Canada. As suggested earlier, these studies have not, generally, been able to obtain statistically significant effects on cost for more than one or two output measures.

The principal problem with using cross-section data is that costs observed for each company (particularly the costs of capital) are not necessarily those needed to meet demand today but reflect the mix of technology used to meet demand over the past 30 years. We deal with this problem by revaluing the capital stock in current day's dollars and by including the mix of technology as a cost determinant. This enables us to estimate marginal cost as a function of technological mix and thereby to reflect more closely costs incurred with current technology. Moreover, using pooled time-series cross-section data, we also directly evaluate the effect of changes in output on cost currently.

B. Exclusion of Factor Prices

We have also excluded factor prices from our analysis. Differences in capital costs and labor costs across companies therefore show up in the error term of our model. Factor prices have been included in most prior efforts because a principal object of those analyses was to determine the degree of factor substitutability in the production of telecommunications services for which factor prices are essential. (See, for example, Christensen, Cummings and Schoech (1983) or Evans and Heckman (1983, 1984).) In the present case, factor prices have been excluded because we have no direct interest in factor substitutability, because neither capital or labor rates vary very much within the sample, because obtaining valid measures of these prices would have been quite difficult, and because we had no reason to believe that factor prices were systematically correlated either with output or technology measures. Under these assumptions, the estimated parameters of the model are unbiased estimates of the true cost function evaluated at average factor prices.

C. Output Measures

Output measures used here are also different from those used in earlier studies. Kiss (1986) relates the history of various output measures employed in cost modelling of telecommunications. The first models employed Tornquist-weighted single-output measures. Multi-output functions have since appeared, but with one exception (Taylor and Yanez, 1987) none of these measures have included access lines. This is clearly insufficient for our purposes. Since the principal objective of this study is to evaluate marginal cost of specific outputs, a multi-output analyses was key. Specifically, we examine the effect on cost of a number of access lines and either number of minutes of local and toll calling or number of toll and local calls. These outputs data were obtained from Statistics of Communications Common Carriers, and from quarterly reports to the FCC on minutes of usage. Unlike earlier studies, which typically measured output by deflating changes in revenue by changes in price, we have measured physical outputs directly. This approach is dictated by the data within which there are sharp variations in output prices.

D. Some Other Limitations

Some of the limitations of this study are inherent in the available data. The cost estimation observed here involves an analysis of data for 39 local exchange companies observed over a four year period--1984 to 1987. (Where calls data were used, we had data only on 37 companies). Since the annual observations are not totally independent (there is substantial autocorrelation in the errors), this constitutes a rather limited sample upon which to derive cost estimates. More reliable estimates would require more data.

Second, the available data contain only limited information on the technological mix of existing capital investment. The only technology variable available was the percentage of lines served by electronic equipment. While this

division is useful, to estimate current marginal costs we would have to identify the effect of digital switching equipment and fiber optic interoffice equipment on cost. Without these more detailed technological descriptions, the analysis here should be regarded only as illustrative since it cannot describe the incremental cost of delivering telephone service today. This should be regarded as a limitation on the model used here but not on the technique itself. If the results observed here seem generally plausible, it might be worth refining the measures of technology.

Third, limitations of time and resources required overly simplistic approaches to estimating the value of the capital stock. We examined capital investment only in aggregate and did not, therefore, take into account differences in price escalation or depreciation by equipment type. Moreover, much of the change in value for the historic capital stock reflects substitution of new electronic for old electromechanical equipment. Except where the effect of these technological changes is reflected in changes in the aggregate cost index, the effect of such changes on the value of the capital stock has not been taken into account.

Finally, in using cross-section data to measure the effect of outputs and technology on cost, we are assuming that other cost determinants not included in the regression are uncorrelated with the measures of output and technology which are included. In general, this assumption seems reasonable, except that one might plausibly expect population density to be related to phone costs (inversely) and to output (positively). However, efforts to include density variables in the model indicated no significant relationship to cost.

CONCLUSION

In general, this exercise in the econometric assessment of marginal cost leaves us optimistic about this approach. The econometric analysis accounts for much of the differences in cost among companies and provides generally plausible

estimates of marginal cost. Moreover, when the sources of difference are understood, the results are not necessarily inconsistent with engineering analysis. In fact, if the interpretation posed here is valid, econometric analyses may be a necessary supplement to engineering assessments in order to cover costs incurred at a system-wide level and costs incurred in large lumps. This study also provides useful evidence in the gains from system modernization, an issue often debated before state public utility commissions.

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TABLE 1

COST REGRESSIONS FOR TELEPHONE COMPANIES

	Regression Based on Calls			Regression Based on Minutes		
		Coefficient (t-Statistic)			Coefficient (t-Statistic)	
	Variable Means (Millions)	Ordinary Least Squares	Random Effects	Variable Means (Millions)	Ordinary Least Squares	Random Effects
		-----(1984 Dollars)----			----(1984 Dollars)----	
	(1)	(2)	(3)	(4)	(5)	(6)
Total Cost	1,621	-	-	1,571	-	-
Constant	1.0	$-33.72	$-62.60	1.0	$-90.32	$-83.85
		(1.18)	(2.33)		(2.49)	(2.30)
Access Lines	2.8718	349.44	459.60	2.7712	496.99	458.88
		(4.91)	(8.00)		(4.10)	(5.96)
Local Calls	9,394	0.1668	0.1197	40,055	0.0214	0.0231
		(9.29)	(10.90)		(4.56)	(8.24)
Toll Calls	1,437	0.2389	0.1238	11,513	0.0392	0.0324
		(6.69)	(4.36)		(3.16)	(4.84)
Electronic Calls	7,660	-0.1275	-0.0628	36,244	-0.0192	-0.0135
		(9.92)	(14.17)		(6.14)	(10.912)
Bell Lines	2.6060	-108.22	-174.87	2.4723	-133.44	-171.79
		(3.21)	(5.68)		(2.78)	(3.83)
Number of Observations		37	142		39	142
Adjusted R-Squared		0.997			0.994	
Standard Error		0.100			0.137	

TABLE 2

MARGINAL COSTS

	Econometric Estimation				
	Calls Regression		Minutes Regression		
	Ordinary Least Squares (1)	Random Effects (2)	Ordinary Least Squares (3)	Random Effects (4)	Engineering[1] Estimate (5)
Lines Per Month	$20.94	$25.08	$31.49	$25.47	$12.5-$14
Local Minutes: (Cents/minute)					
Electromechanical	3.8	2.7	2.1	2.3	1.1
Electronic	0.9	1.3	0.2	1.0	0.2
Toll Minutes: (Cents/minute)					
Electromechanical	2.9	1.5	3.9	3.2	
Electronic	1.4	0.7	2.0	1.9	1.0

Sources and Notes

[1] For usage, these estimates reflect costs per switched minute. Interoffice calls are measured both at the originating and terminating office (i.e., a 4.0 minute interoffice call generates 8.0 switched minutes) and the measure includes minutes generated by uncompleted calls.

TABLE 3

CALCULATION OF REVENUES AT MARGINAL COST AND AVERAGE COST

	Ordinary Least Squares	Random Effects	Percentage of Total Revenues: Ordinary Least Squares	Percentage of Total Revenues: Random Effects
	--------(1984 $Millions)-------			
	(1)	(2)	(3)	(4)
Total Revenues	$1,761	$1,822	100.0%	100.0%
Total Revenues at Marginal Cost Using:				
Calls Regression				
Average Technology	1,655	1,686	94.0	92.5
Electronic Technology	1,251	1,487	71.0	81.6
Minutes Regression				
Average Technology	1,661	1,658	94.3	91.0
Electronic Technology	1,367	1,451	77.6	79.7

Case 95-C-0657
Case 94-C-0095
Case 91-C-1174

REBUTTAL TESTIMONY OF DR. TIMOTHY J. TARDIFF

1 Q. Please state your name and business address.

2 A. My name is Timothy J. Tardiff. I am a Vice President at National Economic
3 Research Associates, 1 Main Street, Cambridge, MA 02142.

4 Q. Please describe your educational and professional qualifications.

5 A. I received the B.S. degree from the California Institute of Technology in mathematics
6 (with honors) in 1971 and the Ph.D. in Social Science from the University of
7 California, Irvine in 1974. From 1974 to 1979, I was a member of the faculty at the
8 University of California, Davis. I have specialized in telecommunications policy
9 issues for about the last 14 years. My research has included studies of the demand
10 for telephone services, such as local measured service and toll; analysis of the market
11 potential for new telecommunications products and services; assessment of the
12 growing competition for telecommunications services; and evaluation of regulatory
13 frameworks consistent with the growing competitive trends. I have filed testimony
14 and reports on behalf of Pacific Bell before the California Public Utilities Commission
15 on incremental cost principles, rules for local competition, universal service funding,
16 open access and network architecture, regulation of wireless telecommunications
17 services, the treatment of accounting changes for post-retirement benefits under price
18 caps, the review of California's price cap plan, and flexible pricing for Centrex
19 service. I have also submitted reports on behalf of Pacific Bell before the Federal
20 Communications Commission on price cap productivity, access to intelligent
21 networks, interconnection pricing policies, and the treatment of accounting changes

for post-retirement benefits under price caps. I have also testified for GTE North on intraLATA presubscription before the Illinois Commerce Commission, and filed a report with the New York Public Service Commission on intraLATA presubscription on behalf of New York Telephone. Exhibit 1 is a copy of my resume.

I. INTRODUCTION

Q. What is the purpose of your testimony?

A. In this testimony, I evaluate whether the Hatfield model provides a proper basis for pricing network elements. AT&T's witness Eugene Floyd has recommended the Hatfield model as a basis for establishing the costs of network components in New York. Professor Nicholas Economides for AT&T and Dr. August Ankum for MCI have endorsed the model as being consistent with sound economics. Neither conclusion is true. The model is *not* consistent with sound economics and it produces results that systematically understate the costs that New York Telephone Company (or any local exchange carrier) faces in providing its services and offering unbundled elements to competitors. In particular,

- The model's assumption that prices should be set as if all volumes currently served by local exchange carriers will be served by a brand new entrant that instantly materializes is inconsistent with both reality and sound economics. Accordingly, costs based on such a model will *not* be representative of the costs incumbent LECs incur providing services and unbundled networks components.

- The model employs approximations that produce serious inaccuracies when the relationships upon which these approximations are based depart from their historical relationships. For example, the model estimates the costs of installing cable facilities as well as the structures for cable facilities by using multiplicative factors applied to the price of the cable itself. As a result, the model has the undesirable property that a reduction in the cable price itself causes the total cost of cable-related investment (such as investments in poles) to fall proportionately.

- The inputs (e.g., central office equipment prices) are consistently lower than what local exchange companies actually pay.

II. HISTORY OF THE HATFIELD AND RELATED MODELS

Q. Mr. Floyd reports that the Hatfield model is constantly being renned. Do you agree?

A. Yes. If anything, Mr. Floyd's characterization is an understatement. A brief review of the Hatfield model evolution will show why. The first Hatfield model, sponsored by MCI, was introduced in 1994.[1] That model employed a "greenfield" (or "scorched earth") approach, i.e., the model completely ignored all existing locations of telephone plant and analyzed the cost a hypothetical network built instantaneously on a featureless plain. The major purpose of the model was to develop an estimate of the size of the nationwide universal service subsidy.

[1] Hatfield Associates, "The Cost of Basic Universal Service," Prepared for MCI Communications Corporation, July 1994

Q. Mr. Floyd testifies (p. 9) that a "Benchmark Cost Model" (BCM) is incorporated "as an integral part" of the Hatfield model. What is the BCM?

A. The BCM[2], which was filed with the FCC by MCI, NYNEX, Sprint, and U.S. West in September 1995, identifies geographic areas where the costs of providing basic residential access service are relatively high or low. The purpose of the model was to aid in targeting universal service funding for high cost areas. The sponsors describe their model as follows:

> The BCM does not define the actual cost of any telephone company, nor the embedded cost that a company might experience in providing telephone service today. Rather the BCM provides a benchmark measurement of the *relative* costs of serving customers residing in given areas, i.e., the CBGs [Census Block Groups].[3]

What is noteworthy about this description of purpose is that the costs that the original BCM produces are not the actual costs of any particular company. Despite this acknowledgment, the proponents of the Hatfield model incorrectly propose to use parts of the BCM to produce actual prices for the incumbent LEC's unbundled elements.

Q. Are there yet more recent versions of the Hatfield model?

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[2] I understand that Sprint and US West released an updated version of the BCM to the FCC on July 3, 1996. I have not had an opportunity to review this new version. It is clear, however, that Version 2.2 of the Hatfield model uses parts of the *original* BCM.

[3] MCI Telecommunications Corporation, NYNEX Corporation, Sprint Corporation, and US West Inc., "Benchmark Cost Model," (submitted to the FCC, CC Docket No. 80-286, September 12, 1995), at 3 (emphasis supplied).

1 A. Yes. In the FCC Interconnection proceeding (CC Docket No. 96-98), AT&T
2 released Version 2.2 of the Hatfield model. This is the model that Mr. Floyd's
3 testimony describes. At the same time, MCI attached an updated version of a
4 "greenfield" model to its comments to the FCC.[4] Although the bulk of my
5 discussion focuses on Version 2.2 (and its use of the original BCM), I refer to
6 some of the other "Hatfield models" as needed.

7 Q. Do you consider your review of the Hatfield model to be complete?

8 A. No. Not only is the model "constantly being refined," it is far from user-friendly.
9 I understand that an electronic version of the model was only recently released.
10 Even then, the model's parts (Hatfield, the original BCM, and the LERG [Local
11 Exchange Routing Guide] file) had to be acquired. In addition, computer
12 hardware requirements are substantial.

13 III. THE HATFIELD MODEL IS INCONSISTENT WITH SOUND ECONOMICS

14 Q. How does the Hatfield model depart from sound economics?

15 A. In a number of ways that fail to reflect the costs of a local exchange carrier that is
16 facing increasing competition as a result of technological advancement and
17 regulatory developments. The Hatfield model documentation characterizes the

[4] Hatfield Associates, Inc., "The Cost of Basic Network Elements: Theory, Modeling, and Policy Implications," March 29, 1996.

1 model as "scorched node"—it starts with the existing locations of central offices,
2 then builds a brand new system instantaneously from the ground up.[5] That is, the
3 model puts in place all facilities to serve current demand levels without
4 accounting for the growth dynamics that produce real networks. While
5 proponents of this approach claim that it approximates the textbook definition of
6 long-run cost, it is grossly at odds with how real businesses incur costs,
7 especially capital-intensive firms that expand their facilities by adding capacity in
8 discrete modules.[6] Almost five years ago, Professor Alfred Kahn (a former Chair
9 of the New York Public Service Commission) advised the FCC of the need to
10 employ a realistic and practical perspective.

11 In strict economic terms, the concept of long-run marginal costs
12 relates to a hypothetical situation in which all inputs are variable,
13 and a supplier confronts the possibility of installing entirely new
14 facilities, in effect from the ground up. And the "marginal" relates
15 to the incremental cost of a single unit of output. The concept of
16 long-run incremental cost, in contrast, is more pragmatic: it takes a

[5] A number of long-run incremental cost studies performed by local exchange carriers have employed a different version of the "scorched node" assumption. For example, Pacific Bell and GTE have developed costs based upon consensus costing principles adopted by the California Public Utilities Commission. The Hatfield model departs from the California principles in at least two significant ways: (1) Hatfield only uses the existing locations of central offices, while the California principles require that the existing location of outside plant be used as well and (2) by positing an "instantaneous" network, the Hatfield version of "scorched node" ignores the impact of changes in demand on cost.

[6] Even the theoretical definition must be conditioned by reality. For example, Professor Varian has noted: "Long run and short run are of course relative concepts. Which factors are considered variable and which are considered fixed depends on the particular problem being analyzed. You must consider over what time period you wish to analyze the firm's behavior and then ask what factors can the firm adjust during that time period." Hal R. Varian, *Microeconomic Analysis* (3d ed. 1992), at 66.

> firm's past history as given, does not assume that it is writing on a blank slate, but recognizes that it will ordinarily be planning the installation of new capacity, at whatever that additional investment will cost given its current situation, and it spreads the costs over either the total output of that additional capacity—in that sense it is a kind of average incremental cost—or over the additional output that is likely to be induced by a price reduction under consideration (or curtailed in response to a price increase.)[7]

Q. Does the Hatfield model properly represent the fact that telecommunications carriers are subject to continuous technological change?

A. Absolutely not. In an industry with rapid technological progress, such as telecommunications, no company would set prices based upon costs determined by the Hatfield model. The reason is that as technology advances, basing prices on the Hatfield view of the world would never recover costs. Professor Kahn and I recently noted this phenomenon as follows:

> In a world of continuous technological progress, it would be irrational for firms constantly to update their facilities in order <u>completely</u> to incorporate today's lowest-cost technology, as though starting from scratch: investments made today, totally embodying <u>today's</u> most modern technology, would instantaneously be outdated tomorrow and, in consequence, never earn a return sufficient to justify the investments in the first place. For this reason, as Professor William J. Fellner pointed out many years ago, firms even in competitive industries would systematically practice what he calls "anticipatory retardation," adopting the most modern technology only when the progressively declining real costs had fallen sufficiently below currently prevailing prices as to offer them a reasonable expectation of earning a return on those investments

[7] Affidavit of Alfred E. Kahn (submitted to the FCC, CC Docket No. 91-141, August 6, 1991).

> over their entire economic life. In consequence even perfectly competitive prices would not be set at the level of these (totally) current costs—unless, to put it another way, the calculated costs of the new plant included an extremely high rate of return and of depreciation, in reflection of the exposure of any such investments to costs and prices progressively declining in real terms over their life.[8]

The Hatfield model's scorched approach to cost modeling essentially assumes that a LEC's entire demand for telephone services is constantly up for grabs. In effect, the succession of incumbent LECs would hand over their entire business to the newcomer, which in turn would instantly size its plant to perfectly accommodate this demand, taking advantage of all the economies that come with serving the demand with perfectly sized facilities obtained at the maximum volume discounts. It would be nice if the world worked this way, because we would all like to pay less for what we consume. Unfortunately, it does not. A real firm grows to meet demand as it materializes. As such, it adds capacity taking into account the trade-off between the lower per unit costs of bigger modules (e.g., larger cable sizes) and the costs of carrying the unused capacity that deploying larger modules would entail.

[8] Declaration of Alfred E. Kahn and Timothy J. Tardiff (submitted to the FCC, CC Docket No. 96-98, May 30, 1996) (footnote omitted). Professor Jerry Hausman's reply affidavit, filed in this docket on the same day, makes a similar point in the context of depreciation. Professor Hausman's findings will be discussed later when depreciation issues are addressed.

Q. Does the Hatfield model exclude other costs that need to be considered in setting prices?

A. Yes. There are two such costs. First, to the extent that historical depreciation rates have lagged behind economic depreciation rates, the reserve deficiencies thus created represent costs that incumbent LECs should continue to have the opportunity to recover. Second, the current configuration of the LEC's network captures the effects of regulatory obligations such as carrier-of-last-resort. To the extent that a hypothetical network fails to represent such legitimate forward-looking costs, its results would understate the actual cost of providing services and unbundled network elements.

IV. THE HATFIELD MODEL INCORRECTLY REPRESENTS LOOP PLANT AND SWITCHING

Q. Mr. Floyd characterized the Hatfield model as conservative. Is he correct?

A. No. The basis for his characterization is (1) the claim that the use of Census Block Groups (CBG) underestimates loop distances because it assumes a uniform distribution of households within the CBGs, (2) the use of historical factors to estimate out-of-pocket expenses and (3) the inclusion of a 10 percent overhead factor.

Q. Why do Mr. Floyd's three reasons not necessarily result in a conservative analysis?

1 A. First, with respect to the uniform distribution of households within CBGs, I note
2 that the developers of the original BCM identified this as a problem primarily for
3 large, low-density CBGs. In fact, New York Telephone has very few CBGs of
4 this type. Over 80 percent of all households are in the two highest density
5 categories of the BCM. Second, the Hatfield model's use of historical factors is
6 *not* conservative for at least two reasons: (1) the factors exclude a large
7 proportion of operating expenses and (2) the multiplicative factors are employed
8 in a manner that reduces out-of-pocket expenses when the amount of investment
9 is understated.[9] Third, because of the large amount of shared and common costs
10 in telecommunications networks, assignment of 10 percent as overheads is hardly
11 conservative.
12 Even if Mr. Floyd is correct on these points (which he is not), his characterization
13 overlooks a host of other factors that cause the model to systematically
14 understate costs. My discussion of these flaws is organized into three major
15 categories: (1) loops, (2) switches, and (3) conversion on investments into
16 monthly amounts.
17 **A. Loops**

[9] For this reason, the sponsors of the original BCM "agreed to disagree" in reporting expenses based on two sets for factors: (1) one similar to the Hatfield model factors and (2) one based on all historical cost contained in the ARMIS data. The latter factor was almost 50 percent greater than the former.

1 Q. How does the Hatfield model represent loop plant?

2 A. For the most part, the Hatfield model's development of loop costs relies on the
3 BCM.

4 Q. How does the BCM represent loop plant?

5 A. The BCM starts with the current locations of the LEC's central offices. The
6 model constructs loop plant (feeder, distribution, and associated structures) from
7 the central office locations to the households in the CBG by means of specific
8 engineering rules, e.g., the lines served by a particular central office are the result
9 of assigning CBGs to the closest wire centers.

10 Unfortunately, the BCM assigns substantial percentages of households to the
11 wrong wire center. As a result, the network represented by the BCM departs
12 from the LEC's actual network. The Hatfield model's proponents may argue
13 that the BCM has assigned households more efficiently than the LECs have. A
14 more likely explanation is that the extremely abstract representation of the
15 network—a featureless plain[10]—ignores real world constraints, such as physical
16 barriers, e.g., rivers, lakes, and hills, between a CBG and its closest central office.

[10] The only distinguishing characteristics are a number of factors (water table, soil characteristics, and density) used to estimate the cost of installation and support structures for aerial, buried, and underground placement.

1 Because the BCM assumes that loop facilities are installed instantaneously, the
2 model selects the largest available cable sizes to serve a given static volume. In
3 contrast, because real networks evolve as demand grows and changes, firms face
4 a trade-off between deploying larger cable sizes (and enjoying the economies of
5 scale that result at or near full capacity) versus using smaller sizes, thus reducing
6 the carrying costs of the extra inventory that large cable sizes entail. In this
7 regard, the BCM may underestimate loop cost, because it could assign
8 larger/less-costly facilities (on a per-unit basis) than an efficient firm would
9 deploy. Such "savings" are illusory, not real. What has been left out of the BCM
10 is the carrying charges on the unused capacity that the larger cable sizes would
11 require for several years, until actual demand materializes.

12 Q. What are the problems you have identified with BCM/Hatfield representation of
13 loop plant?

14 A. Problems fall into three major areas: (1) the use of multiplicative factors to
15 estimate the costs of installation and structures, (2) the abstract representation of
16 distribution facilities, and (3) the use of excessive fill factors.

17 **1. Installation and Structure Multipliers**

18 Q. How does the BCM estimate the costs of installation and structures for loop
19 plant?

A. For loop plant, both feeder and distribution, the BCM calculates the investment costs of installation and structures by multiplying the cost of cable by factors that represent the installation labor cost and support structure investments. While properly developed factors can give reasonable representations of average installation and structure costs if current conditions are similar to those from which the factors were based, there are two features of the BCM that make these factors problematic.

The first problem comes from the fact that changes in the cost of cable pass through directly into changes in the cost of installation and structures. In other words, the model would predict that two otherwise identical areas would have different installation and structure costs if they were served by companies that paid different amounts for their cable. Similarly, the model would predict that cost of installation and structures would decrease when a company is able to secure a better discount on the cost of the cable itself.

If installation and structures were a modest proportion of total loop investment, the conceptual problem with the multiplier, albeit troublesome, may not have a large impact on estimated total costs. Unfortunately, installation and structures account for a substantial proportion of the investment cost of loop plant. For example, I am advised that cable itself accounts for about only one-third of

1 NYNEX's loop investment costs. That is, because structure and installation
2 costs appear to account for a majority of loop costs, the use of structure
3 multipliers is truly an example of the tail wagging the dog.

4 Q. Please illustrate the problems that can arise from the use of multipliers.

5 A. Because the cost of cable itself accounts for only one-third of loop costs, the use
6 of multipliers overstates the impact of a change in the price of cable. For
7 example, if the price of cable decreased by 50 percent, while other prices stayed
8 the same, the cost of loop plant would decrease by approximately 17 percent
9 (50% x 1/3). In contrast, the BCM would predict that loop costs would increase
10 by almost 50 percent.

11 **2. Modeling Distribution Facilities[11]**

12 Q. How does the BCM model distribution plant?

13 A. The BCM constructs feeder plant from the central office to the edge of the CBG.
14 All loop plant within a CBG is assumed to be distribution plant. The BCM
15 assumes that CBGs are square in shape and that households are uniformly
16 distributed over the area of the CBG, neither of which is true of real CBGs. The

[11] In the Hatfield model, feeder plant is assumed to run from the central office location to the boundary of a CBG. Loop plant within the CBG is assumed to be distribution plant. In engineering terms, feeder plant runs from the central office to the serving area interface (SAI), Loops plant from the SAI to the customer location is distribution plant.

1 BCM also uses an abstract representation of the distribution plant within a CBG.
2 The BCM assumes that CBGs have exactly four distribution cables of length
3 equal to three-fourths of the square-root of the area of the CBG.[12]
4 Q. What inaccuracies are introduced by this simplistic representation of distribution
5 plant?
6 A. The abstract representation of distribution plant can produce results that differ
7 from reality, i.e., loop lengths can be inaccurate, cable sizes can be incorrect, and
8 the number of cables within a CBG can differ from the four cables assigned by
9 the BCM.
10 For example, although the BCM documentation describes CBGs as containing on
11 average 400 households, there is, in fact, considerable variation in the number of
12 households within a CBG. The consequence is that CBGs with a large number of
13 households exceed the size of the distribution areas that particular LECs may
14 employ. In turn, the BCM allows larger copper cable sizes than some LECs
15 typically employ. In New York, while fewer than one percent of loop cables
16 exceed 2,700 pairs. the BCM permits cables as large as 4,200 for feeder and
17 3,600 for distribution. Thus, because larger cables have lower unit (per pair)
18 costs, the BCM would understate the cost of cable investment.

[12] The model assumes that CBGs are square. Therefore, the square root of the area is the side of the square.

Moreover, the use of exactly four distribution cables in the BCM can cause substantial bias. To see how this abstract representation of distribution plant may introduce distortions, observe first that there are two basic cost drivers of distribution (and feeder) installation and support structure: (1) sheath miles and (2) pair miles. Further observe that BCM estimates the cost of installation and structures by applying multipliers to the price of the cable itself. Accordingly, if there are more than four distribution cables, the BCM will understate the costs that vary with sheath miles.

Q. Can you illustrate the errors that using exactly four distribution cables can produce?

A. A hypothetical example will illustrate the problem. Consider an area requiring 1,000 loops with an average distribution length of 5,000. The following prices prevail:

- Cable[13]: $0.01 (per pair foot)
- Installation and structure cost (per pair foot): $0.02
- Installation and structure cost (per sheath foot): $5.00

[13] This is roughly the cost per pair-foot for cable sizes in the 1000 pair range reported in the Hatfield Model documentation. As a simplification, I assume that changing the number of routes does not change the required capacity or cable size, so that the same unit price is used.