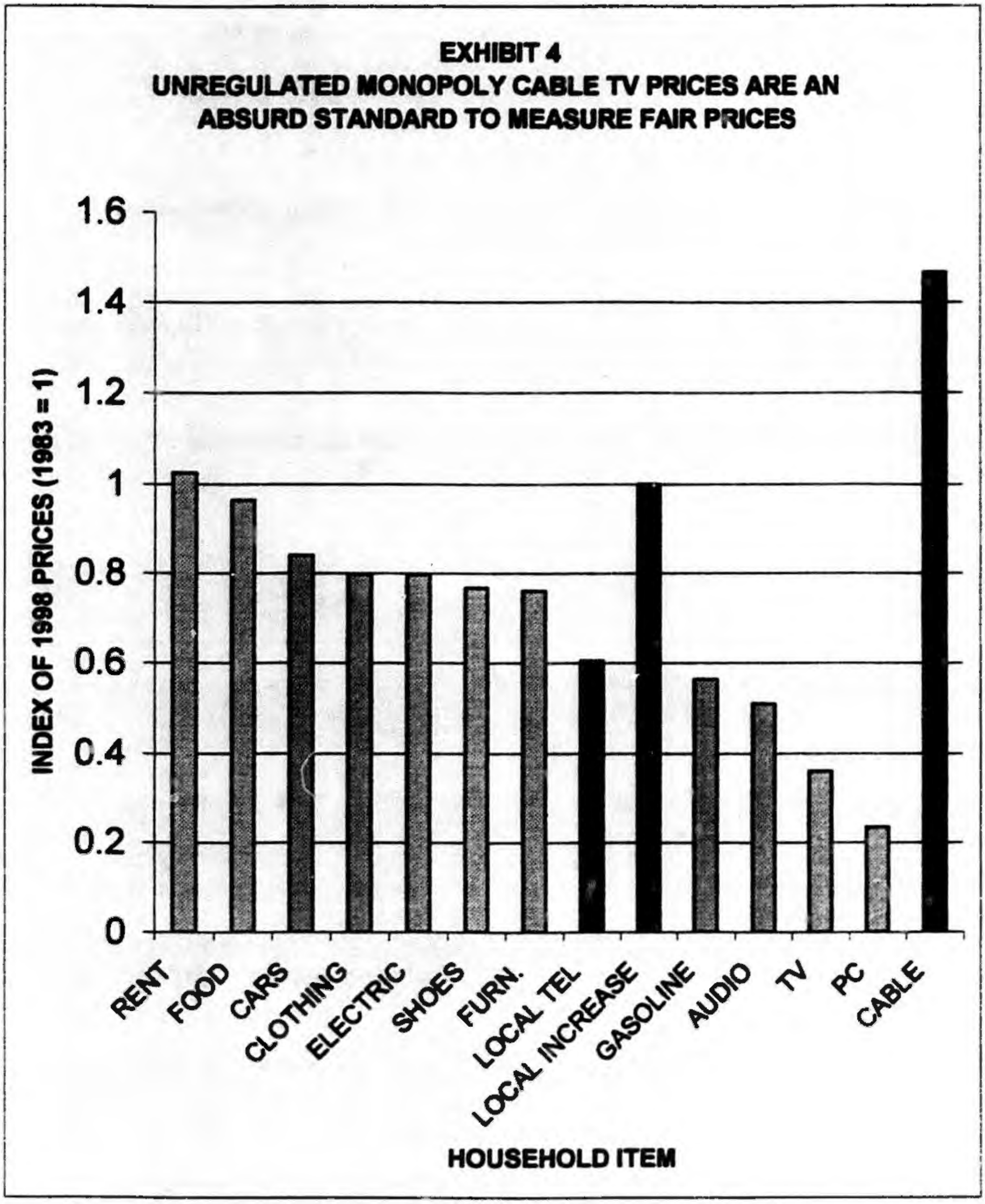
Another comparison the telephone companies use is particularly bothersome to consumer advocates. The telephone companies point to cable TV prices as a standard of fairness (see Exhibit 4). We know that these prices have risen dramatically, one of the few commodities that has increased in real terms. But this is what an unregulated monopolist does to the public. Cable TV is absolutely not the standard to use to measure fairness.

The other comparisons that have been presented to the Commission are comparisons to telephone rates in other states. Florida has treated its residential ratepayers more fairly than

EXHIBIT 3
ALLOWING PROPOSED INCREASES WOULD MAKE LOCAL SERVICE ONE OF THE WORST PERFORMING OF HOUSEHOLD COSTS



Source: CONSUMER PRICE INDEX; REPORT ON RESDIENTIAL TELEPHONE SERVICE IN FLORIDA, Robert G. Harris



Source: CONSUMER PRICE INDEX, REPORT ON RESIDENTIAL TELEPHONE SERVICE IN FLORIDA, Robert G. Harris.

other states. We believe Florida should follow the anticonsumer policies of other states.

If Florida's policies on unemployment, on school spending, on the ratio of industrial electricity rates to residential electricity rates are considered, it turns out Florida is consumer friendly (see Exhibit 5). It spends more on its students per pupil, more on unemployment compensation per person, and has a smaller differential between industrial and residential rates for electricity than neighboring states. These are proconsumer policies that we regularly encourage other states to follow.

Neither the comparison to other commodities nor the comparison to other states makes an increase in basic service charges fair.

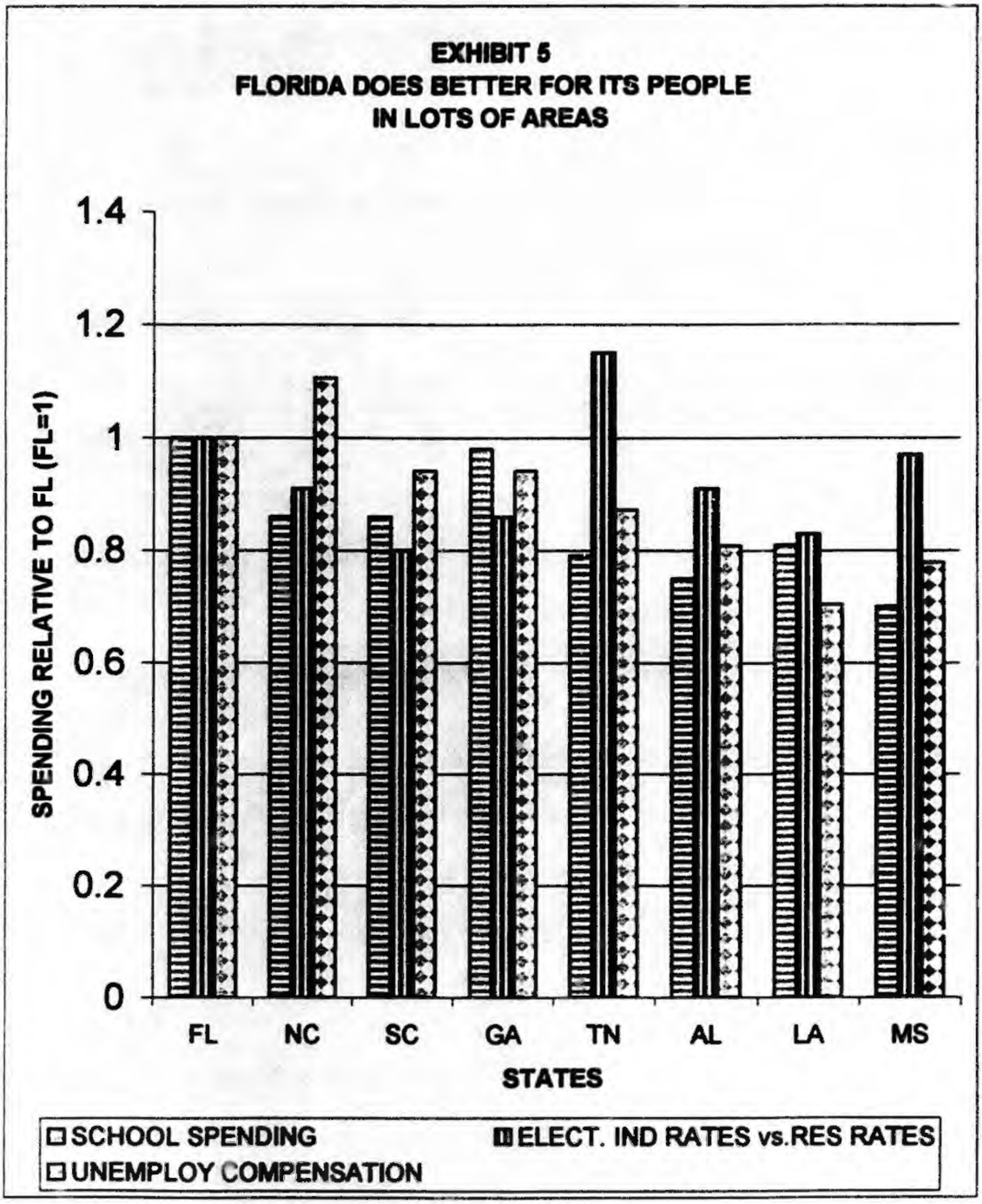
AFFORDABLE RATES

Telephone companies say: Even with dramatic increases, telephone service would remain affordable because most people would continue to subscribe.

AARP responds: Affordability involves the burden that the cost of necessities places on households budgets, not just people's willingness to suffer price increases.

- Lower income and elderly households would be hardest hit by rate "rebalancing" because the services which would be increased in price are a much larger part of their bills than the services which would be lowered in price.
- Some people will be forced off the telephone network as a result of the substantial increases proposed by the companies.
- Many more will suffer a significant burden on their household budgets.

The telephone companies have made the point that even with dramatic increases in basic service prices, service would remain affordable because most people would continue to



Source: STATISTICAL ABSTRACT OF THE UNITED STATES, 1998, Table 262, 596;
ELECTRIC SALES AND REVENUES, Table 12.

subscribe. AARP recognizes that consumers, particularly older Americans, will cling to telephone service, but that is not what affordability it about. We believe that affordability involves the burden that the cost of necessities imposes on people, not simply whether or not they will keep paying. It is the relative burden that matters, not the absolute burden that matters. We know people will not give up their phones and we know particularly that older people will not. They have a lower elasticity of demand because that is their lifeline. Public policy has dictated that we not impose a burden on them for this necessity, and obviously we think that is good public policy.

We also hear a lot of statements about people being better off with rate rebalancing so that raising basic service prices will not undermine affordability. We think these statements are misleading. The kind of language used is again noteworthy.

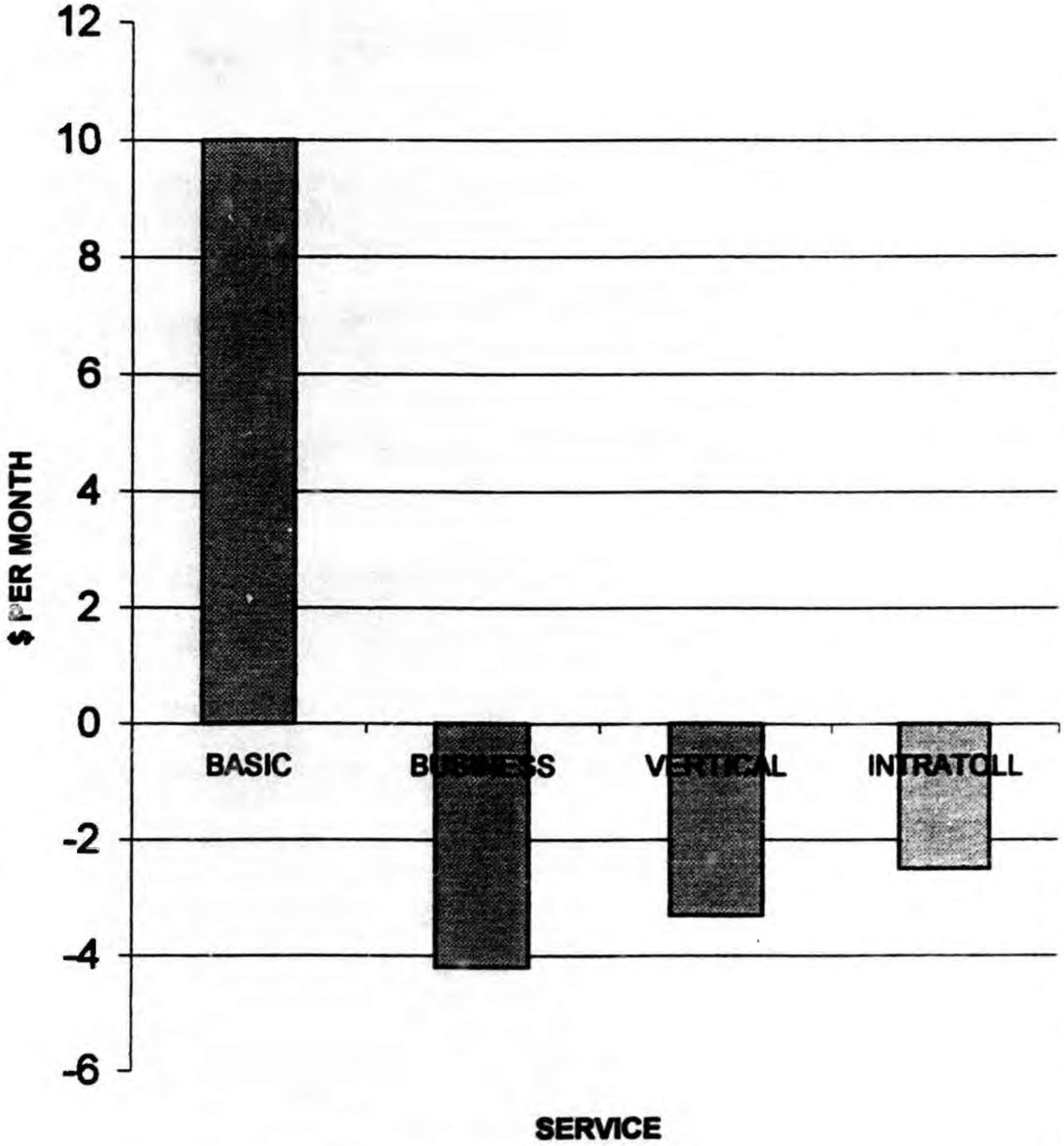
> 'While many customers' bills will be cut and others little affected, some customers will probably pay more.'

The adjectives are all scrambled in that sentence. Our analysis of the cost and revenue studies that the Commission has required the companies to undertake (the contribution analysis) suggests that the correct sentence is as follows.

> 'While some customers' bills probably will be cut and others little affected, many customers will pay more.'

We arrive at this conclusion about the impact of rate rebalancing being proposed to the Commission based on the contribution analysis performed by the companies on intrastate rates and the estimated cost of basic service (see Exhibit 6). The analysis claims that a $10 monthly increase in basic service rate would be necessary to cover their costs – to make up for the shortfall in their "contribution." Out of that total, the equivalent of over $4 per month would be

EXHIBIT 6:
RATE IMPACT OF REBLANCING "CONTRIBUTION"



Source: BELL SOUTH CONTRIBUTION ANALYSIS, Response to FPSC Staff 1st Data Request, Item No. 1, converted to monthly bill equivalent used to lower the "contribution" of business services. It shows that out of every $10 increase in basic service rates, over $3 would go to lower the "contribution" of vertical services. If the company rebalances "contributions" as it proposes, these other services would be lowered as basic service rates increase. We are left with approximately $2.50 to flow through to intraLATA toll rate decreases.

With over 40 percent of the rate reductions going to business customers, there is not enough money left to lower the prices for other residential services to offset the increase in basic monthly bills. In the aggregate, residential consumers must end up with a substantially higher bill. As a class, the net increase in residential bills must be almost $4 per month. Moreover, with over 30 percent going to vertical services, only the customers who are heavy users of these services are likely to see a net reduction in their bills.[1]

Based on the survey of Florida consumers conducted by the PSC, we conclude that low income and older consumers would be especially hard hit by this rebalancing. Given the way the questions were asked, we define low income as all respondents with an income below $10,000. This group represents approximately 11 percent of the total respondents. This result is consistent with the most recent current population survey for Florida published by the Bureau of the Census.

All respondents in this group would be considered to have an income below 125 percent of the poverty level. There would be another set of respondents with incomes in the range of $10,000 to $17,500 who are also considered to have income below 125 percent of poverty because of their large family size. The PSC survey does not make it possible to identify this

[1] Residential ratepayers may be at risk for the equivalent of an additional $4 of contribution which would be eliminated from other services, although these are not identified in the analysis.

group but it is substantial. It would equal about another 5 percent of the households in the state.

Older single households are defined as single person households with the person older than 65. Older couples are defined as two person households with both persons over 65. This elderly group equals just under 10 percent of the population.

These two groups overlap somewhat. Some older households are low income. The total group we identify as low income or elderly equals 18.1 percent of the population distributed as Exhibit 7 shows.

EXHIBIT 7
DISTRIBTION OF HOUSEHOLDS ACROSS CATEGORIES OF ANALYSIS

		PERCENT OF RESPONDENTS		
		65 & OVER HOUSEHOLDS		
		YES	NO	
LOW INCOME	YES	2.8	8.2	11.0
	NO	7.1	81.9	89.0
TOTAL		9.9	90.1	100

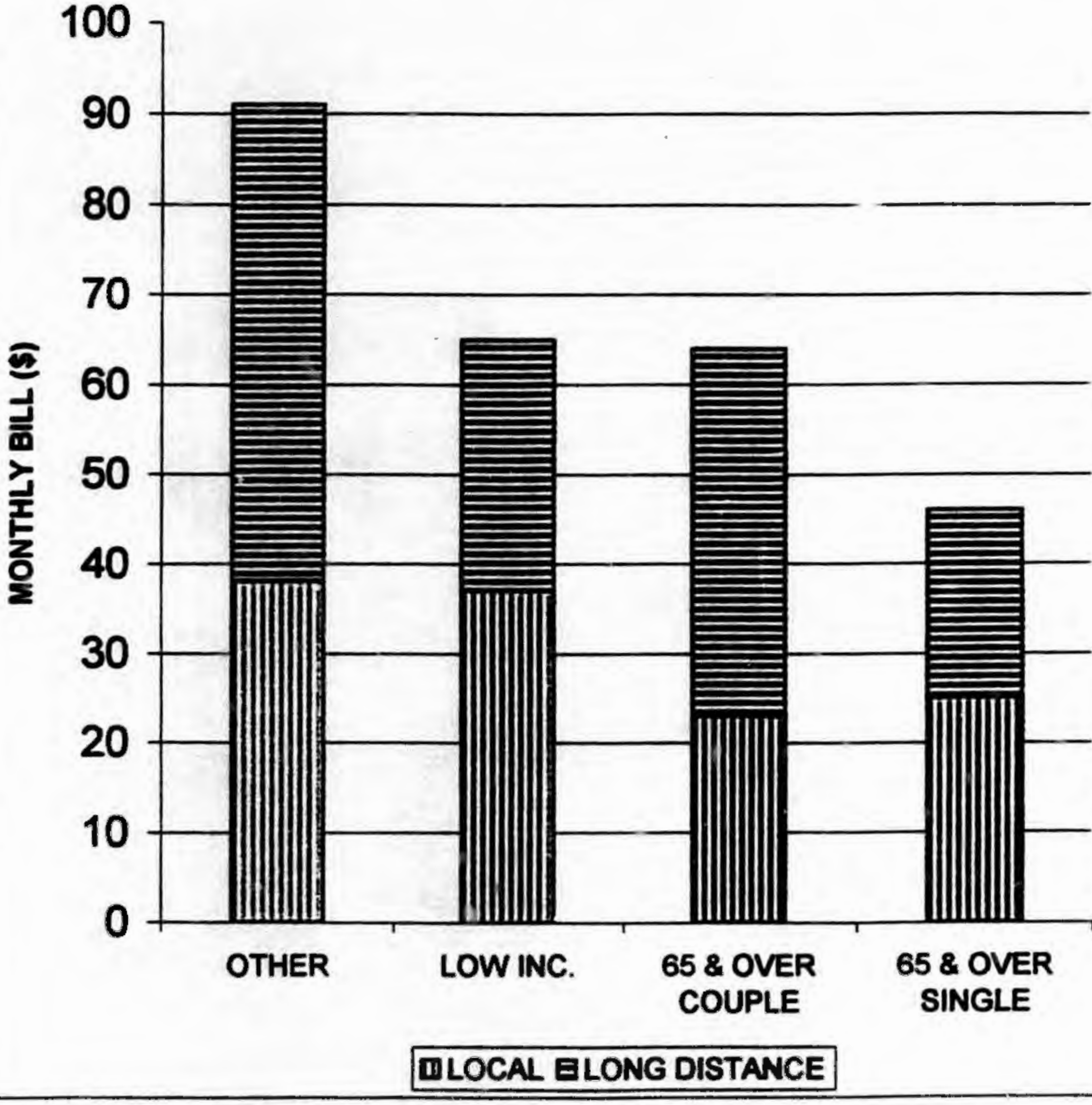
More refined survey data would define a somewhat larger group. The total group would certainly be more than 20 percent (one-fifth) of the population and in all likelihood would be about 25 percent (one-quarter) of the population.

The low income and 65 & Over household groups have distinctive telecommunications consumption patterns. First, low income and 65 & Over households have a lower overall bill than others (see Exhibit 8). They consume less of the frills and spend less on long distance. Thus, they spend more, as a percentage of their total bill, on basic local service than other households. This is the part of the bill that will go up, not down. This is particularly true for 65 & Over "singles.

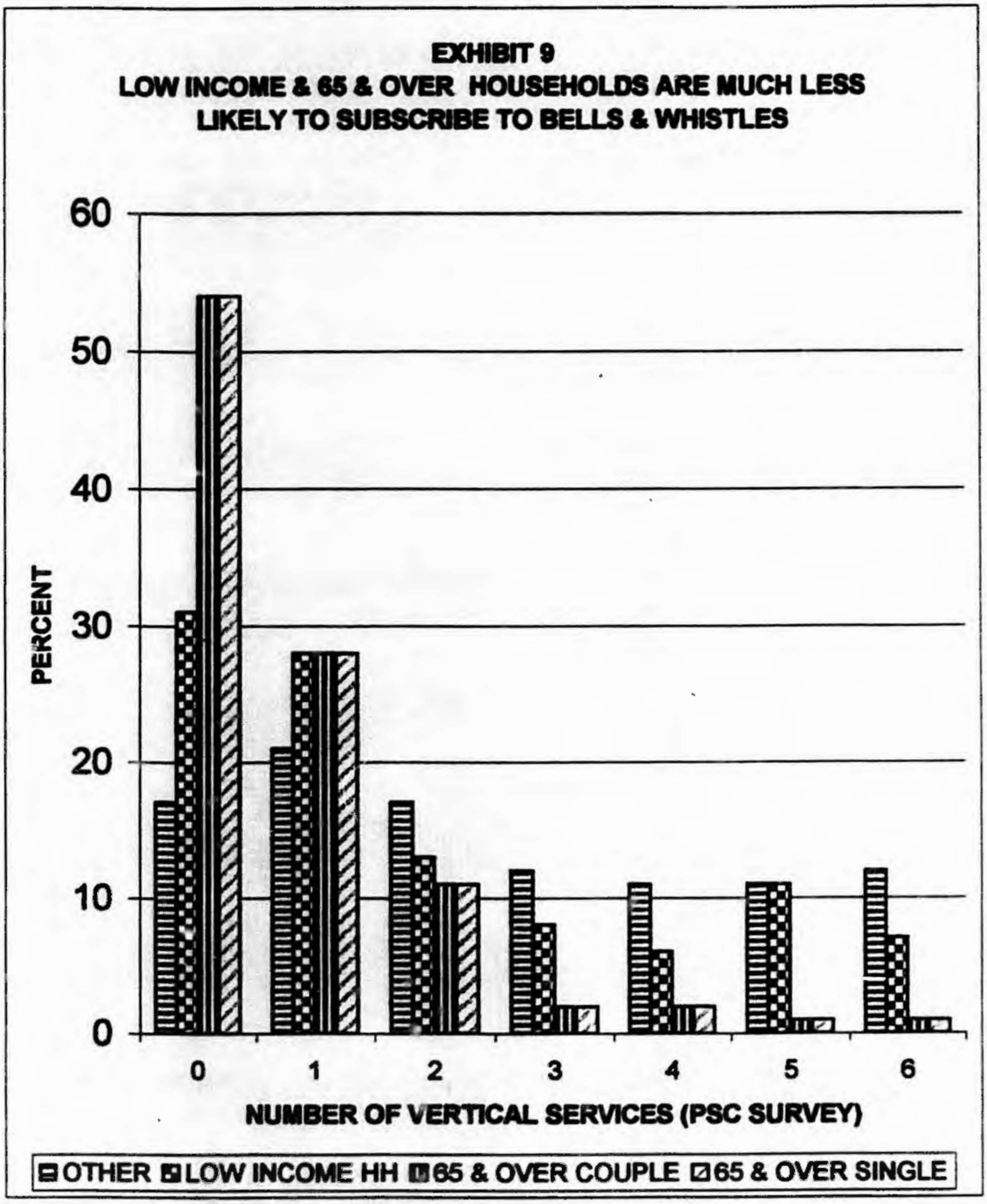
The consumption patterns of the low income and the 65 & Over households stand in sharp contrast to that of other households. We note that the long distance bill of non-low income, non-elderly households alone is larger than the total bill of single 65 & over households. It is equal to more than 80 percent of the total bill of 65 & Over couples and low-income households.

Second, older households are particularly unlikely to buy vertical services (see Exhibit 9). Over half purchase no vertical services whatsoever. Thus, three quarters of the benefit of rate rebalancing (business and vertical) are not going to impact half of the 65 & Over households. Another one-quarter of the 65 & Over households purchases only one. Rate reductions for these services are not likely to significantly benefit these households. Over half of low-income households buy one or fewer vertical services and two-thirds buy two or less. In contrast, among non-elderly, non-low income households almost half buy three or more vertical services.

EXHIBIT 8
LOW INCOME AND 65 & OVER HOUSEHOLDS CONSUME LESS TELEPHONE SERVICE
(LOCAL INCLUDED BASIC AND VERTICAL LONG DISTANCE INCLUDED INTRS AND INTERLATA)



Source: FLORIDA PUBLIC SERVICE COMMISSION SURVEY



Source: FLORDIA PUBLIC SERVICE COMMISSION SURVEY

Given the large share of the benefit of rate rebalancing that would go to business customers and the highly skewed nature of the consumption of vertical service we can draw general conclusions about the overall impact of rate rebalancing, although we urge the commission to conduct actual bill impact analysis (see Exhibit 10). We estimate that the rate rebalancing suggested by the telephone company "contribution" analysis would leave nine out of ten 65 & Over households and eight out of ten low income households with higher bills. About two-thirds of all residential ratepayers would have higher bills. About one-third of residential customers would end up with lower bills.

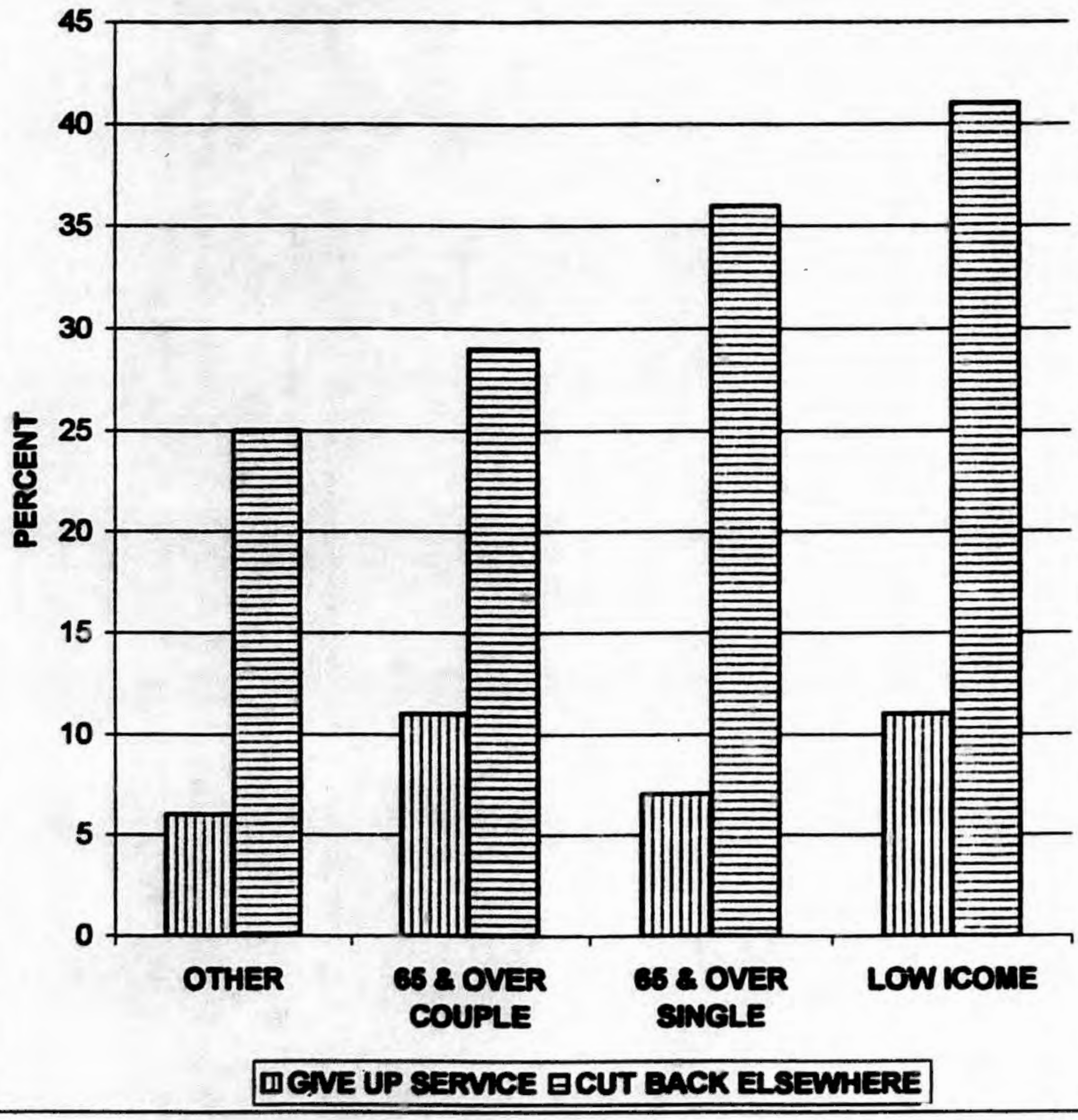
Given these results, it is not surprising to find that low income and older households feel they would be forced to cut back even if the basic service increase were only $2 per month (see Exhibit 11). Even at $2 per month over half the low-income respondents and more than 40 percent of the elderly households say they would have to cut back. When presented with an increase closer to that implied by the telephone company rebalancing proposals -- $10 per month -- much larger percentages say they would have to cut back (see Exhibit 12).

CONCLUSION

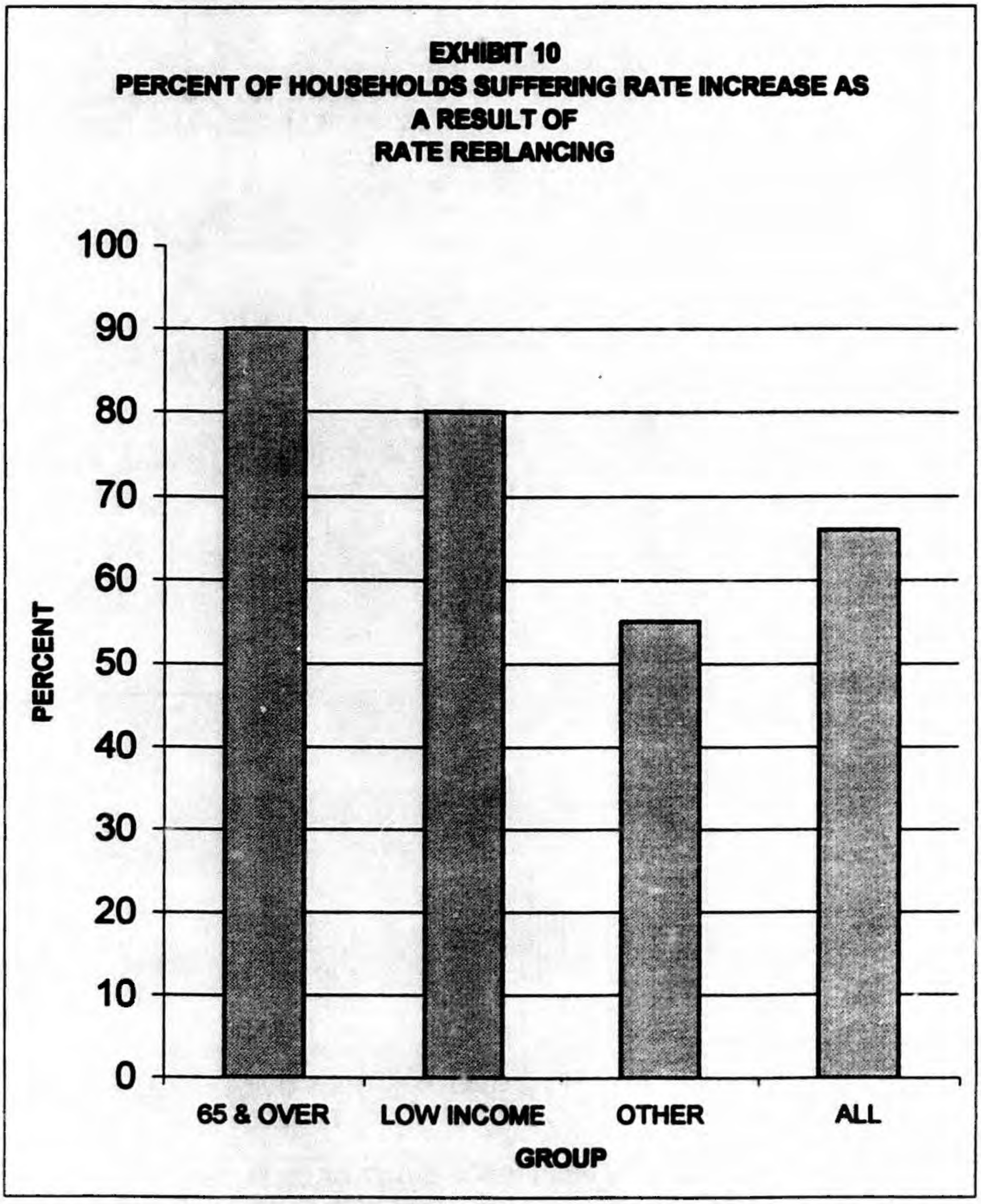
Based on this analysis, we conclude that there is no justification to increase basic service rates. Rates in Florida are just, reasonable, fair and generally affordable today. The dramatic rate rebalancing proposed by the industry would result in a net increase in the bills of most residential ratepayers. The increase would be largest for those least able to afford it, because they consume fewer of the services whose prices would be lowered. Many would suffer under such a policy; some would be forced to give up telephone service.

Imposing this burden on this vulnerable population is not dictated by economic analysis or legal mandates. It is certainly not required in the name of fairness.

EXHIBIT 11
FLORIDIANS FEEL EVEN A $2 INCREASE WOULD CAUSE THEM TO CUT BACK, ESPECIALLY THE ELDERLY AND THOSE WITH LOW INCOMES



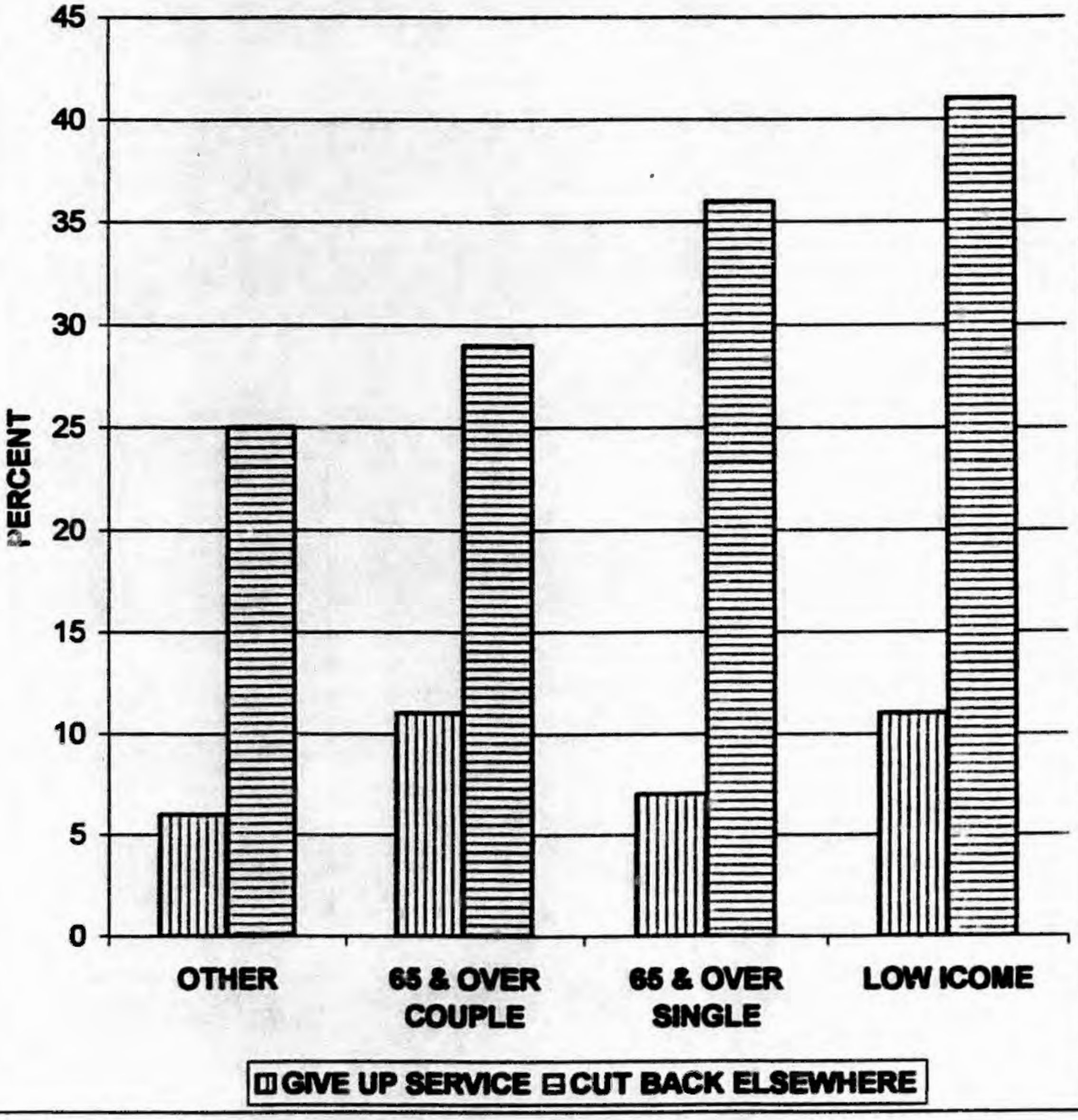
Source: FLORIDA PUBLIC SERVICE COMMISSION SURVEY



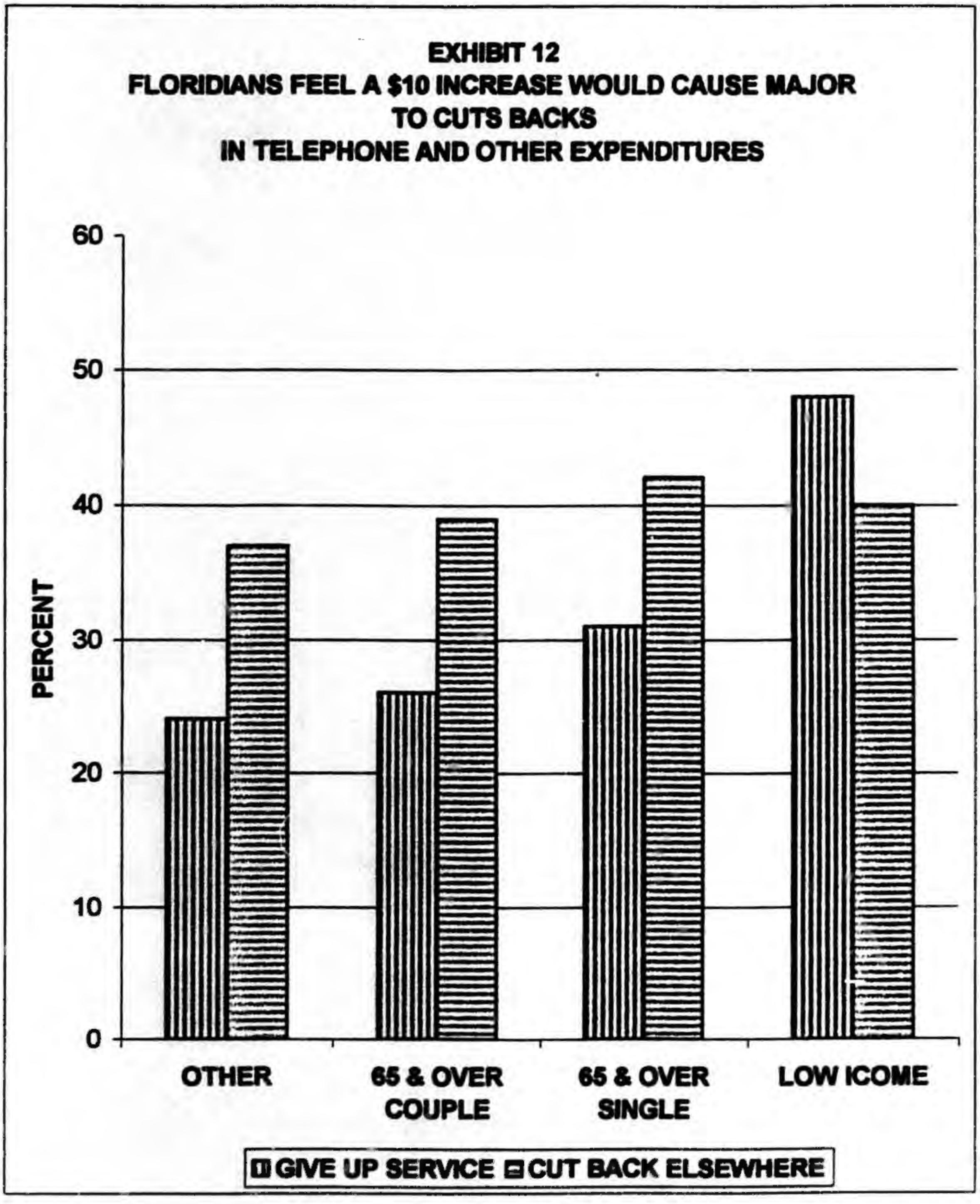
Source: See text for a discussion of these estimates.

EXHIBIT 11

FLORIDIANS FEEL EVEN A $2 INCREASE WOULD CAUSE THEM TO CUT BACK, ESPECIALLY THE ELDERLY AND THOSE WITH LOW INCOMES



Source: FLORIDA PUBLIC SERVICE COMMISSION SURVEY



Source: FLORIDA PUBLIC SERVICE COMMISSION SURVEY

January 1992 C-30

THE IMPACT OF PREMIUM TELEPHONE SERVICES ON THE TECHNICAL DESIGN, OPERATION AND COST OF LOCAL EXCHANGE PLANT

By

Richard Gabel

The Public Policy Institute was formed in 1985 as part of the Division of Legislation, Research and Public Policy of the American Association of Retired Persons. One of the missions of the Institute is to foster research and analysis on public issues of interest to older Americans. This paper represents part of that effort.

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EXECUTIVE SUMMARY

This paper analyzes the impact of providing three premium services -- long distance service at the turn of the twentieth century, direct distance dialing in the middle of the century, and now intelligent network services at the end -- on local telephone exchange plant. The report applies an analytic model of technological change to these three major changes in telephone service. In this model, technological changes are responses to engineering and design problems posed by the provision of new services over existing local telephone exchange plant. Making new services available over existing facilities necessitates a variety of technical transformations, affecting:

* Transmission medium over which communications occur.

* Switches, which determine how messages are routed.

* Signaling systems, which determine how the flow of traffic is controlled.

* Numbering systems, which determine how messages are identified.

* Accounting systems, which determine how transactions are recorded and billed.

As a result of these technical transformations the very organization of the network, who talks to whom and what constitutes communication, is transformed. The success of new services depends not only on technical changes to transmission, switching, etc., but also on the magnitude of the costs associated with those changes, how regulators allocate those costs among existing customers, and how prices for services change as a result of these decisions. The model considers all these factors as they affect both new and existing services. The results of the model are summarized in Table ES-1.

The paper shows that previous instances in the addition of premium services imposed costs on local exchange plant because that plant, which was utilized by all services, had to be upgraded to meet the most rigorous needs of the most demanding services. While the addition of premium services enhanced the quality of telephone service, lax regulatory mechanisms resulted in the misallocation of costs. Premium services brought cost increases, but regulators failed to study cost causation closely. As a result, regulators accepted telephone company arguments that basic service did not cover its costs, when the opposite was actually the case.

The historical misallocation of costs pales in comparison to the potential misallocation of intelligent network service costs. In the next several decades hundreds of billions of dollars will be spent upgrading the telephone network, shifting its focus from voice uses to data and video uses.

This paper demonstrates the need for careful cost causative analysis. The cost disadvantages of the intelligent network technology far outweigh the cost advantages for basic service, and the economic impact of the deployment of these technologies will be to raise total costs considerably. In the past, combinations of cost reduction and revenue growth resulting from the introduction of new services permitted overall price declines, cushioning the burden of cost misallocation, but that is unlikely to occur with intelligent network services. The costs are so large, the benefits are so heavily concentrated in specialized services and the demand for those services is so uncertain that the possibility of price reductions is very small.

Unfortunately, state commissions have not adopted appropriate approaches to allocate the costs of intelligent network services under their jurisdiction. The report urges regulators to recognize that the incentives for creating the new plant are solely directed to meeting the needs of new and premium services. Consequently, they will need to develop allocation methods that consider the cost impacts of premium services.

TABLE ES-1

THE IMPACT OF PREMIUM SERVICES ON LOCAL EXCHANGE PLANT

		MELDING LONG DISTANCE AND LOCAL	CONVERSION TO DIRECT DISTANCE DIALING	CONVERSION TO THE INTELLIGENT NETWORK
PROBLEM	WHAT TECHNICAL PROBLEMS DOES THE PROVISION OF A PARTICULAR SERVICE CREATE?	SIGNAL ATTENUATION RESULTS IN SEPARATE NETWORKS WHICH CAUSE INCONVENIENCE	CUMBERSOME AND INCONVENIENT OPERATOR INTERCONNECTION	SLOW, NOISY VOICE NETWORK INHIBITS BROAD DEPLOYMENT OF ADVANCED SERVICES
TECHNICAL SOLUTION:				
NETWORK ORGANIZATION	WHO TALKS TO WHOM AND HOW IS THAT CONNECTION ESTABLISHED?	INTEGRATION OF LOCAL AND LONG DISTANCE	UBIQUITOUS DIRECT USER INTERCONNECTION	TRANSFORM VOICE NETWORK INTO DIGITAL NETWORK
TRANSMISSION	WHAT IS THE MEDIUM OVER WHICH THE COMMUNICATION IS SENT?	GROUNDED CABLE TO METALLIC CABLE WITH LOADING COIL AND REPEATERS (1890-1910); STAGGERED TWISTED PAIR (LATE 1920s)	[OPEN WIRE/FM TO COAXIAL CABLE, SATELLITE, MICROWAVE]*	[BROADBAND FIBER OPTIC CABLE AND T-1 CARRIER]
SWITCHING	HOW ARE MESSAGES ROUTED BETWEEN SUBSCRIBERS?	MANUAL RINGDOWN	AUTOMATIC ANALOG	DIGITAL
SIGNALING	HOW IS THE STATUS OF THE SYSTEM INDICATED TO CONTROL THE FLOW OF TRAFFIC?	MANUAL D.C. LOOP IN-BAND	A.C., E&M AND SF IN-BAND	OUT-OF-BAND SS7
NUMBERING	HOW ARE MESSAGES ADDRESSED?	7-DIGIT	10-DIGIT	11 TO 15-DIGIT
ACCOUNTING	HOW ARE ACCOUNTS IDENTIFIED AND TRANSACTIONS RECORDED?	MANUAL	AUTOMATIC ACCOUNTING	[COMPUTERIZED]
COST	HOW MUCH DOES IT COST TO DEPLOY THE NECESSARY EQUIPMENT?	35 PERCENT INCREASE IN LOCAL EXCHANGE PLANT	43 PERCENT INCREASE IN CENTRAL OFFICE EQUIPMENT	HUNDREDS OF BILLIONS
REGULATORY RESPONSE	HOW DO REGULATORS TREAT THE INCREASED COST?	FEDERAL: NOMINAL	STATION-TO-STATION ALLOCATES WEIGHTED COST TO LONG DISTANCE BUT IS 90% LOCAL	SUBSCRIBER LINE CHARGE, JOINT COST ORDER -- 90% LOCAL
		STATE: GENERALLY NONE	VALUE OF SERVICE RESIDUAL PRICING, INTRA/INTERSTATE RATE EQUALIZATION	FEW HAVE POLICY. SOME HAVE ABANDONED BASIC ECONOMIC TESTS
PRICE IMPACT	HOW DO PRICES REFLECT REGULATORY DECISIONS?	1900-1940: LOCAL UP 33%; LONG DISTANCE: SHORT HAUL DOWN 20% LONG HAUL DOWN 65%	1949-1959: LOCAL UP 27% LONG DISTANCE: INTERSTATE UP 6% INTRASTATE UP 13%	UNKNOWN

* Entries in brackets are not discussed in this paper but are an important part of the ongoing debate over the deployment of intelligent network services.

I. INTRODUCTION, ANALYTIC FRAMEWORK, OVERVIEW AND POLICY RECOMMENDATIONS[1]

A. Introduction

Throughout its history, the design of local exchange plant facilities has undergone successive transformations to meet the needs of premium communication services which utilize this plant in common with the provision of basic service.

* The development of long distance (toll) service and its integration with local service and the abandonment of separate local and toll networks was one such instance.

* The evolution of message toll from manual, to operator-assisted service, to fully automatic, customer-dialed handling was another step in the progress of telephony.

* Today, the provision of information services over local exchange facilities and the abandonment of separate voice, data and video networks mirrors earlier patterns of the development of premium services.

While the historical process of this development is well known, the extent to which the costs of this transformation were borne by basic exchange ratepayers is barely recognized.

B. Purpose and Analytic Framework

1. Purpose

The purpose of this paper is to examine the impact of the provision of premium services on the technical design, operation, and cost of local exchange plant and implications of their provision for local rates. It begins with historical examples to gain a better understanding of the process of change, but the primary focus of the report is on contemporary technological changes ongoing in the telephone network.

This paper does not offer a prescription for the 'best' method of cost allocation, nor does it seek to present an exhaustive compendium of technological change in the past century. Rather, it seeks to address a prior and perhaps more fundamental issue. It seeks to establish the factual basis for insisting on a careful cost causative analysis of technological change in the first place. It does so by reviewing repeated instances of major technological changes throughout the history of the industry in which the failure to engage in sound cost causative analysis led to serious misallocation of costs to basic local exchange service. The issue has

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[1]Dr. Mark N. Cooper provided a major contribution to the analytic framework in this chapter.

never been whether or not to permit technology, the question has always been who pays for it.

This chapter first provides an analytic framework for understanding technological change in the telecommunications industry, and then briefly applies this model to three case studies: the integration of long distance into the local exchange network; the conversion of the local exchange network to direct distance dialing; and the conversion of the local exchange network to the Intelligent Network. Chapters II and III develop the model more fully. Table I-2 provides a detailed summary of the model.

2. Analytic framework for understanding technological change

The most exacting requirements of the most exacting (premium) service are the drivers of cost in the telecommunications network. In order to understand the impact of premium services it is necessary to consider how the addition of premium services has interacted with and been determined by technical, economic, and regulatory constraints.

The history of technological change in the telecommunications industry can be broken down into five steps, which are roughly sequential (see Table I-1).

1) Problem: What functions do people or companies want the telephone network to perform? What operational characteristics do the functions require?

2) Technical Solution: How does the system work in order to get the job done? What are the design considerations (solutions) that drove the changes in the network?

3) Cost Implication: What capital costs does the technology require? How much does it cost?

4) Regulatory Response: How do federal and state regulators identify costs and allocate them for recovery in rates?

5) Price Impact: Who pays? How do price trends during the period of technological change reflect regulatory decisions?

For each of the major changes in the industry studied in this paper, all five of the above steps are considered. Special attention is given to step 2, the technical changes necessitated by the addition of premium services. For each major change in the telecommunications network that is studied, the impact of the addition of new services on one or more of the key technical building blocks of a telecommunications network is examined. These are the things a telecommunications network has to do in order to function. A technological change will

TABLE 1-1

FRAMEWORK FOR ANALYZING TECHNOLOGICAL CHANGE IN THE TELECOMMUNICATIONS INDUSTRY

PROBLEM ↓	**WHAT TECHNICAL PROBLEMS DOES THE PROVISION OF A PARTICULAR SERVICE CREATE?**
TECHNICAL SOLUTION ↓	**WHAT EQUIPMENT OR ORGANIZATIONAL CHANGES ARE MADE TO OVERCOME THOSE PROBLEMS?** Network Organization: Who talks to whom and how is that connection established? Transmission: What is the medium over which the communications are sent? Switching: How are messages from one subscriber to another subscriber routed? Signaling: How is the status of the system indicated for purposes of controlling the flow of traffic? Numbering: How are messages addressed so that they can get to their destination? Management of accounting: How are accounts identified and transactions recorded for billing purposes?
COST IMPLICATION ↓	**HOW MUCH DOES IT COST TO EFFECTUATE THE CHANGE AND DEPLOY THE NECESSARY EQUIPMENT?**
REGULATORY RESPONSE ↓	**HOW DO REGULATORS TREAT THE INCREASED COST (OR REVENUE) THAT FLOWS FROM THE SOLUTION?**
PRICE IMPACT	**HOW DO THE CHARGES FOR VARIOUS SERVICES REFLECT REGULATORY DECISIONS?**

not have a significant impact on the network if it does not significantly affect one or more of these building blocks:

* Network Organization: The basic way a system is set up and the users of the system interact.

* Transmission: The medium over which the communications is sent.

* Switching: The manner in which traffic finds its way from origin to destination.

* Signaling: The manner in which the status of the system is indicated for purposes of controlling the flow of traffic.

* Numbering: The way messages are addressed so that they can get to their destination.

* Management of accounting: Provision for system management to allow billing, etc.

Table I-2 summarizes the results of the model (the same table also appears in the Executive Summary).

3. The importance of cost causation analysis

This paper is based on the premise that in order to answer the fundamental question of regulation "who should pay?" -- one must understand how the telephone system is designed. One must know what causes costs to be incurred and which services benefit from the deployment of specific pieces of costly capital equipment.

This cost causative analysis is necessary for both economic and equity reasons. If costs are not properly attributed to the services which cause them, prices will not be properly set. If prices are not set to properly reflect costs, resources will be misallocated and income will be transferred from the subscribers of the overpriced service to the subscribers of the underpriced service.

Thus, pricing which is not based on good cost causative analysis is both inefficient and unfair. The fact that cost allocation in a complex network like the telephone system is difficult is not an excuse to neglect cost causative analysis; it is a reason to expend even greater effort on this crucial task.

TABLE I-2

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REGULATORY RESPONSE	HOW DO REGULATORS TREAT THE INCREASED COST?	FEDERAL: NOMINAL	STATION-TO-STATION ALLOCATES WEIGHTED COST TO LONG DISTANCE BUT IS 90% LOCAL	SUBSCRIBER LINE CHARGE, JOINT COST ORDER -- 90% LOCAL
		STATE: GENERALLY NONE	VALUE OF SERVICE RESIDUAL PRICING, INTRA/INTERSTATE RATE EQUALIZATION	FEW HAVE POLICY. SOME HAVE ABANDONED BASIC ECONOMIC TESTS
PRICE IMPACT	HOW DO PRICES REFLECT REGULATORY DECISIONS?	1900-1940: LOCAL UP 33%; LONG DISTANCE: SHORT HAUL DOWN 20% LONG HAUL DOWN 65%	1949-1959: LOCAL UP 27% LONG DISTANCE: INTERSTATE UP 6% INTRASTATE UP 13%	UNKNOWN

* Entries in brackets are not discussed in this paper but are an important part of the ongoing debate over the deployment of intelligent network services.

4. Common local exchange plant and local telephone service

To aid the analysis of cost causation, it is extremely important to emphasize the distinction between basic local telephone service and the common local exchange plant.

* Basic local telephone service is simply voice telephone connections within a specifically defined local service area.

* Common local exchange plant is comprised of those facilities that are physically located within the local area, but are used to supply both the basic and the premium services in common.

The local exchange facilities are common facilities for the different kinds of services that are provided over them. When we say that a facility is common, it simply means that it is utilized by many service classifications. For example, the local loop normally consists of a metallic wire pair which connects the subscriber to his local central office. The subscriber originates and receives local exchange calls, intrastate message toll calls, interstate message toll calls and various forms of data traffic. Each of these service classifications utilizes the local loop as common plant.

The engineering design standards and the investment and expenses incurred for local exchange plant are determined by the variety of uses to which those facilities will be put. When exchange plant is engineered, it is done in such a way as to accommodate the most exacting requirements of the most exacting (premium) services which utilize these facilities.

C. Case Studies

1. Introduction

For many years regulators have accepted telephone company arguments that local exchange telephone service has been subsidized by revenues generated by long distance services. The history of the development and operation of the industry indicate otherwise. That history is characterized by four interrelated themes:

* Basic local exchange plant is generally simple to design and relatively inexpensive to operate and maintain. The services that can be offered over basic local exchange plant are also relatively simple, e.g. plain old (voice) telephone service (POTS).

* Over time, telephone companies have offered more complex, premium services such as long distance services over local exchange facilities.

* The effort to accommodate the technical requirements of the more complex, long distance services has imposed numerous and frequently expensive modifications of otherwise inexpensive local exchange facilities.

* Rate regulators did not properly attribute the costs of those expensive modifications to the services which demanded them. By assigning the increased cost to basic local service, rather than to the services which caused them, they created the illusion that local service did not pay its fair share. In fact, it was carrying a larger share of the costs than the benefits it derived from the technological advances.

The story of long distance cost allocation might be just a quaint vignette of ancient history, if history did not have a troubling way of repeating itself. Today we stand on the verge of another major effort to reconfigure the telephone network to accommodate a much more varied mix of premium services.

Video and data services reflect fundamentally different types of service, each of which imposes additional technical standards and costs on the local telecommunication system. For example, data communication requires different, higher quality signals because computers cannot filter out noise on the line that the human ear filters out in the normal auditory process. In addition, both video and data generally require much more speed and carrying capacity (bandwidth) than voice in order for transmission to be fully effective.

The present public switched telephone network was engineered for voice-grade services, driven by the costs of long distance service. While the existing network structure is perfectly satisfactory for this purpose, it is unsatisfactory for transmission of medium and high-speed data. Hence, it is being converted from voice (analog) to digital at an accelerating rate to accommodate the higher technical requirements of data services (Freeman, 1989 and Crowley, 1962).

Local exchange plant will again be used as a common facility to supply local telephone service and an increasing variety of "premium" services that impose increased costs on the common local exchange plant. If the costs of those services are again misallocated to local telephone service, history will repeat itself. By most estimates, the stakes are huge. In the next several decades hundreds of billions of dollars will be spent upgrading the network from a focus on voice uses to a focus on data and video uses.

Appropriate allocation of these costs has become more critical because the current round of technology deployment is fundamentally different than in prior periods. In the past, combinations of cost reduction and demand growth could quickly cushion the burden of cost misallocation, but that is highly unlikely in the intelligent network. The costs are so large, the benefits so heavily concentrated in specialized services and the demand for those service so uncertain that the near to mid-term possibility of price reductions is very small.

2. Integrating long distance into the local exchange network

At the very beginning of the telecommunications industry, local and long distance service were delivered over separate networks. The technical problem was that sending telephone signals over long distances was considerably more difficult than telecommunications over shorter local distances. As a result, two different technologies were utilized. Local service was delivered to the home of individual subscribers over a single wire. Long distance service was offered between telephone company central offices over two wires.

Integrating the two systems greatly improved the convenience of long distance service, but it also imposed heavy costs on local exchange plant, since that plant had to be upgraded to meet the demands of long distance communications. The costs of this change were imposed almost entirely on local customers, rather than long distance customers. The local exchange companies and their customers were used both to absorb the costs of long distance service and to undercut competing independent telephone companies.

The price changes over this period reflected the preferential treatment afforded to long distance service, in spite of the high demands it placed on the network. While the price of local service increased from the early twentieth century until World War II, long distance rates declined steadily. Between 1900 and 1940 local rates increased by over 30 percent, while long distance rates declined by over 60 percent (see Table II-2). The reduction in charges for long distance rates can be attributable only in part to the enormous improvements in interexchange technology that occurred over this time period.

3. The conversion to direct distance dialing

The image of rows of operators plugging and unplugging telephone lines to complete calls is a classic telephone industry symbol. The interaction with the operator was cumbersome, requiring the caller to say who he or she wanted to call and then waiting for the operator to connect through to another operator who would ring the desired number.

Without major technological changes, however, this interaction was unavoidable because a great deal of work was done by the operator. The manual functions performed by the switchboard operator included trunk selection, signaling, timing and ticketing of calls. These functions had to be supplanted by various mechanized processes for direct subscriber interconnection to be achieved. An additional, and perhaps more interesting requirement, was the introduction of a uniform, nationwide numbering system.

Thus, enormous changes and improvements in the makeup and design of local exchange plant were necessary prior to the introduction of Direct Distance Dialing (DDD). Five requisites had to be met in order for direct distance dialing to be achieved:

* Conversion to local dial services,

* Mechanization of billing and accounting,

* Modification of the signaling system,

* Improvement in switching equipment, and

* Development of a uniform numbering system.

All of these requisites to DDD had major cost impacts. Although these were largely improvements necessitated by long distance (toll) service, the bulk of the additional costs were borne by local exchange ratepayers. Although court cases had led to the use of more sophisticated cost allocation formulas by the time of this conversion, these allocation formulas still placed the overwhelming majority of the burden on local ratepayers.

Consistent price data is available for the period of conversion from manual to Direct Distance Dialing. Although, expensive technical changes to implement DDD were the critical factor driving costs in the industry during the years 1949-1960, the price of basic local service rose by 27 percent between 1949 and 1959, while interstate long distance (toll) rates increased by only 6 percent and state toll rates by 13 percent.

4. The Intelligent Network

The changes necessary to achieve an Intelligent Network are even more demanding than those involved in DDD. The current telephone network has been "optimized" for voice service. Moving data or video is quite another matter. From the point of view of a data network, the voice network is noisy, slow and relatively narrow.

The demands of data communication are fundamentally different than the demands of voice. Some key differences are described below.

DELAY SENSITIVITY :

Voice: High Sensitivity -- Silence in human conversation conveys information so that the voice network cannot add (or remove) periods of silence.

Data: Low Sensitivity -- Most data do not alter in meaning if they are delayed in the network for a few seconds; a packet containing temperature information for the Chicago airport will not change in meaning because of the addition or removal of a short delay in the network.

HOLDING TIME:

Voice: Long -- Telephone calls usually last for a relatively long time compared to the time necessary to set up the call. While it may take 3 to 11 seconds to set up a telephone call, the average local call lasts for about 180 seconds (3 minutes) and a toll call for about 300 seconds (5 minutes).

Data: Short -- Most data traffic is bursty; i.e., the bulk of the data is transmitted in a short period of time, such as checking on a credit card (interactive applications). A 90-10 rule is often cited to demonstrate this: 90 percent of the data is transmitted in 10 percent of the time. Since data transmission will tend to be very fast, long call setup time provides inefficient networks for data service in contrast to voice transmission.

FREQUENCY

Voice: Narrow -- A 3.1 khz passband is sufficient for human voice. Increasing the bandwidth available for the voice call does not affect the duration of the call.

Data: Wide -- Data can use all of a channel's available bandwidth. If additional bandwidth is made available for a data call, the duration of the call can decrease while the speed of transmission can increase. The wider spectrum for voice traffic with its long conversation times becomes an inefficient and redundant use of plant. Data networks operate efficiently at 64 khz.

The limitation of the analog network for premium services can be summarized by noting that it takes over two minutes to send a page of facsimile over an analog network, while it takes about 5 seconds to send it on a digital network.

Converting the telephone infrastructure from voice to data or video is a massive undertaking. The telephone companies propose deploying an Integrated Services Digital Network (ISDN) composed of:

* Fiber optic cable.

* Digital switches.

* An entirely new signaling system (SS7).

The cost and complexity are commensurate with the size of the undertaking. Although it is difficult to know precisely how much the overall cost will be, it is clear that it will be in the hundreds of billions of dollars (Wigand, 1988).

These technologies will raise the cost of providing service. Given these large costs, only increased revenue can hope to make the technologies a net economic benefit to the overall network. Future revenues cannot be credibly projected, however. Independent analysts have predicted that voice communications will continue to generate the greatest portion of ISDN traffic (Strock, 1989, 180 and Finneran, 1991). The vast majority of users will benefit little, but they will bear the costs unless costs are allocated appropriately.

D. Policy Conclusion: Protect Local Exchange Customers

The current replacement of voice-grade (analog) facilities by digital switching and transmission are analogous to the events at the turn of the century when local and long distance were integrated. Consolidation of local exchange and long distance facilities introduced economies of scope in the early days of the industry. But the costs of consolidation were largely borne by local exchange ratepayers, while the benefits accrued to the toll customers.

Policymakers are confronted by a parallel question today as the industry seeks to further modify local exchange plant as part of the desire to accommodate high-speed data and broadband service classifications. POTS customers will receive few service benefits from the development of digital facilities.

The urgency of the policy problem is underscored by the current status of the deployment of intelligent network technologies. The telephone companies have not yet significantly deployed SS7 and ISDN, but they are on the verge of doing so on a very large scale. The Bell Operating Companies (BOCs) are proposing to integrate their conventional local exchange plant digital facilities with independent high-speed data and information networks and accelerate the deployment of these integrated facilities. The BOCs and the major interexchange carriers completed limited ISDN trials in 1990. Almost all major PBX manufacturers that market in the United States have indicated that ISDN-compatible products are either available or under development.

Table I-3 reports the number of Bell Operating Company central offices equipped for ISDN and SS7 service and the number of equipped access lines for the years 1987 and forecast through 1994. It is clear that midway into the 1990 decade ISDN development will continue to be at the periphery of BOC operations. Because new services made possible by SS7 have greater potential to enhance revenues than ISDN-based services, which have yet to generate customer interest, the BOCs have moved more rapidly with the installation of SS7 than ISDN.

TABLE I-3

CENTRAL OFFICES (COs) AND LINES EQUIPPED FOR ISDN AND SS7
BELL OPERATING COMPANIES: 1987-1994

	ISDN						SS7					
	Central Offices			Telephone Lines			Central Offices			Telephone Lines		
Year	Total	ISDN	% ISDN	Lines	ISDN	% ISDN	Total	SS7	% SS7	Total	SS7	% SS7
1987	9,237	4	0.0	96,654	1	0.0	9,237	29	0.3	96,654	1,035	1.1
1988	9,348	82	0.9	99,524	43	0.0	9,348	435	4.7	9,524	10,325	10.4
1989	9,389	179	1.9	102,648	99	0.1	9,389	950	10.1	102,648	21,555	21.0
1990	9,406	426	4.5	105,844	496	0.5	9,406	2,083	22.1	105,844	36,706	34.7
1991	9,393	1,595	17.0	109,228	1,059	1.0	9,393	3,087	32.9	109,228	52,250	47.8
1992	9,373	1,764	18.8	112,476	1,370	1.2	9,373	4,101	43.8	112,476	66,394	59.0
1993	9,375	1,962	20.9	115,700	1,888	1.6	9,375	4,895	52.2	115,700	78,645	68.0
1994	9,366	2,269	24.2	118,961	2,218	1.9	9,366	5,362	57.2	118,961	86,964	73.1

Note: 1987-88 Actual; 1989-94 Projected

Source: CC Docket89-264, Initial Submission, Attachment B, Table 104, Federal Communications Commission

Still, SS7 has developed slowly to date. At the end of 1988, only about 10 percent of the RBOC's lines had access to the new signaling system. But, according to telephone company projections made in 1989, growth will occur rapidly beginning in 1990. By year-end 1994, the carriers expect that nearly three-fourths of their lines will be accessible to SS7.

With costs about to be incurred, there is certain to be a major round of debate over cost allocation and cost causation. Regulators can greatly affect the deployment of the technology and the impact that it has on rates for basic and premium services.

The potential benefits of ISDN and SS7 may be great, but most of these benefits will be realized for new services, not basic service, and will not be realized until many years into the future, if at all. Yet, to obtain these benefits, the telephone companies must undertake substantial up-front investment in new network technology and prematurely retire existing analog facilities. Both economic efficiency and equity dictate that the costs of new investment should be borne by those who benefit by its application. As demonstrated in Chapter III, it is unlikely that the cost advantages of ISDN and SS7 will outweigh their disadvantages, at least until both are universally deployed, decades into the future.

By and large, the state regulatory commissions have not developed methods permitting the proper allocation of the costs of intelligent network services. Some state commissions have removed competitive services which utilize SS7 and ISDN from their regulatory scope. Approaching policy issues from the perspective of individual services is appropriate for some policy issues, such as determining the competitive status of various services, but it is not an appropriate way to approach the allocation of costs associated with SS7 and ISDN. ISDN and SS7 are new network concepts, not singular services. These network facilities will not only offer the established voice, data and video services available today, but will also provide as yet unknown future services as software develops.

The job of protecting the basic ratepayer has become increasingly complex. But no tenable solution is possible until regulators understand and carefully consider the problem. The commissions should recognize that the incentives for creating the new plant are solely directed to meeting the needs of new and premium services and that basic local exchange services should be insulated from any cost effects.

Rather than attempt elaborate cost allocation schemes on a service-by-service basis, commissions should consider allocating costs on the basis of generic service categories, such as voice POTS, voice long distance, data and video. One possible use of this method would involve assigning no more cost to the basic POTS classification than can be identified as necessary under "stand-alone" attribution, the cost of providing POTS alone, independent of the provision of other services.

Another suggested solution for this issue is for the regulatory commissions to defer capital recovery for those investments that can be attributed to future benefitted service categories.

This rate making question presents immediate cost allocation questions for services such as intelligent network services which require the new signaling system (SS7).

E. Outline of the Report

The remainder of the report is divided into two chapters. Chapter II deals with the historical example of long distance service impacting local exchange plant. Chapter III deals with the current round of technological innovation associated with "information age" services. Each chapter will follow the model outlined in Table I-1, whereby technological change is viewed as a response to the technical requirements of new services, and regulators' allocation of costs, and the resulting price changes, associated with technological change.

Within each chapter an effort is made to keep technical discussions to a minimum. More technical discussion is provided in an appendix at the end of the chapter for those interested in a greater level of technical detail.

II. THE TECHNOLOGICAL DEMANDS OF LONG DISTANCE SERVICE AND LOCAL EXCHANGE PLANT COSTS

This chapter will briefly review the history of the design of long distance service and the impact that it had on local exchange plant. Two major changes are examined, the integration of local and long distance service at the turn of the century and the introduction of Direct Distance Dialing in the 1950s.

A. The Integration of Long Distance and Local Service: Creating a Single Transmission System

1. Network organization: separate local and toll networks

The provision of communication over long distances was part of Alexander Graham Bell's "Grand System" concept of 1878. Although toll lines were constructed by the Bell System in limited locations, service was handicapped by the rapid weakening of signals over relatively short distances.

Long distance service was provided on a separate network from local service. Few customers subscribed to both toll and local service. For the majority of telephone users, placing a toll call involved traveling to AT&T's offices in a city.

The toll network involved connecting a customer to a separate toll switchboard through two wires, known as a metallic loop. The construction of local exchange plant, on the other hand, was modeled after the layout of outside plant by the telegraph industry. Local service was provided over one wire (known as a grounded loop since ground was used as the return path). Because of the difference in wiring, each service used a different type of transmitter and switchboard (Gabel, D., 1989).

AT&T conjectured that this inconvenience accounted for the slow growth in the demand for toll service. Consequently, the company chose to integrate its toll and local networks. Integration of the two separate networks, the company reasoned, would make it easier for customers to receive and send toll calls.

2. Technical problems: overcoming transmission problems

The technical problems of long distance signal amplification were alleviated with the invention of the loading coil and the mechanical repeater around the turn of the century (Fagen, 1975). Subsequently, integration of the two networks became technologically feasible and the local loop was converted to metallic cable capable of handling long distance service.

The manufacture of toll cable was also improved by World War I with the introduction of staggered twist pairs. At first, all cable pairs had a three-inch non-staggered twist. In

1920 staggered twist cables were introduced on toll cable that used two different lengths of twist in order to reduce cross-talk in adjacent pairs. Later, as many as five twists were used in a layer. These measures greatly improved cross-talk suppression (Fagen, 1975).

The telephone companies were reluctant to replace the non-staggered local exchange cable as had been done with toll cable, however. Most local calls are short-haul and the problem of cross-talk was not as severe as on long distance calls. It may also be surmised that the extent of plant replacement was a bottleneck; there was much more mileage of exchange cable in the network than there was of toll cable.

By the late 1920s the volume of long distance traffic had grown significantly. Western Electric, the manufacturing arm of the Bell System, discontinued the fabrication of non-staggered cable. In the following decades, thousands of miles of non-staggered local exchange cable plant was removed and replaced by staggered cable facilities in order to achieve satisfactory toll grade quality.[1]

The policy of integrating the networks had the effect desired by the company. As shown in Table II-1, the number of daily local exchange calls grew much more rapidly than the growth in toll calls. In 1883, subscribers averaged 4.76 local calls per day; by 1889 subscribers averaged 5.85 local calls per day. While the volume of toll traffic increased over this time period, it remained relatively constant compared to the increasing number of telephones. Between 1883 and 1889, the number of daily long distance calls per telephone remained at a constant ratio of .04 toll calls per telephone. It was not until 1893 and the succeeding years as the separate networks were gradually integrated, that toll volume shot upward. By 1920 the rate had quadrupled.

3. Cost impacts and the cost burden

a. The Magnitude and Incidence of the Cost Burden

This integration had a significant cost impact. Integration of local and toll facilities by metallicizing its local exchange cable pairs was estimated to increase local exchange costs by

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[1] Information supplied by Mr. A. L. Issette, retired telephone engineer, Michigan Bell Telephone Company. Impairment of intelligence due to cross-talk continued to be a problem with data transmission. This is particularly true when "go" and "return" channels are carried in the same cable. When the two directions of transmission are carried in separate cables, cross-talk is eliminated. But separate cables result in lower average cable fill (Freeman, 1989).

TABLE II-1

**NUMBER OF TELEPHONES,
AVERAGE DAILY LOCAL AND TOLL CALLS,
BELL SYSTEM COMPANIES:
1883-1920**

		Average Daily Calls		Average Daily Calls Per Telephone	
Year	**Telephones (000)**	**Local (000)**	**Toll (000)**	**Local**	**Toll**
1883	124	590	5	4.76	.04
1885	156	747	7	4.79	.04
1887	181	1,012	7	5.59	.04
1889	212	1,240	8	5.85	.04
1893	266	1,872	34	7.04	.13
1900	836	4,773	149	5.71	.18
1905	2,285	11,404	368	4.99	.16
1910	3,933	18,256	602	4.64	.15
1915	5,968	25,184	819	4.22	.14
1920	8,334	31,836	1,327	3.82	.16

Source: "Historical Statistics of the U.S.: Colonial Times to 1957," U.S. Department of Commerce, 1960 ed., Series R-1-9, pp. 480-481; authors' calculations.

35 percent (Gabel, D., 1989). The costs of this service improvement were not distributed in a balanced fashion.

- Most of the financial burden, that is the cost of adding an additional wire to the outside plant facilities, was borne by local exchange ratepayers.

- The costs of upgrading the customer instrument and the switchboard operator equipment were also levied on the local exchange company.

Since AT&T owned a majority portion of each of the local companies, it experienced a proportional loss through the sharing of these costs. On the other hand, the toll company was the primary beneficiary. The development and attractiveness of toll were made possible by subsidies from local exchange customers.

This cost shift had powerful effects on local exchange costs. Given the structure of the industry, not only did local rates bear the burden, but so too did some stockholders of local companies. One seminal case provides interesting insight into this cost shift.

b. An Effort to Redress the Imbalance

In 1893, Alexander Bell's patent on the telephone transmitter expired. Almost overnight, competitors of the AT&T Co., known as Independent Telephone Companies, sprung up around the nation. The Independents were attracted to the provision of local service because of the high profits earned by AT&T during the patent monopoly period.[2] Widespread customer dissatisfaction with the quality of telephone service provided by AT&T also provided a market opening for the Independents (Gabel, R., 1967).

The Independents were most successful in the Midwest. The Central Union Telephone Company, AT&T's local operating company in Indiana, Illinois and Ohio fared poorly. Not only did it see its market share fall quickly from 100 percent to less than 50 percent, it also suspended dividend payments in 1894. Throughout the competitive period, 1894-1913, Central Union operated at a loss (Gabel, D., 1989).

Despite the losses experienced by its subsidiary, AT&T felt it could absorb the local company operating loss for a time in order to eventually destroy the competition. The American Company also took the long-range view of its toll market. Growth of its toll business had not been substantial because of its stand-alone network. The consolidation of facilities would eliminate the need for a stand-alone, toll network and expand the number of customers who could be directly reached over the toll lines.

The benefits of system integration were not universal. The capital costs of the conversion from grounded-to-metallic network upgrade were borne totally by the local company. AT&T did pay compensation to Central Union for connecting its toll lines to the local exchange plant, as well as for Central performing the billing and collection function for long distance calls. But the minority stockholders of Central Union objected. They filed suit in the Superior Court of Cook County, Illinois, charging that they had been compelled to take on costs which were advantageous to AT&T, but had received few benefits in exchange.

[2] For example, between 1880-1899 AT&T paid out 51 percent of its revenue in the form of dividends (FCC, 1938, 584).

The minority stockholders (Read et al.) claimed that the decisions made by Central Union's board of directors were intended to promote AT&T's national position, but that these interests did not coincide with the interests of the minority stockholders. For years the market price of Central's stock had been approximately 25 to 50 percent of its par value. The complainants felt that the long term financial problems of the local firm had been largely an outgrowth of the competitive war which had been waged by Central Union on behalf of AT&T, and in order to best meet the interests of its majority stockholder, AT&T.

The minority stockholders believed that these sacrifices had been made with the understanding that they would share the future gains. Having experienced continuing operating losses since 1893, the minority stockholders believed they could recoup these losses as the competing Independent firms were bankrupted and market prices restored to profitable levels (Dever, 1917).

The court decided the case largely in favor of the complainants. The judge found that AT&T's holdings in Central Union were made with the intent to monopolize the industry. The judge ordered that the losses incurred by the local company due to rate cutting should be borne by AT&T in proportion to the benefits offered. More important to the point of the present paper, the judge found that Central Union stockholders were asked to sponsor the growth of AT&T's toll service. When the gains of the integrated network were not shared, the court found this to be in violation of the law. It ordered AT&T to share the costs of upgrading (metallicizing the local lines) "based on the extent to which it benefitted thereby (Dever, 1917)."

Central Union had helped to sponsor the growth of AT&T's integrated, nationwide system but was denied the opportunity to share in the benefits because of the contractual terms imposed by the parent company. Since AT&T had abused its fiduciary relationship with minority stockholders, the complainants were entitled to court-ordered compensation.

4. Regulation

As suggested by the court case, regulators generally failed to recognize that exchange facilities had to be modified to accommodate toll. Indeed, in these early days regulation was extremely weak. Consequently, costs were inappropriately increased in order to effect compatibility with the new requirements of the premium toll service.

The dominant method of allocating toll costs in telephone ratemaking has varied widely over time. In the early days of the industry the Bell System employed the "Board-to-Board" method of cost allocation. Under this costing system, all the common costs of local exchange plant were assigned to local telephone service and none to toll. This is the underlying problem challenged in the Read case.

The Illinois Public Service Commission also challenged this method after World War I, asserting that since toll service made use of the local plant and imposed costs, it should bear a portion of the costs. This view was ultimately upheld by the U.S. Supreme Court in the case of Smith v. Illinois Bell (1930). That decision provided the foundation for the "Station-to-Station" method of jurisdictional cost separations which would be followed for almost half a century.

5. Price changes

The price changes over this period reflect the preferential treatment afforded to long distance service, in spite of the high demands placed on the network (see Table II-2). While the price of local service increased from the early twentieth century until the Second World War, long distance rates declined steadily. Between 1900 and 1940 local rates increased by more than one-third, while long distance rates declined by one-fifth for short distance, interstate calls and over two-thirds for longer distance calls. The reduction in charges for long distance rates has been attributable only in part to the enormous improvements in interexchange technology that occurred over this time period.

B. Direct Distance Dialing

1. Network organization: user interconnection

The integrated local and long distance telephone network created around the turn of the century relied on manual interconnection throughout the first decades of its existence. Interconnection involved customer-to-operator-to-customer connection. In the case of long distance it involved customer-to-operator-to-operator-to-customer connections. A major change in long distance service was the shift to Direct Distance Dialing -- customer-to-customer interconnection. To provide a uniform, nationwide Direct Distance Dialing service that would automatically interconnect millions of users through thousands of switching centers was a massive undertaking.

With manual switchboard service, the telephone operator, upon insertion of the line cord into the customer jack, would ring the called customer by use of a magneto generator or trip a signal tone to the called line. Under this system, toll switchboard operators were able to switch and dial long distance calls through to termination. They also manually recorded the necessary billing information. With the removal of the switchboard operator, automatic signaling (subscriber line signaling) had to be devised to operate concurrently with the selection of the called line circuit.

With this change, large-scale service upgrading in local plant was required. This change took place in various stages as manual switchboard operations were enlarged and extended. Changes in central office numbering schemes, toll routing, ticketing and billing of long distance calls, as well as upgrading of signaling and transmission methods were made necessary with the automation of plant operations required for DDD.

TABLE II-2

HISTORICAL PRICE TRENDS: 1900-1940

CALL TYPE	PERIOD	PERCENT CHANGE
Local[b,c]	1900-1940	+32
New York to Philadelphia (Toll)[a]	1902-1940	- 18
Local[b,c]	1913-1940	+45
New York to Denver (Toll)[a]	1911-1940	- 71
New York to San Francisco (Toll)[a]	1915-1940	- 81

Sources: a) "Historical Statistics of the U.S.: Colonial Times to 1957," U.S. Department of Commerce, 1960 ed., Series R-13-16, p. 784; authors' calculations.

b) "Primer and Sourcebook on Telephone Price Indices and Rate Levels ," Federal Communications Commission, Common Carrier Bureau, F.C.C., April 10, 1987, Appendix 7.

c) "The Economics of Competition in the Telecommunications Industry," J. Meyer and John Robert (Oelgeschlager, Gunn & Hain, 1980), p. 34.

Introduction of DDD was an evolutionary process. It began with telephone operators dialing calls straight through to the distant telephone, first, in a few cities, then over widening areas. As early as the 1930s some long distance calls were being dialed by switchboard operators between cities and towns within relatively small areas. In the late 1940s the Bell System introduced operator toll dialing more broadly.

Beginning around 1950, the telephone industry introduced DDD as both a service and economy measure in the provision of long distance service. The first community in which telephone users could dial calls directly to distant points was Englewood, New Jersey. This was in 1951. Five years later, 11 million customers could dial nearby towns and cities. By 1965, 90 percent of telephone subscribers were able to use DDD. Today the service is universal.

2. Technical problems and design considerations

To provide this service, the first need was for switching arrangements that could produce a uniform service so that if the most immediate path through the network was busy, an alternate path would automatically be discovered, and for a numbering plan that could be applied nationwide. Above all, this meant that the local switching systems, which were of many varieties and vintages, had to be modified to understand the signaling characteristics and also to translate different inputs into a common language that would be understood through any path through the telephone system.

a. Switching

The first requisite was the need to provide local dial service in which the customer dialed directly through to other local telephone subscribers. Mechanization of local service was a prerequisite to customer long distance dialing. Many common battery manual offices underwent conversion to automatic dial service not for the economies rendered to local exchange service, but because of the expected savings and growth in long distance service.

Provision of local dial service in place of manual switchboard service was supplemented in many instances by the rehabilitation of outside plant. These modifications improved the quality of local service, but were essential to the introduction of DDD.

A second switching requisite was a much more sophisticated switching capability to deal with the problem of distant markets. To accomplish this, Bell Laboratories designed types of equipment additions to the then predominant switching machine - the Crossbar - that was more sophisticated than anything that had been attempted before.

As an example of this machine's upgraded capabilities, assume a coast-to-coast call is dialed at a time when all direct circuits are busy. A direct circuit is one between the city of origination to the terminating city. An alternate route circuit travels through one or more intermediate toll switching centers. The machine is programmed so that when it seeks to comply with the first three digits, and finds all direct circuits busy, it immediately signals, say Chicago, in quest of an alternate route. The Chicago machine checks the first three digits in turn and if it has a direct circuit clear to the destination, it sends the other seven digits on. The system will check a number of centers in search of an open path.

b. Accounting

Another necessity for DDD, was a method of keeping track of who calls where, at what time and for how long. In a customer effectuated interconnect, the operator could no longer provide this function.

For this purpose, the industry developed an Automatic Message Accounting (AMA) system to record and process the information. This system generated electronically recorded, machine readable data for billing. Between 1948 and 1963 the Bell System installed message accounting centers to process AMA tapes. A wide AMA paper tape recorded the called and calling numbers, trunk number, type of billing, and times of beginning and end of each call. The tapes were read by machines at the accounting centers that produced monthly bills for customers (Joel, 1982. 120).

c. Signaling

No less essential to the success of DDD was the development of new methods of signaling.[3] This involved problems of both mechanization and signal strength. When operators started to dial calls straight through to the distant telephone, this was quite a different matter from manual signaling between switchboards, where signaling was accomplished by human operators at both ends. For customer dialing, with no operator

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[3] The basic requirements of a signaling system include:

Calling Subscriber's Line:
* seizure (off-hook) to indicate to the central office that a call is initiated;
* dialed address information (or oral address in manual system) to convey the identity of called telephone number; and
* clear forward (return receiver to cradle or restore on-hook condition) to indicate to the exchange that the call is terminated.

Called Subscriber's Line:
* answer (remove receiver--off-hook); and
* clear back (on-hook) to indicate to the central office that the call is terminated by the called party.

The basic signaling on subscriber lines may be considered as comprising two distinct signaling functions: supervisory and selection. The supervisory function serves to detect or change the state or condition of some element (in general, subscriber lines) of the network and reflect the subscriber's on-hook/off-hook conditions. This involves detection of any consequential changes of the state of lines from the idle to the busy condition, and vice versa. The selection functions are concerned with the call connection set-up process and are initiated by the caller sending the called party's address information.

involved, a further radical change in the signaling system was required. Subscriber line signaling may be regarded as being basic function signaling, signaling which is independent of the type of switching system and type of switched network. A consequence of the conversion to DDD was the rapid obsolescence of many millions of investment dollars in manual.ringdown signal equipment.

Perhaps the most important factor affecting signaling for longer distance calling was the development of a.c. methods of signaling. The line plant in voice-grade networks is usually 2-wire unamplified audio and the line signaling is local direct current (d.c.) loop signaling. Local d.c. loop signaling has a limited range and some local d.c. signaling methods use single wire with return signaling in order to increase the signaling limit. Local d.c. signaling is relatively cheap, requiring one signaling unit per circuit; it is the simplest signaling method.

With tones it was possible to send supervisory and pulsing signals over the same distances as voice signals. A new concept was introduced, that of sending multiple tones that in combination represent a digit, in contrast to the single frequency, spurt tone. With the increase of toll calling and the necessity of signaling to greater distances than permissible under d.c. loop signaling, new and more expensive signaling systems had to be added to the local plant. Low frequency, alternating current (a.c.) or long-distance d.c. signaling was adopted when the local d.c. signaling limit was exceeded. This method required outgoing and incoming signaling terminals, which increased the cost relative to local d.c. signaling (Welch, 1981). (See the Appendix for further discussion of switching changes.)

d. Numbering

The fifth element essential to the conversion to DDD was a uniform numbering system where each telephone would have a unique designation. This designation would be based on a numbering plan for each local dial central office whereby each central office would be reached by a distinctive three-digit code.

The central office code at first consisted of a 2-letter prefix and 1-digit office prefix plus a 4-digit station number making up the subscriber local numbers (e.g., AL-6-3575). Although a 7-digit alpha-numeric designation was needed for toll dialing, as late as 1981, perhaps 45 percent of Bell System offices could complete local calls by using only 3 or 4 digits. (See the Appendix for further discussion of numbering changes.)

3. Cost impacts and the cost burden

All of these changes had to be introduced in both toll and Independent (non-Bell) local exchange facilities for DDD to work. The transition was done smoothly and effectively but with scant recognition of the cost burden imposed on local exchange service in accommodating to these message toll requirements. These toll costs were basically absorbed by local exchange ratepayers. After reviewing all major state telephone rate cases in the

Public Utilities Reports over the decade 1950-1959, the author found no evidence that state regulators recognized the impact of any of these changes on local exchange plant costs.

When the program got under way, nearly half of all Bell Operating Companies furnished manual switchboard service where operators provided the numerous functions of making subscriber connections, providing information service, disconnecting service upon call completion, providing the ringing signals and other supervisory tones. Table II-3 compares the number of Bell System central offices by type and by number of served telephones for the years 1948-1959. At the beginning of the period 47 percent of Bell central offices were either magneto or common battery manual. Manual offices were not candidates for DDD. By 1959, the combined Bell Companies were over 92 percent dial while the remaining manual offices served only 4 percent of Bell Telephone customers.

The average investment in central office equipment per telephone line increased 43 percent between 1948 and 1959. Under prevailing regulatory cost principles, about 90 percent of this higher investment was allocated to basic local exchange service.[4] As discussed below, local rates increased at a much more rapid rate over this period than toll rates.

4. Regulation

The advent of Customer Toll Dialing after 1950 was a technical and service event of major significance in the industry. As we have seen, DDD involved material changes in the composition of plant, i.e., switching, signaling and accounting equipment. These changes were made necessary in the effort to improve and expand message toll services. Therefore, the costs associated with these changes were directly attributable to this premium service. To what extent did federal and state regulators acknowledge this cost attribution and reflect it in telephone rate design?

a. Federal Allocation Approaches

In general, the method regulators use to distribute the costs of common use local exchange plant has failed to recognize the design effects of premium services on costs. Since 1947 the costs associated with the toll use of the common exchange plant have been allocated to the interstate and intrastate "jurisdictions" according to a "Separations Manual." The Manual has been sponsored by the Federal Communications Commission (FCC), which has authority over interstate toll services, and by the National Association of Regulatory Utility Commissioners (NARUC), a trade association of state regulatory commissions.

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[4] The prevailing method allocated costs according to "dial equipment minutes of use" (DEM). Local calls accounted for 90 percent of DEM.

TABLE II-3

NUMBER OF CENTRAL OFFICES BY TYPE OF SWITCHBOARD, TELEPHONES SERVED AND INVESTMENT BELL SYSTEM CARRIERS: 1948 and 1959

	1948		1959	
Type of Switchboard	Central Offices	Lines Served	Central Offices	Lines Served
Magneto-Manual	1,372	499,840	71	26,894
C.B.Manual	2,362	9,477,804	835	2,422,912
Auto-Manual	1	7,536	-	-
Dial-Automatic	4,272	21,373,282	-	-
Step-by-Step Dial	-	-	7,455	29,664,904
Cross-Bar Dial	-	-	2,107	20,476,457
Panel Dial	-	-	516	7,117,092
Other Dial	-	-	3	577
Totals	8,007	31,358,468	10,987	59,708,836
Central Office Equipment Investment (Millions)	$2,654.00			$7,249.00
Investment Per Line	$84.63			$ 121.41

Sources: "Statistics of Communications Industry," Table 25, Federal Communications Commission, December, 1948; "Statistics of Communication Common Carriers," Table 15, Federal Communications Commission, 1959.

While the Separations Manual has been identified as a "cost" manual and professes to pay allegiance to cost causation, the fundamental principle underlying the procedures is the "actual use basis which gives consideration to relative occupancy and relative time measurements" (47CFR, 1989). That is, the Separations Manual allocates common costs to services according to the use they make of common plant.

However, this cost allocation methodology is not appropriate for the allocation of costs in telecommunications (Gabel, R., 1967). For example, the local loop, furnished each telephone subscriber, is completely insensitive to the volume of usage traveling over it. That is to say, the investment in the loop is independent of the quantity of usage originated and received by the subscriber. If usage has no cost impact, then it cannot serve as a rational basis for cost allocation. Yet, relative usage of the separate service classifications has been the basis for apportioning this common plant investment to the separate jurisdictions. The result of using this inappropriate allocation method has been to ignore the changes and modifications to loop design arising from the superior operating requirements of the premium services.

Relative usage has been the method of apportioning jointly used local exchange plant between state and interstate which has prevailed since the first telephone separations plan was introduced in 1946. Under the relative use criterion for apportionment of local loop (distribution) facilities, the relative minutes of interstate toll usage as against the total state and interstate minutes of use was the basis of assignment of common exchange facilities to interstate toll operations.

There is some evidence that the differential toll costs were recognized in 1951 with the adoption of the "Charleston" method of telephone plant separations (Gabel, R., 1967). However, the magnitude of cost transfer to the message toll services to reflect these causative factors was relatively minor. Virtually all local telephone plant is used in common in the rendition of multiple telephone services: state message toll service, interstate message toll service as well as local service.

The Charleston Plan (1951) modified the relative usage measure by introducing a weight of two to the interstate toll minutes of use when deriving the interstate share of local loop costs. The introduction of the weighing factor was explained as acknowledgment of "the greater costs imposed on the network by long distance service." The principle of weighing toll dial minutes of use has continued in separations practice through the Ozark Plan, which survived through 1986.

> The toll dial equipment minutes of use applicable to each office are weighted to reflect the difference in average cost per toll minute of use as compared to the average cost per exchange minute of use (NARUC, 1951).

It is doubtful that the shifts in exchange costs with the Charleston Plan can primarily be attributed to recognition by regulators of toll costs, including the Numbering Plan, imposed on common exchange plant. Controversy at that time revolved about the issue of toll rate disparities (NARUC, 1951). The differential between state message toll rates and interstate message toll rates was extremely large at short lengths of haul (NARUC, 1951, 173). It was political pressure over the disparity issue, exerted in the first instance through the chairman of the Senate Interstate Commerce Committee, that brought Charleston into effect (Gabel, D., 1967).

Introduction of automatic message accounting was one of the few instances where the federal and state regulators recognized the introduction of an investment as necessary for the premium service. Telephone "separations" procedures are intended to distribute common plant costs between the federal and state jurisdictions.

AMA equipment was set up as a separate plant category for allocation to interstate and intrastate operations. Although the principal of cost causality in the allocation of automatic message accounting equipment was recognized, implementation nevertheless resulted in an unfair burden on local ratepayers.

AMA was classified as Category 4, Central Office Equipment. Investment in AMA plant was allocated to the respective state and federal jurisdictions on the ratios of relative messages. However, most large urban communities employed the same equipment for recording and billing of local message unit calls. Message unit calls require only one or two line entries on the perforator and recorder equipment, while toll calls require five line entries. So, on the basis of relative usage, the cost allocation result was biased against the local exchange service.

b. State Approaches

The FCC-NARUC Separations Manual provides a standard governing the cost allocation to interstate message toll service. However, similar rules do not exist for the cost allocation of intrastate message toll service. Examination of state message toll costs by the state regulators is a rarity. Generally, state commissions who regulate this segment of the telephone business set state toll schedules on a "value" basis without reference to toll costs. The meaning of the value-of-service concept in establishing intrastate message charges has varied over time.

Until divestiture in 1984, a major consideration had been minimizing the disparity between state toll rates and interstate toll rates for comparable lengths of haul. The great differences in the composition of toll traffic at the separate jurisdictions ensured significant differences in the level of costs, however.

* Interstate toll trunk groups generally have higher density, -- that is a proportionately larger volume of traffic than intrastate toll trunk groups.

* Unit costs are generally lower for the larger trunk groups. Interstate message toll

has longer lengths of haul than intrastate toll. A large part of interexchange circuit costs are in the terminations. Hence, spreading these termination costs over longer distances generally results in lower costs per message mile for the interstate service (NARUC, 1951).

Where the state toll rates do not cover state toll costs, the telephone company is ensured of recovering all its costs, including return, by the method of residual rate making. Under residual rate making, the dominant state utility ratemaking method for intrastate toll service, tariff schedules are first adopted for all non-basic services (e.g., message toll, private line, custom calling, etc.).

The difference between the aggregate revenue requirements of the utility and the estimated revenues to be generated by these non-basic services became the basis for determining basic exchange rates. The result of residual ratemaking has been to allocate a significant percentage of message toll, private line, and customer calling costs to basic local service customers. Value of service allocation methods have resulted in a subsidization of premium services, just as have allocation methods based on usage.

What role did the impact of premium costs play in the rate designs adopted by the state regulatory commissions? After reviewing virtually all the state commission decisions bearing on telephone rates over the years 1949-1959, the answer is almost none. For example, the Charleston separations plan had reduced intrastate plant allocation by $90 million and intrastate expenses by about $23 million. Every state benefitted to some extent by this relief in state revenue requirements.

Net earnings of several major carriers showed immediate improvement. No state commission, except Indiana which ordered a $4 million rate reduction, attempted any local exchange or state message toll rate reduction during this period (Telecommunications Reports, 1952a and 1952b).

Very few state commissions undertook an examination of the costs of the separated service categories, for example, local exchange, state message toll service (MTS). Rather, the rate design of the intrastate service classifications was based upon "value of service" considerations. The effect of the growth and changes in the nationwide numbering plan were brought on by toll message requirements, not only the interstate MTS, but state message toll as well. These are identifiable and significant costs which should be attributed to the toll services. The author's review of the state commission decisions during this period shows almost no State PUCs recognized this.[5]

C. Price Trends

Against this recounting of the costs imposed on local exchange plant by the demands of long distance service, it is surprising to find that the common view of many economists is that rates prescribed for premium services, especially message toll, <u>subsidize</u> rates for local exchange service (Temin and Peters, 1986 and Temin and Peters, 1985). Not only does the design analysis contradict this view, but so too does analysis of rate changes over the period.

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[5] Notwithstanding the dramatic reductions in toll prices over the years, economists generally still contend that the toll service classifications "subsidize" basic local exchange service. It is important to understand the reasoning which underlies this conclusion (MacAvoy and Robinson, 1983; Kahn, 1984; and Brock, 1986).

While there are many explanations, the "incremental cost" argument and the "efficiency" argument are the dominant views of these economists. McAvoy and Robinson, for example, observe that between 1964 and 1977 the average charge for local service increased by two-thirds, while the "direct costs associated with that service tripled." During the same period prices for interstate long distance service remained nearly constant "while direct costs fell by more than two-thirds." Nowhere do the authors seek to define the composition of these direct costs. All of the fixed common plant costs (loop, station wiring, protector and block) were considered as direct costs of local exchange service.

The so-called "toll subsidy" turns out to be a function of the telephone company definition of costs. The incremental cost of long distance service includes only the traffic sensitive cost of long distance, carefully omitting any assignment of the fixed, common plant costs. If one accepts the argument that all fixed plant costs should be assigned to local service and none to long distance, then one has "proved" by circular reasoning, not cost analysis, that local exchange service was being subsidized by message toll.

A second argument is used to justify the allocation of fixed subscriber plant costs to basic exchange rates in order to prop up the subsidy claim.

"Because subscriber plant costs do not vary in the amount of usage, it is inefficient to charge callers on the basis of usage... Since the marginal costs of using the local loop are zero, the price should also be zero...prices set above marginal costs are not desirable in terms of economic efficiency" (CBO, 1984).

This argument has some merit. Unfortunately for the author, it applies to <u>all</u> services not just toll calls. Subscriber plant costs do not vary with usage by non-toll either. They are also zero. As discussed earlier, usage is not a legitimate basis on which to allocate costs.

In 1925, a coast-to-coast message daytime toll call of three minute duration cost $16.50, and "on a typical long-distance call one could usually hear about two percent of the sound level that left the speaker's lips." (Mabon, 1975, viii) The comparable charge for a customer-dialed daytime call made in 1989 for a three-minute call was $.75 (FCC, 1989 and FCC, 1991). In 1925 the average monthly charge for one-party residential telephone service was about $3.60 (Mabon, 1975). At the end of 1989 the average monthly residential rate was $17.54 (FCC, 1990c).[6]

Thus, we see that interstate message toll rates have come down about twenty-two fold over this 65 year period, while basic local exchange rates have increased nearly five-fold during this same time period. The reduction in charges for long distance rates has been attributable only in part to the enormous improvements in interexchange technology that occurred over this time period.

Consistent data is available for the period of conversion from Manual to Direct Distance Dialing. Expensive technical changes to implement DDD were of the utmost important in driving costs in the industry during the years 1949-1960. It is interesting to compare the prices paid for local service and toll services (see Table II-4). The price of basic local service rose by 27 percent between 1949 and 1960, while interstate toll increased by 6 percent and state toll by 13 percent. If toll rates were "subsidizing" local exchange service, generosity was not too encompassing.

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[6] In 1925 most toll traffic was carried over open wire lines or the most elementary forms of FM carrier systems. Today, toll transmission is via coaxial cable, satellites and high density forms of microwave radio relay and optical fiber. In recognition of the more profitable opportunities available through expansion of its long distance service, the AT&T Company concentrated its research and development effort on improving interexchange facilities. Nevertheless, to accommodate the new toll technologies, corresponding changes were necessary in the end links, the common use local exchange plant.

TABLE II-4

HISTORICAL PRICE TRENDS: 1949-1960
(Price Indices)

	LOCAL SERVICE	LONG DISTANCE SERVICE	
		INTERSTATE	INTRASTATE
1949	118.64	76.44	114.93
1951	127.30	76.43	117.22
1953	138.66	83.40	122.52
1955	142.06	83.38	124.89
1957	146.92	83.35	124.19
1959	150.41	81.41	127.99
1960	150.91	81.27	129.43

Source: AT&T unpublished price indices. Local rates based on 95 major cities.

D. Appendix

1. Modification of switching equipment

About half the Bell System local central offices were upgraded to dial in 1948. There were three dominant forms of dial switching at that time: Step-by-Step, Panel, and No.1 Crossbar. Both the Panel and Crossbar switching systems are referred to as common control. A common control office receives address pulses from subscribers, stores the digits momentarily, determines the routing and routes the call accordingly. The a.c. signaling systems were rapidly adopted by the common control elements of the local crossbar and panel switching system through modification of the registers and senders of these entities.[7]

[7] A register is the first unit of common equipment in a central office. It receives address information, either as dial pulses or as multifrequency signals and stores it momentarily for conversion or translation. The sender receives address information from the

switchboards. The first step in preparation for DDD, was operator toll dialing. The success of operator toll dialing meant that once automatic charge recording was accomplished, customers could dial their own calls directly.

The entire United States and Canada, certain Caribbean islands, and parts of Mexico have been divided geographically into Numbering Plan Areas (NPA) and assigned NPA codes commonly referred to as area codes. In addition, a few NPA codes have been assigned fo: special purpose and are known as Special Area Codes (SACs). Special area codes are dedicated for miscellaneous purposes such as customer instruction (411), calling announcement services (911), etc. These special purposes include inward WATS service, TWX service, and mass calling arrangements such as telethons and elections, which have now gravitated to "900-type" services.

Boundaries were initially established for the NPA codes to last for long periods of time and their locations were based on estimates of future requirements. Like many other forecasts, much better boundaries could have been drawn. Making changes in these boundaries has caused and will cause massive customer disruption and very expensive plant rearrangements.

The North American Numbering Plan (NANP) requires the following structure for a 10-digit number: N 0/1 N NNX XXXX, where X represents any digit from 0 through 9, N represents only those digits in the series 2 through 9, and 0/1 stands for the zero (0) or the unit (1) digit. If a subscriber is permitted to dial both 7-digit and 10-digit numbers, the switching equipment can distinguish between the two by examining the second digit dialed. By precluding the use of the zero and unit digits in the second digit of the central office code, the switch is made aware that a local exchange number is being dialed.

The advent of DDD required several other plant changes in the central office equipment. First, the auxiliary senders in common control offices (Crossbar, Panel) were modified from 7-digit to 10-digit capacity. The sender is a device in a common control switching system which receives address information and pulses out the correct routing digits to a trunk or to the local equipment. The intelligence imparted by the sender switch had to conform to the expanded switch matrix brought on by DDD.

Other ancillary changes were made as a result of the introduction and subsequent alteration of the NANP. This program got under way in the sixties. Common control switching such as Crossbar and Electronic offices contain special translation and code conversion features. These either pass forward digits pulsed by the customer or delete the area code and/or the office code to replace it with another, depending upon the trunking, tandem switching or alternative routing arrangement. The Number 5 Crossbar machines were modified to equip the registers, senders and connectors with sufficient capacity to cope with changes to the 3-digit area code and/or to a 7-digit directory number. The pretranslators were equipped so as to indicate to the originating registers how many digits to expect.

However, the greatest number of local offices at the time were the Step-by-Step central offices. The selector switches in Step offices could not be controlled by these a.c. pulses. In order to accommodate the Step-by-Step central offices to a.c. signaling, many offices were "senderized." Senderization involved the addition of devices to the step switch matrix to add a common control function. This modification permitted Step offices to receive address information, store it momentarily and then outpulse correct routing digits to a trunk or to the local equipment. Senderization was an expensive plant addition, undertaken solely for toll service, but there is no evidence that any part of these plant additions were attributed exclusively to the toll service classification.

Many Step-by-Step central offices were not senderized and therefore were not capable of performing the equivalent call processing function that the register-sender units performed in common control central offices. Implementing DDD in these local offices required them to be arranged to reach points outside of their home numbering plan area. It was costly to expand the selector stages to select and to send the dialed area code to a toll center. For this reason, in these systems, a toll access code, "112," was initially introduced so that these calls would be directed toward a toll recording office. The routing, timing and ticketing function was then completed at the toll office.

Also, dial switching modifications were required of the Panel and No.1 Crossbar local offices. Extensive modification was required of the subscriber senders of these systems in order to handle DDD calls. For example, auxiliary senders were devised to provide extra digit capacity and the ability to handle multifrequency (M.F.) outpulsing.[8] The auxiliary sender received all digits in excess of the eight that the regular sender could register. These were extremely expensive modifications that were undertaken solely to accommodate the local switching network to DDD.

2. Uniform telephone numbering plan

Most long distance calling after World War II was performed through manual toll

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register or routing information from a translator and outpulses correct routing information to a trunk or to local equipment.

[8] The jurisdictional cost treatment of auxiliary senders confirms the general rule that state regulatory authorities gave scant recognition to causative factors when identifying telephone costs. Auxiliary senders were separately identified and classified as Category 5, Other Toll Dialing Central Office Equipment. This investment, in turn, was distributed on the basis of toll minutes of use. Except for the California P.U.C., where three-way cost studies were undertaken, and cost allocation generally followed the FCC Separations Manual, no other state appears to have recognized the character of this plant. This means that the state residual portion of auxiliary sender investment was distributed to basic exchange service on the dominant "value" pricing concept (Bell Telephone Laboratories, 1982).

Since there were no longer manual switchboard operators to time and ticket toll calls, automatic message accounting (AMA) had been introduced to record the traffic. Each change to record additional area code digits required a corresponding change in the AMA equipment. These are costs which have been largely borne by local exchange ratepayers but are incurred in response to the technical operating requirements of message toll service.

Additional costs were incurred for equipment necessary to dial the additional digits. This additional equipment varied by the vintage and type of equipment. For Step-by-Step central offices, initial stages were frequently equipped with digit absorbing selector switches. When the initial digits were dialed, the selector equipment would merely absorb the digits, drop back in place, but pass on no further signal information.

Far more extensive and expensive modifications were required for the Panel and No.1 Crossbar local offices. The subscriber senders of these systems received the dial pulses and, in turn, outpulse modified routing digits to a trunk or internally to the local equipment. While the additional investment for digit absorbing selectors was recognized as a distinct toll investment, subscriber senders were classified as part of the general switch matrix despite their expensive modification.[9]

[9] The bulk of local dial Central Office Equipment was classified as Category 6, Central Office Equipment and distributed on the ratio of dial equipment minutes of use (traffic sensitive). Since about 90 percent of dial equipment usage is for local exchange service, this classification received a disproportionate assignment of the investment in subscriber sender plant. The originating registers, senders and markers in a No. 1 Crossbar office are equipped with five relays for recording each digit of the dialed number. For the handling of DDD calls, these equipment items are equipped with eleven sets of relays in place of four necessary for purely local calls (AT&T, 1961).

III. THE INTELLIGENT NETWORK: ISDN AND SS7

A. Background: From Analog Voice to Digital Data

With the exception of the low income population, the public service objective of universal service was virtually achieved in the United States by the 1970s through the deployment of a universal network optimized for voice telephone service. This telecommunication network is dominated by analog switching and transmission. This is because analog forms of signal representation are voice-based and the predominant form of transmission has been voice service.

At the same time, traditional signaling has been "in-band" where signal information shares the voice channel. In-band signaling uses not only the same physical path as the call it serves, it also uses the same frequency band as the voice signals that are carried. Because the control signals have the same electromagnetic properties as the voice signals, they can go anywhere that the voice signals go.

Today, however, the industry is gravitating to a variety of information services for business and, to a lesser extent, for social activities.[1] To provide these services, the telephone industry is evolving into what has been termed an intelligent network (IN), optimized for the economic transport of all forms of information transmitted in digital form.

As with the previous changes discussed in this paper, a number of changes are being made in the network to achieve this new type of service. Data and voice networks are being integrated, transmission and switching are migrating to digital forms, signaling is shifting to out of band, and numbering is evolving yet again. Needless to say, all of the changes have significant cost implications for local exchange plant.

B. Integrated Services Digital Network

1. Network organization

Although the analog network provides satisfactory service for POTS, it is less than satisfactory for many information/data services. Therefore, the telephone, telegraph and video networks have been largely separate entities. Development of data networks has remained separate to a considerable degree.

[1] Information Service has been defined by Judge Harold Greene of the Federal District Court as "the offering of a capability for generating, acquiring, storing, transforming, processing, retrieving, utilizing or making available information which may be conveyed via telecommunications, except that such service does not include any use of such capability for the management, control of operation of a telecommunication system or the management of a telecommunication service" (United States v. AT&T, 1982).

For example, in the 1970s, digital transmission, via T-1 carrier and digital switching, was introduced separately into the telephone network (essentially a network within the network). At the same time, many private data networks were established using leased communication lines and serving mainly large business organizations. More recently, public dedicated data networks, based either on circuit switching or packet switching have been established to provide non-voice communications for the business community. Thus, networks optimized for the more recent services, such as data transmission, have stood beside a network optimized for voice services.

The Integrated Services Digital Network (ISDN) has evolved as a means of combining conventional voice grade services with non-voice services. The same digital switches and digital routes would be the common path for all services. The ISDN seeks to consolidate the separate networks for voice, telex, audio, data, video, etc., into a single multipurpose network. An ISDN must have many capabilities to be able to handle the different services and performance characteristics of its component service classifications. The network must have the ability to:

* Handle voice, audio, interactive and bulk data, facsimile, compressed video, full motion video and conventional voice.

* Efficiently transport both continuous traffic (e.g., bulk data, compressed video, full motion video) and conventional voice.

* Allocate bandwidth on a demand basis.

* Allow fast call establishment and termination.

* Handle a wide range of transmission speeds and call holding times.

* Guarantee low bit error rates, low end-to-end message delay and low message nondelivery rates.

* Provide various levels of communication security.

While all of the Regional Bell Operating Companies have introduced trial ISDN installations, these have operated as virtual islands in the absence of interconnection. The challenge of integrating information age services into the existing network has generated ambitious plans to evolve the telephone network and operations architecture.

The essential facilities that will still be used as part of the telecommunication system that supplies almost all services remains the local exchange facilities. Just as in earlier decades, when the integration of local exchange and toll service, and the modification of message toll service to Direct Distance Dialing required major network transformation, the move to the intelligent network is being accompanied by vast changes in local exchange architecture and design which causes very large increases in expenditures.

2. Technical problems and design considerations

a. ISDN Transmission and Switching in the Intelligent Network

The starting point for understanding the push to transform the network must be in an analysis of the demands that data and other premium uses place on the network and the limitations of the existing analog network, which was designed and built for voice uses.

The operating needs of data traffic frequently differ significantly from conversational voice calls. Tables III-1 and III-2 identify several key differences, as well as the types of services that require higher levels of system performance. ISDN, with its digital technology, is designed to overcome these limitations of analog service in order to accommodate the technical and operating requirements for the premium information, data and video services.[2]

A large proportion of data traffic is "bursty," extending for very short duration in comparison with a typical voice conversation. Because the time a circuit is engaged in the passage of information is so much shorter for data calls, the need for shorter call setup periods is more critical. For voice calls this period varies from three to twenty seconds, depending upon equipment. On a public switched data network, call setup time is usually less than one second.

A similar disparity in performance requirements applies to the bit rate or speed of service. For a voice call, a rate of 2.4 kbps (2,400 bits per second) will ensure satisfactory transmission performance. The ISDN objective, geared to medium- speed data traffic, has been set at 64 kbps.

An operating problem has also arisen with the use of conventional voice-grade loop facilities as they enter into the transmission of greater volumes of data traffic. Voice grade facilities have long been employed successfully as the medium for passage of slow-speed data signals (viz., 100 baud telegraph, 1200 baud data, and signal services). But as business has moved into successively higher speeds of transmission, the conventional voice bandwidth has proved to be a serious bottleneck: additional spectrum is required.

The need for additional spectrum has resulted in the redesign of loop facilities. In place of the conventional 3.5 khz facility, loops intended to transmit large quantities of high speed data are engineered for 64 khz capacity, nearly a twenty-fold increase in spectrum availability. While conventional voice-grade loops are normally 2-wire facilities, digital loops are 4-wire, thus making available separate paths for simultaneous transmission of

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[2] Sources relied upon in this chapter include (Stallings, 1989; Kessler, 1989; Kraemer and Martin, 1988; and Dorros, 1987).

TABLE III-1

PERFORMANCE COMPARISONS OF VOICE NETWORK IN RELATION TO NON-VOICE SERVICE CATEGORIES AND REQUIREMENTS

Parameter	Public Switched Analog Telephone Network	Public Switched Digital Network	ISDN Objective (Digital)
Call Duration (seconds)	120	CCT: 10 - 3600 Packet: .001 - 1	Variable
Call Setup Time (seconds)	3 - 20	CCT: .1 - 1 Packet: 1 - 10	1 - 3
Information Transfer Time (seconds)	10	CCT: .001 Packet: .1 - 1	10
Error Rate (errors/million)	1000	CCT: 1 Packet: 100	1
Bit Rate (kilobits/second)	2.4	Up to 48	> 64

* Circuit switched

Sources: Electrical Communications, Vol. 56, No.1, 1981, p.6.

TABLE III-2

Business Service Requirements Furnished by ISDN

Service	Bandwidth (kbps)
Telephone	8, 16, 32 or 64
Interactive Data Communication:	4.8 - 64
Electronic Mail:	4.8 - 64
Bulk Data Transfer:	4.8 - 64
Facsimile:	4.8 - 64
Slow Scan TV:	56 - 64
Videoconferencing:	1,544

Sources: ISDN Concepts, Facilities and Services, G.C. Kessler, Table 3.2.

outgoing and incoming signals. Again it is speed and volume of transmission that make the conventional 2-wire analog loop inadequate (see Appendix for more detail).

b. Signaling

It will be recalled that a prime reason for going digital and having recourse to ISDN is speed and volume of information transfer. Analog signaling which is in-band is quite limited for information transfer. With in-band signaling, the channel is only available for control signals when there are no voice signals on the circuit. With out-of-band signaling, a very narrow bandwidth is available. To take advantage of the potential services and to cope with the increasing complexity of evolving network technology, a more powerful control signal response is needed.

With in-band signaling, the amount of delay is considerable from the time a subscriber enters an address (dials a number) and connection is established. With the new types of data and information traffic (e.g., transaction processing) with relatively short holding times per message (viz., three seconds), this call setup time represents an appreciable part of the total transaction time.

Out-of-band signaling addresses these limitations of in-band signaling. By carrying control signals over paths completely independent of voice channels, significant reductions in call setup time can be achieved.

As noted earlier, Signaling System 7 is designed to serve as the signaling mechanism for ISDN. As one industry publication put it, "Coast-to-coast ISDN is only possible with deployment of intelligent network capabilities such as out-of-band signaling" (Telephony, 1990, 9). Out-of-band signaling takes advantage of the fact that voice signals do not use the full 4 khz bandwidth allotted to them. A separate narrow signaling band is used to send control signals. Thus, control signals can be sent whether or not voice signals are on the line, thus allowing continuous supervision and control of a call. (See Appendix for more detail)

c. Numbering

As recently as 1970, industry experts conjectured that the then existent North American Numbering Plan (NANP) would survive for 75 to 100 years without alteration (USTA, 1971). The Nationwide Numbering Plan was initially designed to accommodate changes and growth in the subscriber population. The growth in requirements for telephone numbers in earlier years arose out of enlargement of the normal subscriber population. This growth was systematic and relatively slow (ranging between 1.5 and 2.0 percent annually).

During the last decade, however, the Numbering Plan Area (NPA) codes in at least ten states have exhausted the supply of 3-digit central office codes of the form "NNX." The new growth in demand for telephone numbers has arisen from the addition of new, premium services that require telephone numbers. These new services include ISDN, cellular, paging, gateway functions, services using open network architecture (ONA) and services using multiple numbers assigned to common terminal equipment (e.g., Centrex) (USTA, 1989b). These are among the most rapidly growing services in the telecommunications industry. Their demand for telephone numbers will continue to place a major requirement for greater quantities of telephone numbers.

An impending shortage of NPA codes is forcing modifications to the existing telephone numbering scheme. The existing 10-digit telephone number length is being maintained, but the quantity of valid digit combinations is being increased.

The interchangeable code approach is being used to modify the existing format of both central office codes and NPA codes. A date no later than July 1995 has been chosen as the estimated deadline for the conversion of all offices to interchangeable NPA code capability. By that date, all telephone switching equipment in North America should be capable of recognizing and accepting a new NPA format. Because of format restriction, NPA codes are limited, however, and further changes will be necessary.

The conversion to interchangeable area codes will provide a fourfold increase in the number of area codes (Bellcore, 1986). Unlike the interchangeable central office codes which can be implemented on an area basis, interchangeable NPA codes will have to be implemented simultaneously throughout the North American dial network. Every switching system using the NANP will have to be converted to accept the additional NNX format as NPA codes. (See Appendix for more detail).

C. Cost Impacts and the Allocation of the Cost Burden

1. Advantages and disadvantages of the Intelligent Network

Will users face higher or lower costs with the implementation of ISDN and SS7? These costs will be a function of technology, depreciation policy, functional allocation of the total costs between the network and customer terminal equipment (which partially assume a network functional role) and the policies dictating the rate of return and distribution of revenue requirement between service categories. Because so many of the variables establishing future cost levels are indeterminate at the present time, any record of cost and cost incidence is subject to considerable error. Nevertheless, it is certain that the absolute level of expenditures will be very great and this advance in technology cannot be justified on the basis of cost savings.

The complex mix of enhanced capabilities for existing premium services and new services makes analysis of the net economic effects of the intelligent network complex. However, the net effect is clearly negative. The intelligent network will cost a great deal more.

There are at least five distinct advantages which may be recognized with ISDN.

1. There may be some overall cost savings as multiple networks are consolidated into a single multipurpose network. Space, real estate and other resource savings may arise with this economy of scope. But these saving may not materialize until well into the next century. The transition to ISDN will be slow. In the interim the telephone companies will operate both analog and digital facilities. Whatever economies of scope that may exist will likely occur once the older plant has been completely phased out.

2. The Intelligent Network (IN) allows information to be located in a centralized data base, rather than in each exchange throughout the network as it is now. From the viewpoint of the telephone companies, the greatest attraction of the IN is its ability to reduce the development cycle for new services from years to months (Gilhooly, 1987 and Loosen, 1988). It can take up to four years to equip each exchange with the

software upgrades needed for a new service. The IN aims to avoid this software bottleneck. By having the software centralized in a few locations (viz., the SS7 service point), it will be possible to make new services available throughout the local access transport area (LATA) simply by changing the software at this location. If demand for particular services is sufficiently large, then the intelligence can be distributed to the point of need, i.e., to local exchanges.[3]

3. Cost savings may be realized in systems electronics, maintenance and labor costs. Fewer amplifiers or repeaters are needed with digital facilities and the reported incidence of digital trouble faults is lower than on analog facilities.

4. The industry claims that with a single, consolidated service there will be savings in planning and other costs as well as increased flexibility. Separate networks entail separate facilities together with their respective spare, idle plant. In theory, more effective utilization of bandwidth should be achieved with rendition of multiple services on the common use loop and switch. But conversely, if the new resources are not utilized as forecast in the ISDN projections, costs may increase.

5. In addition to bringing about ISDN connectivity, the introduction of SS7 will permit local exchange carriers to offer new premium services, often called CLASS services. Custom Local Area Signaling Service (CLASS) offerings will be available on a multi-location basis as SS7 spreads. CLASS services are generally based on the use of calling number identification.

Examination of these initial features indicates that many are inherited services from previous telephone company offerings. (e.g., automatic call distribution, toll restriction, etc.). The novel facets arise with the capability of recording and transforming calling number identification. The services are oriented to business markets and, in some instances, to usage by affluent residential households. No benefits to normal POTS users can be discerned. POTS customers will receive few service benefits from the development of digital facilities.

A leading researcher for the National Regulatory Research Institute has commented:

"...there is no direct and widely accepted evidence that POTS monopoly single line residential and business customers will need, use or benefit from these enhanced and more costly services" (Lawton, 1988, 9).

[3] Judge Harold Greene's interpretation of the interexchange provision of the line of business restrictions would require the BOCs to locate SS7 terminations in every LATA. Consequently, these savings from the delivery of software-defined service changes to many LATAs from one central SS7 location may not actually materialize.

Even Bellcore, the research arm of the local Bell companies recognizes the problem:

> "State Commissions are sensitive to 'gold plating', e.g., overbuilding under the guise of ISDN deployment of special loop conditioning that may be required for ISDN. As with any new technology the LECs (local exchange carriers) pass implementation costs to subscribers. However, in the case of ISDN, state regulators fear that LECs will subsidize general network upgrades for ISDN to retain large business customers that might otherwise leave the public network for other alternatives, e.g., advanced private line or other private networks. Since residential users receive little benefit in the near term from ISDN, state regulators are likely to monitor ISDN costs to ensure that the residential ratepayers is not overly burdened with this." (underlining supplied) (Bellcore, 1982).

The disadvantages of the combined network would include at least the following:

1. Beginning about 1962 the industry undertook replacement of its inter-office analog facilities with digital trunks. The economy of the "T-1" PCM digital carrier is generally not challenged. However, the relative economy of total digitization is widely debated. For example, Rolf Wigand, a leading international telecommunications specialist has estimated that the combined cost of the advanced network "will run into hundreds of billions of dollars" and questions whether benefits will equate with the expected costs (Wigand, 1988).

2. Implementation of ISDN technology will require users to replace the existing network with a network that, while it is more sophisticated, may be considerably more expensive. The increased aggregate cost is due to the fact that the intelligent functions have not been explicitly demanded and basic exchange ratepayers may not need to utilize them (Marks, 1984). This problem is also related to functional allocation between the network and customer premises equipment, as well as the cost of "intelligence." With the advent of market competition in the provision of customer terminal equipment, manufacturers have incorporated numerous service features in the software of PBX's and Key Systems. Large commercial firms have increasingly relied on house staff and in-house communication capabilities. It is these same firms to whom the telephone companies look as their primary users of sophisticated vertical services. If these firms rely instead, on in-house services, expected revenues may not materialize for the telephone companies.

3. Although the telephone companies, as well as the manufacturers, continue to predict cheaper digital facilities in the future, whatever savings are ultimately realized will only take place when all equipment is digitized. Although ISDN presupposes implementation of end-to-end, all digital networks in the final stage, in the interim, coders or connectors will have to be maintained between analog and digital facilities. These interface devices are expensive and also impose operating penalties throughout the network.

4. While it is relatively inexpensive to replace trunk lines, it is expensive to replace local loops which connect this local exchange to customer premises. While all early versions of ISDN claimed the intent of using the present loop as much as possible, operating experience indicates that substantial replacement will be required.[4]

5. It is five years since Basic Rate Interface (2B+D) was first installed in local exchange networks. Those networks are still unable to transfer 64 kbps calls to interexchange networks, in part because their new signaling systems do not fully interoperate. Primary Rate Interface (23B+D) services are available from interexchange carriers, but are not generally offered by the local telephone companies. Basic Rate Interface services are available from the local telephone companies, but not from interexchange carriers.

6. As discussed previously, the effect of the heavy replacement of analog facilities with digital technologies, will be to substantially increase costs in the short run. As new investment is brought in while the existing plant is not fully depreciated, ratepayers will bear the cost of write-off of both old and new facilities. No one has successfully demonstrated that the cost increase due to accelerated depreciation will be offset by cost decreases due to more efficient, multipurpose technology.

Given these large costs, it is clear that savings in other costs cannot justify these technologies. These technologies raise the cost of providing service. Only increased revenue can hope to make them a net economic benefits to the overall network. As one analyst recently put it,

"If the deployment of ISDN is to be justified in economic terms, it will be done on the basis of revenue enhancement, not cost reduction. For the service provider, ISDN is not about costs, it is about revenue...the LECs need new applications to drive revenue generation" (Finnie, 1989, 67).

Future revenues cannot be credibly projected, however. Independent analysts have predicted that voice communications will continue to generate the greatest portion of ISDN traffic. The vast majority of uses will benefit little, but they will bear the costs.

"...it does not pay to build a network to the highest requirement which for eighty to ninety percent of the time will be used for the lowest requirement." (de Hass, 1982, 39).

2. The magnitude of costs

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[4] Removal of load coils and bridging points is only a small part of the cost difficulties encountered in order to accommodate the passage of high speed data (Data Communications, 1988).

Both ISDN and SS7 have been technologies which have engaged the interest of industry participants for a number of years. It may be useful to cite the observations made by a number of these experts with respect to probable cost levels.

Estimates of ISDN investment per access line range from $3,500 to $10,000 depending upon the effect of the many variables noted previously. These amounts compare with the year end 1989 investment of the seven RBOCs of approximately $1,800 per access line which largely exclude ISDN and SS7 (FCC, 1989).

The local switching plant of the industry was designed and built to furnish voice-grade telephone services. As observed in prior discussion, this analog switching is seriously deficient in accommodating the requirements of the data/information market. All of the carriers have gradually abandoned hundreds of millions of dollars of electromechanical switching systems and are currently replacing their analog ESS machines with digital central office equipment. An interesting indicator of the likely cost of switching center upgrade is reflected in accelerated depreciation charges.

In addition to the cost of deploying the new technology, the cost of taking out the old technology has been a source of concern. Accelerated retirement of analog central office equipment was followed by a precipitous increase in annual depreciation rates (FCC, 1980 and FCC, 1989). Between 1980 and 1989 annual depreciation charges of the seven Regional Bell Operating Companies increased from $7 billion to $13.6 billion. This increased expense includes all depreciable accounts.

A separate estimate was prepared for the central office equipment accounts. As calculated in Table III-2, the annual increase in depreciation charges for the years 1980-1988 attributable solely to the higher annual depreciation rates applicable solely to central office equipment was in excess of $2 billion. Other industry sources have published estimates of the various costs associated with introduction of ISDN and SS7:

"It will cost $2 billion to replace existing analog switches with digital" (Deere, 1988, 50).

" The cost of designing and building such advanced networks (SDN) will run into hundreds of billions of dollars..." (Wigand, 1988).

Similarly, the cost of the changeout in numbering will vary within each Numbering Plan area and will vary somewhat depending on the types of switching equipment located in each area, but it will also be considerable. As the American Telephone Company observed several years ago when contemplating the proposed code format changes: "...the total cost will be very large" (AT&T, 1981, 6).

"To implement these changes, millions of dollars will be spent on hardware, software and public notification throughout North America by all local exchange carriers (LECs)"

(Epstein, 1990, 60).

"The economic impact of the international traffic changes may be considerable" (USTA, 1989a, 2).

The Illinois Bell Telephone Company recently estimated the cost of the changeover in its Chicago NPA. Chicago has a high proportion of digital and analog electronic central office equipment. The cost of such changes are naturally lower for electronic equipment because only software modifications are required, compared to the older electromechanical central office equipment which will require hardware changes.

For Chicago, "the cost of technically preparing for the new code, including labor, is expected to reach $15 million. But... that does not include mailings, public relations efforts and business packages designed to smooth out the transition" (Telephony, 1989, 11). Extrapolating the Chicago cost experience to the balance of the Numbering Plan Areas indicates a nationwide cost would be in the neighborhood of $2.3 billion. Including the overhead costs, it is reasonable to expect the combined nationwide cost will exceed $3 billion.

3. Incidence of the cost burden

To date, little or no recognition has been made of the causative nature of the higher depreciation costs. In general, they have been distributed indiscriminately among all service categories with no attempt at assignment on the basis of cost causation. This has meant that the basic exchange ratepayer who has benefitted least from the changeover of plant facilities has borne the heaviest cost burden.

For example, the mainstay of ISDN basic rate architecture is the use of 64 kilobit channels. This standard is highly desirous in accommodating the passage of high speed data services. But this is clearly an overbuild for voice services which still constitute the majority of the common network usage. We know that transmission of voice at 32, 16 and even 9.6 kilobits will provide highly acceptable service quality (Felts, 1982).

A similar conclusion is in order with respect to the costs of numbering changes. We have previously observed that the growth of basic subscriber demand does not threaten the integrity of the Nationwide Numbering Plan. It is fair to say that the costs imposed by these

TABLE III-3

ANNUAL INCREASE IN DEPRECIATION CHARGES FOR CENTRAL OFFICE EQUIPMENT, REGIONAL BELL OPERATING COMPANIES: 1980-1988

Plant Account	Estimated Investment 1/80[a] ($000)	Annual Depreciation[b] Rates			Increased Depreciation Expense ($000)
		1980 %	1988 %	Increase %	
Step-by-Step	5,412,092	17.0	22.8	5.8	313,901
Crossbar	11,973,119	15.7	20.9	5.2	622,602
Analog ESS	12,849,939	5.5	11.2	5.7	732,447
Circuit Equipment	12,958,693	6.2	9.8	3.6	466,513
Totals	$43,193,843				$2,135,463

a) Central office equipment investment of BOCs as of 1/1/80 of $43,195,644,000 distributed to sub-accounts after deducting circuit equipment estimated at 30 percent and panel @ $1.8 million excluded. The balance distributed to Step 17.9 percent, Crossbar - 39.6 percent, Analog ESS-42.5 percent on the ratio of stations.

b) Annual depreciation rates are an estimated average of the prescribed COE depreciation rates for the principal Bell carriers in 1980 and 1988.

Source: "Statistics of Communications," 1980, s 8, 12, Federal Communications Commission; "Files of Depreciation Branch," Common Carrier Bureau, Federal Communications Commission.

services on the Nationwide Numbering Plan, its modification and enlargement, are not reflected in a proportionate allocation of this cost burden to the causative service classifications. Again, it is the POTS classification which appears to bear the major cost assignment.[5]

The deployment of information age technologies not only raises questions about the misallocation of costs and benefits between service categories, but because the new technology is so dependent on creating new streams of revenues, it raises serious problems about the misallocation of costs and benefits across generations. One company's projections of costs and revenues in support of its request for increased rates to support the installation of out-of-band signaling is instructive (see TABLE III-4).

Although industry forecasts of revenues and expenses cannot be accepted at face value,[6] their own projections indicate that it would require four years of growth under company projections before the service would yield a positive return. It takes four years until the company anticipates revenues to exceed expenses in the metropolitan New York LATA. the investment does not break even until at least six years after the program is under way. Who will bear the onus of revenue deficiency in the intervening years?

D. Rate Regulation of Information Age Services

Experience has taught that it is essential that state regulators arrive at their own conclusions regarding the procedure for allocating costs associated with the ISDN-based advanced technological services. Both state and federal regulatory commissions have expressed real concern over the possible level of capital and recurring costs for ISDN and SS7. Hence an FCC Staff Inquiry was launched in February 1990 which sought an estimate by the RBOC carriers of the SS7 and ISDN investment and recurring expenses - defined as

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[5] The North American Numbering Plan (NANP) is administered by Bellcore, the R&D arm of the regional Bell companies. The leading expert of the NANP recently told an association gathering of state regulators: "It's not population growth but the growth in the number of new services that is exhausting the phone number supply" (State Telephone Regulation Report, 1990, 1). So there should be no dispute concerning the causative factor generating these additional costs. Since basic exchange service is clearly not the cost causative service category, it should be immunized from the cost effects. However, unless and until the regulators recognize the problem, under prevailing jurisdictional separations and rate design methods, it will be basic exchange ratepayers who will bear the bulk of these costs.

[6] The Company's projection of revenue is highly speculative. After nearly a decade of provisioning various Custom Calling Services (Speed Dialing, etc.), New York Telephone has still not reached the market development forecast for five years growth (New York Telephone, 1990).

TABLE III-4

NEW YORK TELEPHONE REVENUE, INVESTMENT AND EXPENSE TO IMPLEMENT LOCAL COMMON CHANNEL SIGNALING ARCHITECTURE METRO LATA ($ millions)

Year	Revenue	Investment	Expenses	Net Revenue
1990	0.0	24.1	12.2	- 36.3
1991	3.9	29.0	36.4	- 61.5
1992	19.2	30.6	64.0	- 75.4
1993	73.5	19.5	59.2	- 5.2
1994	22.6	- 7.9	22.6	7.9
1995	132.1	- 0.3	18.0	114.4
1996	158.9	- 2.6	11.4	150.1

Source: NY Tel Response by A.L. Culmone to CPB Info Request NO.132, Case No.90-C-0191.

"direct" - covering the years 1989-1992.[7] Some states have begun major reviews of telephone company modernization plans (New York, Tennessee).

1. Federal approaches

The conventional cost allocation measures adhered to by the FCC - subscriber line usage, relative minutes of use, etc. - rely upon an overly simplistic assumption of

[7] The inquiry launched by the staff of the Joint Conference on Open Network Architecture, Feb 23, 1990 sought to examine the investment and expenses associated with Public Packet Switched Networks (PPSN) as well as ISDN and SS7. The questions raised may have been directed to the jurisdictional impact of these costs. However, the data cited in the text refer to the RBOC estimates of aggregate direct costs, excluding common and overhead costs.

homogeneity of causation by all services.

Since 1984 the F.C.C. has made a serious effort to reverse this principle and, by indirection, to re-establish the Board-to-Board principle. Amendments to the Separations Manual, undertaken since 1984, eliminated the weighting factor in the allocation of the toll portion of traffic sensitive common exchange plant.

Although there is no economic justification for allocating fixed plant costs solely to basic exchange customers, doing so has had significant equity implications. The FCC and the industry agreed after June 1, 1986 that most local exchange plant facilities were non-traffic sensitive and accordingly, relieved the interexchange carriers from major responsibility for compensating the local exchange carriers for this cost. Instead, the FCC adopted the Subscriber Line Charge (SLC). As of April 1, 1989, single line residential customers pay $3.50 per month for the use of local plant in the rendition of interstate long distance toll service.

The imposition of the subscriber line charge has been largely responsible for the shift in distribution of local and long distance rates since the divestiture of the Bell System. Most toll traffic is generated by large commercial firms and affluent residential households. Approximately a fifth of households originate no message toll business. On the other hand, for reasons of public safety, health, and social needs, all households require local telephone service. The increase in local telephone rates has been disadvantageous to the elderly and to the poorer members of the community because they originate fewer long distance calls. At the same time, members of the business community and affluent residential households who generate a large number of toll calls have saved money.

> "Between 10 and 20 percent of all households place no long distance calls in a given 4 to 6 month period... Over two-thirds of households pay more in subscriber line charges than they saved as a result of the reduction in the rates for usage." (Cooper, 1987)

Of additional concern is the Joint Cost Order, which is intended to be the guide to separating the costs of basic and premium services. This order perpetuates the faulty allocation principles which are based on the quantity of use, rather than the quality of use. Common costs are allocated as if there was a common need for the recent round of expensive investment, when that is clearly not the case. Once again, the cost allocation formula misallocates costs to POTS customers.

The FCC, for example, has adopted a minute-of-use standard for allocating all access services in the provision of equal access for interexchange toll facilities. Under current jurisdictional separations procedures the investment in out-of-band signaling facilities is apportioned on the basis of relative usage. Implementation is somewhat more complex.[8]

2. State Approaches

A number of state regulatory commissions have adopted this subscriber line charge and have levied intrastate SLC charges on local ratepayers to reduce the cost burden for intrastate message toll service (Mathios and Rogers, 1987). The effect of this shift in cost allocations has been detrimental to the majority of residential consumers.

The Regional Bell Operating Companies are seeking authority to change non-basic rates without a rate filing with the local Public Utility Commission. These efforts are proving increasingly successful in many states. Thus, it appears highly likely that by the time that these future Intelligent Network services are available and, in light of the competitive environment in which they largely fall, they will be "below the line." Clearly, current telephone ratepayers should not be required to fund expenditures for future subscriber services that will likely be outside regulatory commission scrutiny and which will return no revenues to the regulated side to pay for the investments financed by regulated customers.

The transition to Intelligent Network services poses problems of (1) investment timing and (2) mismatching of costs and benefits. The latter may occur if current ratepayers pay more than their fair share of the costs of ISDN, for example, if one class of ratepayers, e.g., POTS pays a share of costs greater than its share of benefits.

E. Price Trends

The great uncertainty in the magnitude of the costs that the Intelligent Network will impose and the uncertainty about regulatory decisions makes it extremely difficult to estimate what the price impact will be. The stakes are certain to be large, however.

An indicator of the impact can be found in the decision of the FCC to shift costs back to the local service level and industry efforts to obtain rate increases after divestiture. Between the break up of the telephone company in 1984 and 1990, local rates went up over 60 percent (see Table III-5). In dollar terms, the increase for local service nationwide was about $6.00

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[8] For example, Tandem switching equipment is apportioned on the basis of the relative number of study area minutes of use of this equipment. COE Category 3-Local Dial Switching, in study areas with more than 50,000 access lines, is apportioned on the relative dial equipment minutes of use (DEM). Wideband and exchange Trunk Facilities (CAT2) are apportioned between state and interstate on the basis of the relative minutes of use (MOU). Interexchange Cable and Wire Facilities - Category 3 Message is apportioned on the basis of conversation minute miles. While these principles appear simple, there are convoluted measures taken by the carriers to implement them. For a statement of the principles, see C.F.R., Part 67, Parts 123, 124, 125, 132, 143 and 138.

TABLE III-5

HISTORICAL PRICE TRENDS: 1982-1990
(Annual % Changes)

	Local Service	Long Distance Service	
		Interstate	Intrastate
1982	10.8	2.6	4.2
1983	3.3	1.5	7.4
1983	17.2	4.3	3.6
1985	8.9	-3.7	0.6
1986	7.1	-9.4	0.3
1987	3.3	-12.4	-3.0
1988	4.5	-4.2	-4.2
1989	0.6	-1.3	-2.6
1990	4.4	-2.9	-2.7

Source: "Trends in Telephone Service," Federal Communications Commission, Common Carrier Bureau, F.C.C., August 20, 1990.

per month. At the same time, interstate long distance rates declined about 33 percent, while intrastate long distance rates increased about 8 percent.

These changes can be used to put the cost of the information age in perspective. In Florida, it was estimated that deploying fiber optic cable on an accelerated basis would cost an average of $5.00 per month for several decades (Cooper, 1990). This does not include the cost of digital switches or SS7 technology. In Tennessee, it appears that deploying the latter two technologies will cost about $4.00 month (RCG, 1990).

F. Appendix

1. The new basic ISDN plant

Two primary types of service are currently available through ISDN. Basic service will provide two 64 kilobits per second (kbps) "B" channels and one 16 kbps "D" channel (2B & D) for a total of 144 kbps. The D channel is used to transmit network control information between the network user and the telephone company. For large business users, Primary service will be offered. Primary service will consist of 23 "B" channels of 64 kbps and one "D" channel of 64 kbps (23B & D) for a total of 1.544 megabits per second (mbps).

To understand why analog and digital network standards are so far apart, it is necessary to explain certain elementary properties of the separate service.

The human voice can produce tones in the frequency band of 50 to 15,000 hertz (hz) or 15 kilohertz (khz). The ear can hear sounds in the 60 to 20,000 hz passband. But the passband of the telephone local loop is roughly 300 to 3400 hz. How can a channel with a passband of 3.1 khz carry the information of a channel with a 14.95 khz bandwidth (15 khz-50 hz). The local loop is optimized for human voice and is not intended to carry just any analog signal. The major portion of the relative energy of the human voice signal is in the frequency range from about 200 to 3500 hz. Thus, the conventional loop design is adequate for quality human voice transmissions.

Now consider what happens when greater spectrum requirement is demanded for another service. Take the case of music, which is intended to be pleasing to a larger frequency spectrum of the ear. A transmission facility carrying music must use a larger bandwidth than voice. This is particularly important for the trunks connecting telephone switching offices. Filters and load coils in the network cut out the voice signals below 300 hz and above 3400 hz, even though the voice itself is capable of carrying much higher frequencies. Similarly, to pass high speed data signals a much greater passband is required.

A major stumbling block to sending digital signals between the central office and customer sites is today's local loop. The local loop comprises a twisted pair of 22 to 26 gauge unshielded copper wire. The average length of a local loop in the United States is about 18,000 feet.

Load coils are placed on the local loop to reduce the voice frequency attenuation (power loss) in the wire pair. While the load coils ensure that the voice signal is strong enough to travel the distance between the customer site and the central office, they effectively limit the voiceband to about 300 to 3400 Hertz. Data signals require the greater bandwidth for effective transmission. Bridged taps are also present on the local loop. They reduce installation time for new customer connections but they also adversely affect digital transmission on the loop. The problem with the analog local loop is that while 3.1 khz is sufficient for carrying analog human voice signals, it is not sufficient for carrying the frequencies required to represent digital data.[9]

2. **Signaling System 7**

The local exchange network today is based on a single network technology. Both subscriber calls and the signaling and control information are transported on the same facilities and use the same switches.

Conventional signaling in voice networks tends to be designed for different types of transmission media in order to reduce signaling cost. The line plant in analog networks is usually two-wire unamplified audio and the line signaling is d.c. loop signaling. Local d.c. loop signaling has a limited range and some local d.c. signaling methods use ground return to increase the signaling limit. Low frequency a.c. may be adopted when the local d.c. signaling limit is exceeded. In both cases, all signals use the same transmission path over which the information is being relayed. Hence, the usual reference to "in-band" signaling.

In contrast, SS7 signaling utilizes a separate path, a facility independent of the path employed for information transmission. Thus, the reference to "out-of-band" signaling.

In the long-distance interexchange networks, in-band signaling technology has largely been replaced by two closely coupled networks -- the message transport network, and a separate interoffice (digital) data network that carries all signaling and network control data in a common channel. Separating the signaling, which is inherently digital, from the message traffic itself, results in faster call setups to accommodate the needs of data users; reduces the trunk requirements required for the same volume of busy-hour traffic; and of great importance to the telephone companies, has made possible the development of new services (Bellcore, 1990; Levine, 1989; Kessler, 1989; and Mitchell, 1990).

Local exchange carriers are in the process of introducing this technology into the local network using Signaling System No.7 (SS7) protocol. The initial benefits from the new technology are being realized for tandem-switched calls. But with additional equipment and software, this technology also provides the opportunity to make a wide variety of new services available. These services are produced by specialized computer processing software that is supplied either within the local exchange network or by enhanced service providers connected to it.

To understand the elements of the SS7 technology required for new premium services, it is helpful to follow the handling of an interoffice POTS call that passes through a common channel signaling network (SS7). Figure III-1 represents a simplified diagram to show the

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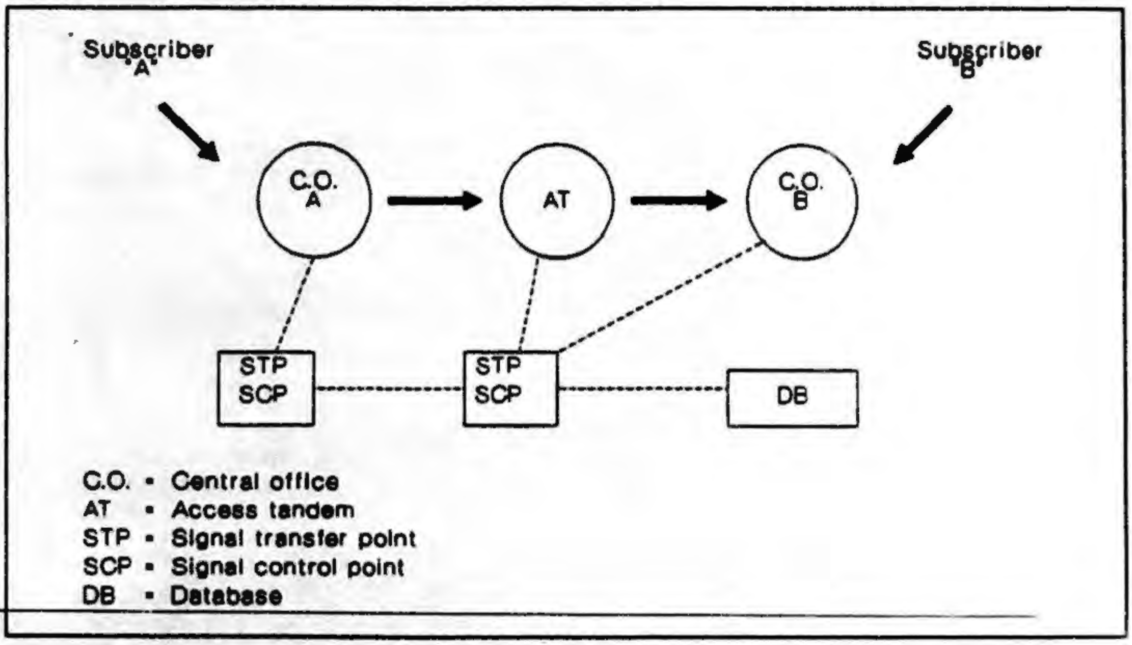
[9] It should be noted that some current local area network (LAN) products and standards use unshielded twisted pair at data rates up to 16 mbps. The length of the wire, however, is limited to a few hundred feet, well short of the local loop requirements of several miles.

FIGURE III-1

DIAGRAM OF SIGNALING SYSTEM 7



Source: Incremental Costs of Telephone Access and Local Use, Bridger Mitchell.

path of a call from subscriber A to subscriber B served in a different local office.

At A's central office, the local switch sends a data message containing both A's and B's telephone numbers over the data network, shown as dashed lines in Figure III-1. This message is passed through the signaling network to B's central office. There the switch determines whether B's line is busy. If it is, it returns a "line busy" data message. A's office receives the message and plays a busy-tone to caller A.

If the line is not busy, the switch in B's central office rings B's telephone. When B answers, the switch sends an "answered" data message back. Only then does the network establish a connection for the voice traffic between office A and office B, shown by solid lines. When the conversation is finished, the two switches send "hang-up" messages to the signaling network, which then removes the voice connection.

The common-channel network itself consists of 56 or 64 kbps digital links that connect the central office switches to special packet switches called signal transfer points (STPs).

Geographically separated STP's are linked in pairs (as spares) to ensure a high degree of reliability. Each has sufficient capacity to perform the task of the other, should one fail (Boatman, Larman, and Shabana, 1987).

In addition to providing capabilities for internal network control and administration, SS7 has two features that are of direct interest to end users: the Transaction Capabilities Part and the ISDN End Users Part. The Transaction Capabilities Part permits a telephone company switch to query a database (STP the Figure) for information on how a call should be handled; for example, how to route an IN-WATS (800 type) service call. The End User Part is intended to permit end-to-end transmission of information through the network, such as the identity of the called or calling number.

The last link in the User Part chain is the ISDN D-channel. It carries signaling information between customer premises equipment and a telephone company's switch. If a subscriber is not served by an ISDN switch, the information will not go beyond the telephone company's switch.

The BOCs began deployment of SS7 in 1987. The timetable for local SS7 availability will extend into the next century. "To equip the thousands of end offices operated by local carriers will involve a major reconfiguration effort and will be very expensive" (Levine, 1989).

3. Numbering

Because of format restrictions, NPA codes are limited to 152 and central office codes are limited to 640. The central office (CO) code digit format (NNX) has excluded combinations which make it look identical to the NPA (i.e., in the N 0/1 format). Interchangeable codes, however, are in the NXX format, permitting central office codes to have digits identical to the NPA. The change increases the number of available CO codes available in each NPA by 152, thus extending the life of the NPA.

With interchangeable NPA codes, every switch in the North American Numbering Plan will be required to accept the new format (NXX) for the NPA. When interchangeable CO codes are introduced, NPA and CO code formats will become indistinguishable. Therefore, a switch's ability to distinguish between 7-digit and 10-digit calls based on the first three digits dialed will be lost. Consequently, methods must be found to distinguish between them and route different call types. While three different methods for making this distinction have been recommended, the "Prefix Method" appears to be most likely to be adopted as the one with the least objectionable features.

In the prefix method, all 10-digit calls are prefixed with a "1" to indicate that 10 digits will follow. All 7-digit calls are dialed without a prefix. This means that even toll calls within the home numbering plans area will require the use of the prefix and 10-digit dialing. However, except for some crossbar equipment, which is being phased out of service, the plan can be implemented with nearly all switching systems so that dialing consistency across the nationwide network can be achieved.

The CCITT (Consultive Committee for International Telegraph and Telephone), the international body responsible for developing service compatible solutions to common telephone problems across nations, has recommended that the capability to translate and route international telephone numbers will require up to fifteen digits in length. This does not include prefix digits such as "011" which are used throughout the world for international DDD access. The capability is required to be in place in all switches and networks by December 21, 1996.

This international technical standard will have enormous financial impact on the domestic network's screening and routing translations as well as billing systems. Most switching equipment in the United States today has been designed to perform routing for numbers up to ten to twelve digit lengths. Billing and accounting systems are also typically designed based on 10- to 12-digit length. These requirements are in addition to the need to implement interchangeable NPA/CO code capability caused by the exhaustion of current NPA codes within the North American Numbering Plan.

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