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ESTIMATING THE COST OF SWITCHING AND CABLES BASED ON PUBLICLY AVAILABLE DATA

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FOREWORD

This report is one of a series of focused and timely NRRI analyses of high-priority issues that flow from the Telecommunications Act of 1996—which creates both challenges and opportunities for state regulators. One of those challenges and opportunities is to determine the cost of providing the set of telephone services included in the universal service package and to determine the cost of unbundled network elements provided to entrants.

This report describes the process of gathering data that is in the *public* domain and using it to develop estimates of the cost of placing outside plant facilities and digital switching equipment. The estimates presented in this report may be used in a variety of contexts, including that of determining the cost of universal service and the cost of unbundled network elements. In addition, analysts may use the data bases and other supporting files that accompany this report to develop their own estimates of these costs. The intended audience is commissioners and senior technical staff who need to develop cost estimates or judge the reasonableness of estimates submitted to them. We hope they will find it useful and timely.

Douglas N. Jones
Director
Columbus, Ohio
April 1998

CHAPTER 1

INTRODUCTION

State regulators face many challenges and opportunities as a result of the Telecommunications Act of 1996. This report is intended to provide information and data to assist state regulators in meeting the challenge and opportunity created by their having to determine the cost of providing the universal telephone service and the cost of unbundled network elements provided to entrants. This project began as an outgrowth of the Federal Communications Commission's (FCC) January 1997 workshops on cost proxy models. During those meetings it was apparent that, whatever the chosen model platform, the costs used as inputs in the models should be able to be validated by regulatory commissions. The sponsors of the Benchmark Cost Proxy Model (BCPM) and the Hatfield Model (HM) have been criticized for relying too much on private information. The parties have used private information to make claims regarding the cost of installing cables, switching, and circuit facilities. Although much progress has been made during the past year to improve the cost proxy models, more needs to be done. Moreover, the FCC subsequently concluded that there is a need for better data on such items as the costs of switching, digital line carrier, and non-investment related expenses.[1]

This report uses data that is in the *public domain* to provide independent estimates of the cost of placing outside plant facilities and digital switching equipment. The chapters that follow describe the process of gathering the raw data, manipulating it into usable form, and using the data to develop statistical estimates of the cost of

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[1] See, for example, FCC 97-157, *Report and Order* in Docket 96-45, "In the Matter of Federal-State Joint Board on Universal Service" (released May 8, 1997), paras. 26, 241, 244, and 278.

placing outside plant facilities and digital switching equipment. The cost estimates presented in this report may be used in a variety of contexts, including developing cost inputs for use in estimates of the cost of universal service and establishing the cost of unbundled network elements. In addition, analysts may use the data bases and other supporting files that accompany this report to develop their own estimates of these costs.

Two sources of data were used in this report. The outside plant data was provided by the Rural Utilities Service (RUS), which also provided the switch cost data for small companies. The switch cost data for large companies was provided by the FCC.[2] The data derived from RUS contracts has been entered into a Microsoft (MS) Access data base that is available to any interested party from the NRRI's web site.[3]

Chapter 2 contains the discussion and analyses of the outside plant data. The RUS data base contains 12,679 records of the unit costs of labor and materials associated with installing various outside plant facilities. Records are drawn from 171 contracts covering 57 companies in 27 states. Estimates are provided for placing a variety of outside plant under different conditions and in different density zones.

Chapter 3 contains the discussion and analyses of the digital switch cost data. The RUS data set used in Chapter 3 includes 181 observations on the purchase price of telephone switches — 139 observations for new switches and 42 for augmenting existing switches. The data set also includes cost data for both host and remote switches. The FCC data set for large companies includes 3,394 observations for the 1985-1995 period, including a mix of host and remote switches.

The Appendix contains a listing and description of the data set files that are available for download from the NRRI's website. The data files include the data used in the statistical analyses as well as logs of the statistical estimations that were conducted.

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[2] Some other parties also have copies of the contracts. The outside plant and switching contracts were provided to Bell Atlantic and AT&T in a unbundled network elements proceeding before the Maine Public Utilities Commission.

[3] The NRRI's website may be accessed at: http://www.nrri.ohio-state.edu.

CHAPTER 2

USING THE RURAL UTILITIES SERVICE'S OUTSIDE PLANT DATA FOR REGRESSION ANALYSIS

Need for New Data

As noted above, there is a need for new and independent data for use as inputs into the proxy cost models. The Federal Government's RUS provides loans to independent companies that are used to finance the reconstruction of existing exchanges, as well as the extension into new territory. A loan recipient must abide by the engineering standards established by the RUS and must issue a request for proposals, if the installation is done by a contractor. The contract is awarded to the firm that submits the lowest bid and abides by the Federal engineering standards.

Working in cooperation with Joel Shifman of the Maine Public Utility Commission, the authors identified RUS companies that operate under various soil and weather conditions, as well as population densities. RUS provided recent contracts for the firms on the list and, where data was unavailable for a particular company, it provided a substitute contract.

The raw contract data was initially entered into MS Excel. In this format, certain fields, such as the "Full RUS Code" field, were parsed into smaller subfields, such as the "RUS Code prefix" subfield, to allow for ease of analysis. This Excel worksheet was then imported into MS Access, where it was processed for subsequent regression analysis by the STATA statistical program.[1]

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[1] In this context "processed" refers to the set of procedures which were used to modify the raw RUS data to make it suitable for analysis. These procedures are discussed in the section, below, entitled "Data Collection and Processing," and in the appendices to this chapter.

The organization of this chapter is as follows: The first section is a brief discussion of the need for outside plant data derived from *public domain* sources; the next section describes how the data was processed and addresses miscellaneous issues regarding the use and interpretation of the data (Appendix 2B contains a flow chart that outlines the various steps involved); the final section provides regression estimates of the cost of installing poles, cables, and drops.

Outside Plant Cost Data Contained in the Hatfield Model and the Benchmark Cost Proxy Model

The two proxy models use distinct methods to obtain estimates of the cost of installing cables. This section of the paper reviews the two methods and discusses how competitively bid contract data was used to estimate the cost of installing cables, manholes, conduits, serving area interfaces, drop wires, and other components of the loop.

Method Used by BCPM Sponsors to Obtain Cable Cost Estimates

The BCPM model has used three steps to obtain its estimates of the cost of installing cables. In the first step, the model sponsors identified the cost of different activities. This data was derived from proprietary contracts between the local exchange carriers (LECs) and construction companies. The reasonableness of some of these costs was addressed in *Improving Proxy Cost Models for Use In Funding Universal Service* (NRRI 96-34).[2]

The next step indicates the model sponsors' estimate of the likelihood that these procedures will be used. In this step, the percentage estimates were established by asking outside plant engineers what they believed to be the likely mix of different activities. Table 2-1 reports the BCPM version 1.1 estimates for construction in density

[2] See David Gabel, *Improving Proxy Cost Models for Use in Funding Universal Service* (Columbus, OH: NRRI), 1996.

group zero to ten. The first column of data shows the cost for different methods of installing cables.

In the final step, the unit cost is multiplied by the likelihood of the activity. The sum of these products is the weighted cost of installing a cable for a given density band. The product and the sum is shown in the last column of the table.

In a review of the BCPM's predecessor, the Benchmark Cost Model Version 2, it was noted that the BCM2 uses a weighted cost for the different activities:

> Although I have found that the cost of the individual activities appears to be reasonable, the composite numbers appear to be high. Thus, the weighting factors are probably incorrect. The weighting factors appear in the column headed, "% of Activity," and are difficult to validate. However, since the weighted cost estimates do not comport with the prospective values reported by New England Telephone (NET), I conclude that they are incorrect.[3]

The sponsors of the BCPM obtained their estimated mix of activities by discussing the matter with a team of experts.[4] In order to validate the claimed mix of activities, the Commission or other party would need to consult with engineers that are familiar with the installation practices of the utility.

Obtaining this type of expert opinion would be difficult. An interested party or regulatory commission will find it difficult to find its own panel of outside plant engineers that could indicate the mix of activities for the different companies it regulates. For each of the regulated companies, the panel would need to know how the mix of activities varies across density zones and by soil type.

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[3] Ibid., 46.

[4] Contractors are paid a higher price per foot when trenching takes place in difficult situations. Identification of a difficult installation is often done either by a field inspection or by the contractor claiming that because of rocky conditions, a rock saw or blasting had to be used rather than a backhoe or plowing. The extent to which these field conditions correlate with the mix of activities identified by the models are estimated in this chapter.

Table 2-1

Cable Installation Costs (Density Group 0-10)

Underground Normal	Install	Feeder			Distribution		
	Cost per Unit	% of Activity	% Assigned Telephone	Weighted Amount	% of Activity	% Assigned Telephone	Weighted Amount
Trench & Backfill	$ 2.27	75.00%	100.00%	$ 1.70	87.00%	100.00%	$ 1.97
Rocky Trench	$ 4.22	0.00%	100.00%	$ 0.00	0.00%	100.00%	$ 0.00
Backhoe Trench	$ 2.70	17.00%	100.00%	$ 0.46	5.00%	100.00%	$ 0.14
Hand Dig Trench	$ 4.99	2.00%	100.00%	$ 0.10	2.00%	100.00%	$ 0.10
Boring	$11.80	2.00%	100.00%	$ 0.24	2.00%	100.00%	$ 0.24
Cut & Restore Asphalt	$ 8.72	1.00%	100.00%	$ 0.09	1.00%	100.00%	$ 0.09
Cut & Restore Concrete	$ 9.63	1.00%	100.00%	$ 0.10	1.00%	100.00%	$ 0.10
Cut & Restore Sod	$ 3.75	2.00%	100.00%	$ 0.08	2.00%	100.00%	$ 0.08
Total Underground Cost per Foot		100.00%		$ 2.76	100.00%		$ 2.70

Buried Normal	Install	Feeder			Distribution		
	Cost	% of Activity	% Assigned Telephone	Weighted Amount	% of Activity	% Assigned Telephone	Weighted Amount
Plow	$ 1.14	96.00%	100.00%	$ 1.09	86.00%	100.00%	$ 0.98
Rocky Plow	$ 1.37	0.00%	100.00%	$ 0.00	0.00%	100.00%	$ 0.00
Trench & Backfill	$ 2.27	0.00%	100.00%	$ 0.00	10.00%	100.00%	$ 0.23
Rocky Trench	$ 4.22	0.00%	100.00%	$ 0.00	0.00%	100.00%	$ 0.00
Backhoe Trench	$ 2.70	0.00%	100.00%	$ 0.00	0.00%	100.00%	$ 0.00
Hand Dig Trench	$ 4.99	0.00%	100.00%	$ 0.00	0.00%	100.00%	$ 0.00
Bore Cable	$11.80	0.00%	100.00%	$ 0.00	0.00%	100.00%	$ 0.00
Push Pipe & Pull Cable	$ 6.80	0.00%	100.00%	$ 0.00	0.00%	100.00%	$ 0.00
Cut & Restore Asphalt	$ 8.72	1.00%	100.00%	$ 0.09	1.00%	100.00%	$ 0.09
Cut & Restore Concrete	$ 9.63	1.00%	100.00%	$ 0.10	1.00%	100.00%	$ 0.10
Cut & Restore Sod	$ 3.75	2.00%	100.00%	$ 0.08	2.00%	100.00%	$ 0.08
Total Buried Cost per Foot		100.00%		$ 1.35	100.00%		$ 1.47

Table 2-1 (Continued)

Cable Installation Costs (Density Group 0-10)

Aerial Cable	Install Cost	Feeder & Distribution		
		Installation Cost per Unit	% of Sharing	Weighted Amount
Poles	$ 68.17	$ 358.58	50.00%	$ 363.38
Anchors and Guys	$ 68.00	$ 255.00	100.00%	$ 53.83
Total Aerial Cost per Pole				$ 417.21

Source: Authors' construct.

Method Used by the Hatfield Sponsors to Obtain Cable Cost Estimates

The sponsors of the HM consulted their own group of outside plant engineers. Version 2.2.2 of the HM contained cable installation costs that were largely based on the opinion of their consultants. These consultants claimed that the mix of activities identified by the BCPM resulted in an overstatement of installing cables.

Apparently, in reaction to the criticism that the opinion of the Hatfield engineers was difficult to validate, the sponsors of the HM solicited cable cost bids from different vendors. They asked the vendors what they would charge for placing cables in different soil types. The vendors' responses exhibited significant variation, the cause of which was not clear. Some variation may be attributable to the lack of a clear definition of what constitutes a suburban or rural area, or normal versus sandy and rocky soil.[5]

[5] See "In the Matter of the Interconnection Contract Between AT&T Communications of the Mountain States, Inc. and GTE Southwest, Inc. Pursuant to 47 U.S.C. Section 252," New Mexico State Corporation Commission, Docket No. 97-35-TC, para. 47.

Need for a New Method for Obtaining Estimates

The Census Block Group (CBG) surface codes are quite numerous—the BCPM 3.0 and Hatfield 5.0 list over 250 separate surface texture classifications.[6] The model sponsors have attempted to identify how these numerous soil, rock and water conditions affect the cost of installing cables, poles, and conduit.[7] Commissions might reasonably be concerned about the large number of value judgments involved in the process. The model developers had to reduce the geological conditions to a manageable number of cost conditions. This process involved the engineers making many judgments, which are difficult, if not impossible, to audit.[8]

It is essential that the development of cost data be transparent. The current methods for identifying the cost of installing outside plant facilities involves too many value judgments. Therefore, the authors have collected and processed data that can be used to obtain estimates of the cost of installing equipment.

Data Collection and Processing

The RUS data base contains 12,679 records representing the units costs, broken out by labor and material cost, of installing different types of outside plant facilities. This cost data was drawn from a set of 171 RUS contracts from 57 companies in 27 states. RUS utilizes a very detailed coding system for identifying the different types of outside plant. The codes pertaining to the types of plant contained in

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[6] BCPM, file BCPM.XLS, folder fixed tables.

[7] The BCPM also adjusts the loop costs if the minimum or maximum slope factors are exceeded. (Benchmark Cost Proxy Model: Model Methodology, February 12, 1997, p.19.) In order to evaluate the reasonableness of these adjustments, it would be necessary to evaluate the physical placement of loops in situations where the minimum or maximum slope factors are exceeded.

[8] The disagreement between the Hatfield and BCPM engineers regarding the cost of installing cables illustrates that, even if a Commission obtains a second opinion regarding the likely mix of activities, it will be difficult to determine which opinion is more reasonable.

the database are reproduced in Appendix 2-A. A more detailed description of the coding can be obtained by reading the following RUS documents:

1) Specifications and Drawings for Construction of Direct Buried Plant; REA Bulletin 345-150;

2) Specifications and Drawings for Underground Cable Installation; REA Bulletin 345-152;

3) Specifications and Drawings for Construction of Pole Lines, Aerial Cables, and Wires; REA Bulletin 345-153;

4) Specifications and Drawings for Conduit and Manhole Construction; REA Bulletin 345-151;

5) Specifications and Drawings for Service Entrance and Station Protector Installation; REA Bulletin 345-154.[9]

Once the cost data was imported into the MS Access database it was matched with geological and line data from Hatfield 4.0, Hatfield 5.0, and BCPM 3.0 by a process described later in this document.

Use of Geological and Line Data from Hatfield and BCPM

Hatfield 4.0 and Hatfield 5.0 Geological and Line Data by CBG

Using MS Access, the following information, by CBG, for each RUS company was extracted from the Hatfield 4.0 database and placed into the MS Access *RUS Outside Plant* database as the table *Hat 4-1 CBG Data*:

[9] It should be pointed out that some of the RUS symbols in the data base do not conform to standard RUS specifications. This being the case, descriptions of them are not found in the documents cited here. For these cases, RUS personnel consulted the detailed contract records. From those records, they determined the descriptions the companies had given to the symbols that were not found in the above cited documents.

Field Number	Variable
1.	CLLI code
2.	CBG designation
3.	Area (sq. Mile)
4.	Fraction Empty
5.	Total Lines
6.	Total Bus Lines
7.	Total Res Lines
8.	Special Lines
9.	Public Lines
10.	Single Business Lines
11.	Water Depth
12.	Rock Depth
13.	Rock Hardness
14.	Surface Texture Affect
15.	Surface Texture
16.	Surface Texture Description

This table was then used to generate the *Hat 4-1 Area and Line Data* table. This table contains totaled line and area data by RUS company. The fields contained in this table are:

Field Number	Variable
1.	State
2.	Company
3.	Total Number of CBGs
4.	Total Area (Sq Miles)
5.	Total Populated Area (Sq Miles)
6.	Total Number of Lines
7.	Total Number of Business Lines
8.	Total Number of Residential Lines
9.	Total Number of Special Lines
10.	Total Number of Public Lines
11.	Total Number of Single Business Lines

The fifth designation, Populated Area (sq. Mile), was calculated by using the formula:

Area (sq. Mile) * (1- Fraction Empty) = Populated Area (sq. Mile).

The *Hat 4-1 Area and Line Data* and the *Hat 4-1 CBG Data* tables were then used to calculate weighted geological indicator values via a series of MS Access queries. The first query, the *Hat 4-1 placement difficulty* query, contains the following fields:[10]

Field Number	Variable
1.	State
2.	Company
3.	Total Lines
4.	Populated Area
5.	High Water Indicator
6.	Bedrock Copper
7.	Bedrock Fiber
8.	Bedrock 48 In
9.	Soil Surface Texture Indicator
10.	Bedrock Copper Weighted by POP
11.	Bedrock Fiber Weighted by POP
12.	Bedrock 48 In Weighted by POP
13.	Bedrock Copper Weighted by Lines
14.	Bedrock Fiber Weighted by Lines
15.	Bedrock 48 In Weighted by Lines
16.	SST by POP
17.	SST by Lines
18.	High Water Indicator by POP
19.	High Water Indicator by Lines

[10] Formulas concerning the Weighting of Geological factors may be found in Appendix 2-D.

The *High Water Indicator* is calculated using the formula:

Iif([Hat 4-1 CBG Data]![WATER DEPTH]<=5,2,1)

where the value 2 indicates the presence of a high water table and the value of 1 indicates the absence of a high water table. The value of 5 indicates a water table depth of 5 feet. This is the default value used in Hatfield 5.0, where it was used only in the cost calculation related to manhole placement.[11] Water table depth was not a factor in any of the cost algorithms in Hatfield 4.0. It was included as a variable in the RUS database in order to test the possibility that, in rural situations and for smaller independent LECs, it may act as one of the cost factors for outside plant placement.

The value for the variable *Bedrock Copper* is given by the formula:

Iif([Hat 4-1 CBG Data]![ROCK DEPTH]<=24 And [Hat 4-1 CBG Data]![ROCK HARD]="HARD",3.5,IIf([Hat 4-1 CBG Data]![ROCK DEPTH]<=24 And [Hat 4-1 CBG Data]![ROCK HARD]="Soft",2,1)).

This formula states that, IF the depth to bedrock is less than or equal to 24 inches, and the rock hardness designation is "HARD," then the value for *Bedrock Copper* is 3; IF the depth to bedrock is less than or equal to 24 inches and the rock hardness designation is "SOFT," then the value for *Bedrock Copper* is 2; IF neither of these conditions holds, then the value for *Bedrock Copper* is 1.[12] The variable *Bedrock Fiber* has the same

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[11] Hatfield Model Release 5.0; Inputs Portfolio, January 5, 1998, p. 70 "Ground water is not normally a problem with plowing and trenching; it softens the ground and usually does not hinder excavation work. In the rare cases of very wet conditions, contractors simply make sure they always use track vehicles, which is the normal type of equipment used in any case.

Manhole excavation and placement, however, can involve somewhat increased costs. In very high water table areas, a concrete manhole will actually tend to float while contractors attempt placement, requiring additional pumping and dewatering during construction work. After the manhole is in place, no additional cost is involved because of water."

[12] Hatfield Model Release 4.0; Model Description, August 1, 1997, p.30, and/or p.38-39 of Hatfield Model Release 5.0; Model Description, January 5, 1998.

formula but has the ROCK DEPTH set to <=36 inches.[13] The variable *Bedrock 48 In* has the ROCK DEPTH set to <=48 inches. This variable was created because it was noted in entering the RUS data that some of the contracts called for cable placement at this depth. This variable, therefore, was created as an optional explanatory variable. It was not used in the regression analysis.

Note that the Hatfield documentation gives the *Hard Rock Placement Multiplier* as being 3.5 and goes on to state that "The model causes the rock placement multiplier to vary with rock depth...." This was not done in the RUS database. For the purposes of the regression, all that was required was that variables be created to indicate the presence, or absence, of bedrock, which might interfere with cable placement and increase the cost of that placement, and whether that bedrock was hard or soft. The variables *Bedrock Copper*, *Bedrock Fiber*, and *Bedrock 48 In* can have the following values:

1=Bedrock is too deep to affect cable placement;

2=Bedrock is of a depth to affect cable placement, and it is soft, and;

3=Bedrock is of a depth to affect cable placement and it is hard.

These values are not cost multipliers, such as are used in the HM.

The variable *Soil Surface Texture Indicator* can have values ranging from 1 (normal) to 4 (very slatey).[14] These values are in increasing order of difficulty and cost for cable placement; 1 being the easiest, or normal, and 4 being the most difficult and most costly. These values are used as cost multipliers in Hatfield 5.0.

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[13] The value of 36 inches is the default value for fiber placement found in the BCPM model, version 1.1 and later.

[14] The values for the *Soil Surface Texture Indicator* are from the "Surface Texture Multiplier" table found in Hatfield Model Release 4.0; Inputs Portfolio, August 1, 1997, p.123. The same values are used in Hatfield 5.0, as can be verified by looking at the table on p.134 of Hatfield Model Release 5.0; Inputs Portfolio, January 5, 1998.

The output generated by the MS query *Hat 4-1 Placement Difficulty* is used by the *Hat 4-1 Weighted Placement Difficulty*[15] query to calculate weighted geological indicator values for each company in the RUS database. This query contains the following fields:

Field Number	Variable
1.	State
2.	Company
3.	Number of CBGs
4.	SST by POP
5.	SST by Line
6.	High Water Indicator by POP
7.	High Water Indicator by Lines
8.	Bedrock Copper Weighted by POP
9.	Bedrock Fiber Weighted by POP
10.	Bedrock 48 In Weighted by POP
11.	Bedrock Copper Weighted by Lines
12.	Bedrock Fiber Weighted by Lines
13.	Bedrock 48 In Weighted by Lines

Fields 4 through 6 contain values for the various geological indicators weighted by populated area or by the number of working lines. These weighted averages were calculated in the following manner, using the variable *SST by POP* as an example.

The formula for *SST by Pop,* call this step 1, in the *Hat 4-1 Placement Difficulty* query is:

[Soil Surface Texture Indicator]*[Populated Area].

[15] The variable names and the associated formulas are to be found in Appendix 2-D.

The formula for *SST by Pop,* call this step 2, in the *Hat 4-1 Weighted Placement Difficulty* is:

> SST by POP: Sum([Hat 4-1 placement difficulty]![SST by POP])/Sum([Hat 4-1 placement difficulty]![Populated Area]).

So, in step 1, a value is calculated by multiplying the *Soil Surface Texture Indicator* of a particular CBG, which can range from 1 to 4, by the *Populated Area* of that CBG, in square miles. In step 2, the value derived in step 1 is summed over all the CBGs served by a company, and that sum is divided by the total populated area served by the company. Numerically this example can be illustrated by considering Table 2-2, below.

Table 2-2

Weighting Methodology

Step 1

Company	Census Block Group Number	Total Lines	Populated Area-sq Miles	Soil Surface Texture	SST by POP, Step 1
Any LEC	210319905001	179	27.27543	1	27.27543
Any LEC	210319905002	441	53.88686	1.5	80.83029
			Sum of SST by POP		108.10572

Step 2

Company	Number of CBGs	Total Total Lines	Populated Area-sq Miles	Sum of SST by POP, Step 1	Weighted SST ÷ POP, Step 2
Any LEC	2	620	81.16229	108.10572	1.331969

Source: Authors' construct.

The value of 1.331969 in Table 2-2 was calculated using the formula:

[(1*27.27543) + (1.5*53.88686)]/(27.27543+53.88686)=108.10572/81.16229=1.331969.

The other weighted geological indicator values were calculated in a similar manner.

The weighted geological indicator values generated by this process are to be interpreted in the following manner:

> For the *Soil Surface Texture Indicator*, values greater than or equal to 1 but less than or equal to 2, indicate a surface texture quality that ranges from normal at a value of 1 and approaches the soft rock designation as the value gets closer to 2. Values greater than or equal to 2, but less than or equal to 3, indicate a surface texture quality that ranges from soft rock at a value of 2 and approaches the hard rock designation as the value gets closer to 3. Values greater than 3 indicate that the surface texture is becoming extremely difficult for the placing of outside plant.
>
> For the various *Bedrock* indicators, values greater than or equal to 1 but less than or equal to 2, indicate a surface texture quality that ranges from normal at a value of 1 and approaches the soft rock designation as the value gets closer to 2. Values greater than or equal to 2 but less than or equal to 3 indicate a surface texture quality that ranges from soft rock at a value of 2 and approaches the hard rock designation as the value gets closer to 3.
>
> For the *High Water Indicators*, values equal to 1 indicate the absence of a high water table; values equal to 2 indicate the presence of a high water table; values between 1 and 2 indicate that a high water table is present to some degree in a company's serving area. The closer the value is to 2, the more likely it is that a high water table is present throughout the serving area of a company.

For the Hatfield Model 5.0 the same procedure as that outlined above for Hatfield 4.0 was used, with a couple of exceptions. One difference is that Hatfield 5.0 has geographical and line data broken down by clusters within a CBG, whereas Hatfield 4.0 had geographical data by CBG.[16] Also, Hatfield 5.0 does not have a field for *Populated Area,* so the field *Total Area* was used for weighting in place of the *Populated Area* field used in Hatfield 4.0. The *Total Area* field represents the total area, in square miles, for a cluster.

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[16] For a full account of the clustering methodology used in the Hatfield 5.0 model the reader is referred to the discussion starting on p. 24, section 5.4.3 of the Hatfield Model Release 5.0: Model Description, January 5, 1998.

BCPM 3.0 Geological and Line Data by Feeder Distribution Interface (FDI) Code

The BCPM 3.0 also contains geological data which are used in various costing algorithms.[17] BCPM 3.0 starts by using customer and geological data at the census block (CB) level. BCPM 3.0 then uses what it calls a "dynamic grid process.." coupled with a carrier serving area (CSA) and distribution area (DA) engineering design approach to assign customers to wire centers.[18] The geological and line data in the BCPM 3.0 is then reported at the grid level. Weighting calculations for BCPM 3.0 geological data were performed in the same manner as outlined for the HMs. The raw geological inputs into the weighting calculations, however, are different in BCPM 3.0. These differences are outlined below:

1) The Hatfield Model(s) uses a water table depth of 5 feet and less as the value in the *High Water Indicator.* BCPM 3.0 uses a water table depth of 3 feet as its critical value.[19]

2) Hatfield 5.0 soil surface texture indicator values range from 1, for normal, to 4, for very slatey.[20] In BCPM 3.0 these values are 0, for normal soil, and 1, to indicate that the soil surface interferes with plowing.

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[17] See Appendix C for a more in-depth discussion as to how the various models use geological data in their costing algorithms.

[18] For a full account of the clustering and customer location methodology used by BCPM 3.0, the reader is referred to the discussion starting on p. 21, section 5.2 of Benchmark Cost Proxy Model Release 3.0; Model Methodology, December 11, 1997 edition.

[19] From the Miscellaneous Inputs tab of the BCPM 3.0 Inputs workbook.

[20] The values for the *Soil Surface Texture Indicator* are from the "Surface Texture Multiplier" table found in Hatfield Model Release 4.0; Inputs Portfolio, August 1, 1997, p.123. The same values are used in Hatfield 5.0 as can be verified by looking at the table on p.134 of Hatfield Model Release 5.0; Inputs Portfolio, January 5, 1998.

3) Hatfield 5.0 default value for buried or underground cable placement is 24 inches.[21] In BCPM 3.0 the default values are 24 inches for copper and 36 inches for fiber.[22]

Taking the above into account, the weighted geological indicator values generated from the BCPM 3.0 geological data are to be interpreted in the following manner:

For the *Soil Surface Texture Indicator*, values equal to 0 indicate a soil surface texture that does not interfere with plowing. Values equal to 1 indicate a soil surface texture that does interfere with plowing. Values greater than 0 but less than 1 indicate a soil surface texture that increasingly interferes with plowing the closer the value approaches 1.

For the various *Bedrock* indicators, values greater than or equal to 1 but less than or equal to 2 indicate a surface texture quality that ranges from normal, at a value of 1, and approaches the soft rock designation as the value gets closer to 2; values greater than or equal to 2 but less than or equal to 3 indicate a surface texture quality that ranges from soft rock, at a value of 2, and approaches the hard rock designation as the value gets closer to 3.

For the *High Water Indicators*, values equal to 1 indicate the absence of a high water table; values equal to 2 indicate the presence of a high water table; values between 1 and 2 indicate that a high water table is present to some degree in a company's serving area. The closer the value is to 2, the more likely it is that a high water table is present throughout the serving area of a company.

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[21] Hatfield Model Release 5.0; Inputs Portfolio, January 5, 1998. p. 39

[22] From the Miscellaneous Inputs tab of the BCPM 3.0 Inuts workbook.

Equipment Typing Methodology

In consultation with personnel from the RUS, an assignment table was established to assign RUS engineering unit code designations to the appropriate **equipment types** (See Appendix 2-A, below). An MS Access query was used to perform this task within the data base. Using the query, every **RUS unit code** which had been entered into the data base was assigned an **equipment type**.

Equipment type designations containing the term "***loading***" had their unit labor and material costs distributed to the appropriate **equipment type** by a weighting methodology described later in this section. For example, **equipment types** designated as "*Cable Loading, Buried*" had their unit costs reassigned to Buried Fiber and/or Buried Copper cable. The exception to this methodology occurs for *"pole loadings"* and "*pole costs*." For these units a different methodology, discussed below, was used.

For those instances where the **RUS unit code** designation was ambiguous, the BM76 and BM73 units can be either buried, underground, or aerial. For example, the query would return "*Cable Loading, Buried or Underground*" as an **equipment type**. In this case, in order to narrow the scope of reference so that unit cost assignments would be as accurate as possible, the query was augmented by referring to the contract. For those relatively rare instances where the scope of reference could not be narrowed sufficiently, the unit costs for the designated equipment were spread, by appropriate weighting, among the costs of the cable units appearing in the contract.

Cable Cost Weighting Methodology

Once the appropriate **equipment types** had been assigned, the next step was to assign the units costs for those **equipment types** designated as "*loading*." For cable costs this was done using series of MS Access queries to arrive at the final query,

Weighted Cable Costs With Geological and Line Data, which contains the weighted cable cost data with associated geological and line data. The weighted cable costs contained in this query were determined in the following manner:

Step 1) The cross-tab query *RUS Cross-tab by Cable Type* was created for all cable types in the database. *Equipment type* was used as the column designation, and *State*, *Company Id*, *Company*, and *Contract Number* were used as the row designations. When run, this query gives the sum of the extended cost for each specific cable type by contract. Each cable type has its own column, and if any contract has costs associated with a cable type, that cost is reported in the cell whose column designation is that cable type and whose row designation is the contract in which the cost appears.

Step 2) The cross-tab query *RUS Cross-tab by Cable Loading Type* was created for all cable loading types in the database. *Equipment type* was used as the column designation, and *State*, *Company Id*, *Company*, and *Contract Number* were used as the row designations. When run, this query gives the sum of the extended cost for each specific cable loading type by contract. Each cable loading type has its own column, and if any contract has costs associated with a particular cable loading type, that cost is reported in the cell whose column designation is that cable loading type and whose row designation is the contract in which the cost appears.

Step 3) The query *cable loadings to cable ratios* was then created using the cross-tab queries from steps one and two. This query developed cable loadings to cable ratios, by contract, for the various cable equipment types appearing in the RUS database.[23] For example, for fiber and copper Aerial Cable the ratio formula is:

Aerial Ratio: Nz([RUS Cross-tab by cable loading type]![Cable Loading, Aerial])/(Nz([RUS Cross-tab by cable Type]![Cable, Aerial Copper-filled])+Nz([RUS Cross-tab by cable Type]![Cable, Aerial Copper-nonfilled])+Nz([RUS Cross-tab by cable Type]![Cable, Aerial Fiber])).

[23] The formulas used in this query appear in Appendix 2-E.

This formula divides the sum of the extended cost for all equipment units in a contract which have the *Cable Loading, Aerial* designation by the sum of the extended costs for all *Cable, Aerial Copper-filled* equipment units + the sum of the extended costs for all *Cable, Aerial Copper-nonfilled* equipment units + the sum of the extended costs for all *Cable, Aerial Fiber* equipment units in a contract.

Step 4) The *cable loadings to cable ratios* query is then used in the *Weighted Cable Costs With Geological and Line Data* query to make the final calculation of weighted cable costs. For example the formula for the weighted cost of the equipment type *cable, aerial copper-filled* is:

Weighted Cost of Aerial Copper Filled Loading: IIf([RUS Engineering Codes]![Equipment Type]="cable, aerial copper-filled" And [RUS Outside Plant Data]![Number of Units]>0,[RUS Outside Plant Data]![Total Unit Cost]+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Total Cable ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Aerial Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Aerial or Buried Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Copper Ratio]),0).

This formula says that, IF a record in the RUS Access database has the equipment type designation cable, aerial copper-filled, and IF the number of units of that record having that designation is greater that zero, THEN weighted unit cost of *cable, aerial copper-filled* is equal to the total unit cost of *cable, aerial copper-filled* + the total unit cost of *cable, aerial copper-filled* * Total Cable Ratio + the unit cost of *cable, aerial copper-filled* * the Aerial Ratio + the unit cost of *cable, aerial copper-filled* * Aerial or Buried Ratio + the unit cost of *cable, aerial copper-filled* * the Copper Ratio. This process is outlined in Table 2-3 below.

Table 2-3

Weighting Methodology Example

RUS unit code	Equipment Type	Number of Wire Pairs	Cable Gauge	No. of Units	Total Unit Cost	Extended Unit Cost
BM6M	Cable Loading, Aerial or Buried			14.00	8.30	116.20
CFL	Cable Loading, Aerial			9.00	5.25	47.25
HA	Cable Loading, Aerial			29.00	5.25	152.25
CW	Cable, Aerial Copper-filled	8	22	5.00	139.95	699.75
CW	Cable, Aerial Copper-filled	12	22	3.00	160.77	482.31
BFC	Cable, Buried Copper	6	24	1.00	180.87	180.87

Source: Authors' construct.

In Table 2-3 there are three different types of cable and three **RUS unit code** designations whose **equipment type** designations are *Cable Loading, Aerial* and *Cable Loading, Aerial or Buried.* What needs to be done is to spread the unit costs of the three **equipment types** among the various **cable** types.

Using the formula outlined in step 3 above, two ratios are calculated.

1) The Aerial ratio is calculated by dividing the sum of the extended costs for *Cable Loading, Aerial* by the sum of the extended costs for *Cable, Aerial Copper-filled.*

   Numerically this gives the following result:

   (47.25+152.25) / (699.75+482.31) = .168773

2) Next the Aerial or Buried ratio is calculated by dividing the sum of the extended costs for *Cable Loading, Aerial or Buried* by the sum of the extended costs for *Cable, Buried Copper* + the sum of the extended cost for *Cable, Aerial Copper-filled.*

   Numerically this gives the following result:

   116.20/(180.87+160.77+139.95) = .085257

This ratio is used to compute the weighted unit costs for *Cable, Aerial Copper-filled* and for *Cable, Buried Copper* in the manner outlined in step 4, above. Using the 8-pair, 22-gauge *Cable, Aerial Copper-filled* as an example, the weighted unit cost would be calculated in the following manner:

> total unit cost for the aerial cable + total unit cost for the aerial cable * the Aerial Ratio + total unit cost for the aerial cable * the Aerial or Buried Ratio = Total Weighted Unit Cost.
>
> Numerically this gives the following result:
>
> 139.95+139.95*.168773+139.95*.085257 = 175.50

The procedure outlined above was used in spreading the total unit costs of all **equipment type** designations containing the term "loading," with the exception of pole loading which was treated in a manner to be outlined below. After the data was processed in this fashion, regression analysis was used to estimate the placement and costs that are line-related.[24]

It should be noted that not all equipment types designated as cable loaders were factored into weighted cable costs. For example, if a particular contract had some *Cable Loading, Buried or Underground* **equipment types** but contained only aerial copper and/or aerial fiber cable, then these loadings were not assigned to the total unit costs of any of the cable in that contract. This is because it was not possible to ascertain with any degree of certainty whether these loading costs were present in the contract as replacements for equipment units on existing buried or underground cable, or whether the loadings had been improperly identified as being buried or underground loadings. This situation occurred in 36 of the 154 contracts used in the analysis of cable placement costs. For the most part, as Table 2-4 indicates, the costs involved were not that significant.

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[24] The Cable Cost related regressions were performed only on those observations from the *Weighted Cable Costs with Geological and Line data* query that contained costs for both material and labor and had total number of units greater than zero.

Table 2-4

Comparison of Access Generated Weighted Cable Costs with Total Extended Cable and Cable Loading Costs

Contract Number	Weighted Extended Cable Cost from Access	Total Extended Cable and Cable Loading Costs	Total Extended Costs - Access Weighted Extended Costs	Difference as a Percentage of Total Extended Cost
CONT A-37X	123,654.45	123,976.60	322.15	0.26%
CONT COL-28	1,021,906.38	1,023,106.38	1,200.00	0.12%
CONT P-64	561,110.87	572,792.57	11,681.70	2.04%
CONT P-82	156,729.18	158,184.18	1,455.00	0.92%
CONT ek1	581,776.24	583,291.24	1,515.00	0.26%
CONT ILL-28	134,789.11	134,809.11	20.00	0.01%
CONT L-29	202,346.65	207,566.65	5,220.00	2.51%
CONT F-57	763,770.38	802,334.38	38,564.00	4.81%
CONT F-60	501,155.81	517,413.81	16,258.00	3.14%
CONT F-61	715,021.43	743,467.13	28,445.70	3.83%
CONT ek5	761,677.37	773,388.59	11,711.22	1.51%
CONT ek6	138,444.49	142,944.49	4,500.00	3.15%
CONT ek7	1,232,030.04	1,236,545.04	4,515.00	0.37%
CONT P-68X	1,592,685.95	1,598,494.65	5,808.69	0.36%
CONT 517NM	1,679,646.04	1,687,246.04	7,600.00	0.45%
CONT 512NM	3,878,035.69	3,893,010.69	14,975.00	0.38%
CONT A-1*	132,145.69	136,434.69	4,289.00	3.14%
CONT ek11	1,079,595.81	1,114,192.84	34,597.03	3.11%
CONT 375	66,474.11	66,741.11	267.00	0.40%
CONT 377	53,325.32	53,715.36	390.04	0.73%
CONT 425	69,001.62	69,313.48	311.86	0.45%
CONT 427	80,676.83	81,114.68	437.84	0.54%
CONT U-136	729,313.98	736,533.48	7,219.50	0.98%
CONT V-156	215,470.10	216,526.10	1,056.00	0.49%
CONT N-61f	281,985.28	285,515.28	3,530.00	1.24%
CONT ek8	249,469.80	250,009.80	540.00	0.22%
CONT T-106	317,966.83	332,932.75	14,965.92	4.50%
CONT T-109	56,994.57	58,698.79	1,704.22	2.90%
CONT T-110	244,580.65	257,045.60	12,464.95	4.85%
CONT T-112	399,818.24	446,435.41	46,617.17	10.44%
CONT T-113	270,022.73	286,861.15	16,838.42	5.87%
CONT T-94	160,370.14	164,542.64	4,172.50	2.54%
CONT P-70	102,033.36	108,693.59	6,660.23	6.13%
CONT P-71	289,852.07	310,077.07	20,225.00	6.52%
CONT 654TX	746,903.55	755,153.55	8,250.00	1.09%
CONT 569TX	2,106,353.65	2,121,553.65	15,200.00	0.72%

Source: Authors' construct.

Understanding the Indicator Columns

Colocation Designation

In the RUS documentation, a suffix of D attached as part of the designation of a cable unit indicates that the particular cable unit in question as been placed with another cable unit.[25] For example, the designation BFC(50-24 & 25-19)D indicates the two buried cables, one 50 pair, 24 gauge and one 25 pair, 19 gauge, have been placed together. Since many contracts had several cable items placed together, the following numbering scheme was developed. For the first instance of colocation, the units being colocated were given the value of 1, with each specific item assigned a letter of the alphabet. Table 2-5 provides an example:

Table 2-5

RUS Colocation Indicator

Full RUS Code	Colocation Indicator
BFC(50-24 &	1a
25-19)D	1b

Source: Authors construct.

The "a" and "b" designations are used only to keep track of which elements have been placed together and are not to be interpreted as indicating anything other than that.

[25] For example see Specifications and Drawings for Construction of Pole Lines, Aerial Cables, and Wires, REA Bulletin 345-153, p.2

Trenching Indicator

In the RUS documentation, a suffix of T attached as part of the designation of a cable unit indicates that the particular cable unit in question as been placed in a trench.[26]

Difficult Placement Indicator

In the RUS documentation, a suffix of P attached as part of the designation of a cable unit indicates that, in the judgment of the engineer, the particular cable unit in question will be much more difficult to install than normal.[27]

Rock Excavating and Ripping Unit Indicator

A Y in this column indicates that a particular contract contains this particular unit(s).

Concrete and Asphalt Assembly Unit indicator

A Y in this column indicates that a particular contract contains this particular unit(s).

Underground Pipe and Non-pipe Crossing Assembly Unit Indicator

A Y in this column indicates that a particular contract contains this particular unit(s).

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[26] Specifications and Drawings for Construction of Direct Buried Plant, (REA Bulletin 345-150): 5.

[27] Ibid.

Miscellaneous Issues

Additions to Existing Plant Versus New Construction

The RUS contracts do not provide a cost breakout between additions to existing plant and new construction. Gary Allan of RUS is of the opinion that the majority of the contracts are dealing with rebuilding plant, which is essentially additions to existing plant, as the installation both replaces existing facilities and provides additional capacity. This point is made clear by Ed Cameron of RUS Bureau:

> In our part of the industry, you about have to do both of these at the same time. You wait to "rebuild" until you have exhausted the capacity of the majority of your plant. So, you are right, most of these jobs do involve rebuilding, but they are resizing for the reasonable future at the same time.[28]

Analysis of the data in the database indicates that this seems to be mostly the case with aerial plant. Where buried and underground are concerned, there are contracts that deal with new construction. This is probably reflective of the gradual switch from aerial to buried or underground that is taking place in much of the country.

The authors believe that there are no significant cost differences between new construction and existing plant in the RUS territories. This belief is based on feedback from Gary Allan of RUS and from a Fax dated February 5, 1997, from Claire E. Kamla of TDS. TDS provided the authors with some loan applications that the company had submitted to RUS. In response to the question, "Shouldn't the cost to place cable next to existing cable be more than the cost of placing new cable since more obstacles are encountered (avoiding the existing cable)? Why is there no difference in the unit costs?," TDS replied, "In theory, yes, the cost to place cable next to existing cable should be more. However, the information provided in the loan designs is an estimate

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[28] Ed Cameron, Rural Utilities Service Bureau (memo dated August 13, 1997).

used to specifically determine the amount of REA funds needed. The actual cost difference between the two scenarios is so minimal that it would not change the amount of REA funds needed. The REA funds actually utilized would be based on actual cost, and not the estimate provided in the loan design." Furthermore, Ed Cameron stated that:

> There is little or no difference between additions and new construction. We keep up with new miles, for density purposes, but we have never thought that categorizing the construction as new construction and plant additions made any difference. It is not a reliable predictor of cost.[29]

For an example of the lack of differentiation in cost between new plant and additions to existing plant, look at contract PA 559, B-14. Page 5 of this contract states that there are approximately 8 miles of buried plant in new construction corridors and approximately 4 miles of buried plant placed in the same construction corridors as existing buried plant. Yet, on page 31, where the unit prices for the buried fiber being placed in these respective corridors is mentioned, there is no separation of the costs for *new* construction versus the costs for *additions* to existing plant. The PA 559 contract was not a loan application. Rather, the prices reflect the cost levels established through the competitive bidding process.

Loading for Telephone Company Engineering

The RUS data does not include the cost of LEC engineering. It does include the cost of engineering undertaken by the contractor winning the bid on the job. RUS recommends that the contract prices be increased by 15 to 20 percent in order to account for the LEC engineering.

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[29] Ibid.

The RUS loading factor may not be appropriate for larger companies. The Benchmark Cost Model (version two) used a loading of 5 percent for engineering.[30] The sponsors of the HM have claimed that engineering constitutes about 15 percent of the cost of installing outside plant cables.[31] The 15 percent includes both the engineering undertaken by the construction firm and the LEC. For this data set, the cost of the construction company's engineering is already reflected in the contract price.

Splicing

For the contracts included in the data base, the ratio of splicing expenditures to fiber and copper cable investment are 4.7 and 9.4 percent, respectively.[32] For some of these contracts, the splicing expenditures are quite high, relative to the cable cost; for others, the value is zero.

Cable costs are provided in three different columns. First, cable costs are reported without any loadings. Then they are reported with all applicable loadings, including the splicing dollars reported in the contracts. For those contracts with no splicing expenditures, no dollars were included. But for other contracts, the loading for splicing seems to cover activity beyond the cable associated with the contract.

The third approach was to add on all cable loaders, with the exception of splicing. It was this third set of cable costs that were used in the regression analysis (Excel column: *Total Weighted Unit Cost of Cable Without Splicing)*. An analyst could apply a loading factor for splicing to the cable costs reported in this column. Note that in BCM2 the loading factor for splicing for fiber and copper of 4.5 percent and

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[30] BCM2 folder, "table inputs," cell B41.

[31] Direct Testimony of Dean Fassett, *In the Matter of the Pricing Proceeding for Interconnection, Unbundled Elements, Transport and Termination, and Resale*, Washington Utilities and Transportation Commission, UT-960369, February 21, 1997, Exhibit, p. 21.

[32] File: splicing.xls.

7 percent, respectively.[33] The loadings should be applied to the predicted value of the cost of the cables.

Sharing

Sharing of structural investment occurs when one more utiities share the cost of placing outside plant facilities. For example, electric and telephone companies may use the same pole to place their cables; or telephone, electric, and cable television companies may place their cables in a common trench. When sharing does occur, the cost of placing telephone plant is reduced.

The cost proxy models allow the user to declare the extent to which facilities are shared. For example, a user could declare that only 50 percent of the cost of installing poles is recovered from telephone operations.

This report presents data on the cost of installing outside plant facilities. The contracts do not state the degree to which the final contract prices reflect sharing. This section explains how these contract prices should be further adjusted to reflect sharing.

Buried Cables

The contracts show that, in the service territory of Rural Utilities Service companies, buried cable is the predominant mode of cable facility. The contracts also indicate that the vast majority of the buried cable is plowed rather than trenched.[34]

If the cost of placement is born exclusively by the telephone company, the cost of plowing in normal soil is less than the cost of trenching. When cables are placed

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[33] BCM2 folder, "table inputs," cells B42 and B44 respectively.

[34] When the cable is placed in a trench, the RUS contracts require a "T" designation. Column I, "Trenching Indicator," indicates that trenching is not widely used by the RUS contractors. To some extent, cables placed with trenching may not be properly identified either in the contracts or the data base.

through plowing, the cost is rarely shared with other utilities.[35] But to the extent sharing does occur, the buried cable costs reported in this data base largely reflect the costs incurred by LECs after taking sharing into account.

There is one area in which this data set does not reflect sharing. When a developer incurs the cost of opening up the ground, multiple utilities place their cables or pipes into the pit. Since the cost of opening the ground is born by the developer, rather than the utilities, the cost of this activity would not be included in the data set. In order to take this type of situation into account, assignment of less than 100 percent of the buried structural costs to telephone operations merits consideration. On the other hand, to the extent that this does occur, the cost savings would be reflected in the data.

Poles

The contracts indicate the use of many different sizes and classes of poles. The higher the pole height, the greater the likelihood that it is shared by multiple utilities.

The proxy models assume that a 40-foot, Class 4 pole is installed. The contracts do not indicate whether any of the pole costs have been shared with other utilities. It is the authors' understanding that the poles are owned exclusively by the LEC. Therefore the costs recorded in the data base do not reflect any sharing of pole structural investment.

Population Density

This data set is constructed from information on file with the RUS of the Department of Agriculture. RUS companies generally serve rural, low-density areas.

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[35] See, for example, *In the Matter of the Pricing Proceeding for Interconnection, Unbundled Elements, Transport and Termination, and Resale*, Washington Utilities and Transportation Commission, Docket No. UT-960369, Tr. Vol. 10 (July 8, 1997), pp. 323-326.

These companies also provide service in some suburban areas.[36] The RUS companies do not provide service in major cities. Therefore, the data provide only limited insights into the cost of serving urban territories.

An analyst could consider using the RUS data to estimate the cost of serving urban territories. For example, an analyst could use the regression estimates to forecast costs that would be incurred in more densely populated areas. As a matter of sound econometrics, however, caution must be exercised when parameter estimates from a data set are used to forecast costs for areas that are too dissimilar to those from which the data was obtained.

Alternatively, an analyst could use the RUS data set to analyze a proxy model's inputs for rural and suburban areas. If, for example, the data from the RUS contracts are 15 percent higher than the inputs to a proxy model, the proxy models inputs for urban areas could be adjusted upward by 15 percent. The underlying hypothesis of such an adjustment would be that the error for rural and suburban areas is systematic and, therefore, the same magnitude of adjustment should be made for urban areas.

Matching Census Block Groups to Contract Data

The RUS contracts identify the payments made by LECs for various types of cable installations. The contracts indicate the name of the LEC, and in certain cases, the name of the wire center(s). The contracts do not indicate either the census block or census block group in which the facilities are being installed. Consequently, the contract prices have been linked with the soil, rock and water conditions that exist throughout the LECs service territory.

The smaller the number of census blocks served by a LEC, the less the need to aggregate data on soil, rock, and water conditions. This suggests that analysts might want to consider limiting their analysis to companies that serve only a few census block

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[36] North Pittsburgh Telephone Company has the highest line density in the data set--187 lines per populated square mile.

groups. While this could be done, there is a potential downside to limiting the analysis to smaller LECs. To the extent that a larger company possesses greater buying power, the unit cost estimates obtained from smaller companies may not provide as good an indicator of the costs incurred by large companies as does the total data set.

Does This Data Set Reflect TELRIC Standards?

The FCC and many states have determined that costing models should estimate the cost of constructing facilities to satisfy the *total*, rather than the *incremental* demand for service.[37] With regards to the loop, this involves estimating the cost of serving *all* customers, rather than just the additional expenditures needed to satisfy the demand of *new* subscribers.

The authors believe that this data largely reflects the cost of installing facilities to satisfy total, rather than incremental demand. This conclusion is based on examination of the conditions under which an RUS company typically obtains financial assistance from the Department of Agriculture. The funding typically occurs when a RUS company concludes that it needs to rebuild its plant. The company decides that the existing facilities are no longer sufficient, and, therefore, there is a need to rebuild a portion of, or its entire, service area. Typically, RUS funding is not provided to satisfy some incremental demand, such as a new housing development. Rather the more typical case involves a rebuild of a portion or the entire service territory. During the rebuild, all pre-existing facilities are not displaced. Nevertheless, the size of the projects are larger than required to satisfy some small increase in demand. Thus, this data set can be used either to provide inputs to a proxy model or to evaluate the reasonableness of the inputs proposed by other parties.

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[37] See FCC Rules, Part 51, §51.505(b), established in FCC 96-325, August 8, 1996. Total means the entire production of the element, not just the next piece. A TELRIC study is different from an incremental cost study, which represents only the cost of the next unit of production, not the total cost. The TELRIC cost analyst is looking at reconstructing the entire network which provides the elements, not just building additional elements onto the existing network.

Verification

All the cost data used in this project was provided in a hard-copy (paper) form by the RUS. Consequently, all the information had to be entered manually. In order to insure that the data set reflected the values provided on the paper, a criterion that the margin of error on any one contract had to be less than 1 percent was used. That is, the data included in the data base is within 1 percent of the value shown on the contracts.[38]

Data concerning line counts, area, and geological items were extracted from the BCPM 3.0, Hatfield 4.0, and Hatfield 5.0 Models.[39]

Regression Results

Model Specification

In this section, estimates of the cost of installing different types of outside plant facilities are provided. The regression estimates were obtained through a three-step process. First the cost data from the RUS was collected. In the second stage, the cost data was processed and combined with information provided by the proxy model sponsors. The processing involved loading miscellaneous activities, such as splicing and street restoration, on to the cost of the cables. Also, all cost data was converted to 1997 dollars. For each of the companies in the data base, information on line counts,

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[38] The data set does not include the cost of removing existing equipment or rearrangements of existing plant. These units, when they occur, are coded with the suffixes W, XX, or XZ. All units with these designatios have been removed from the data base.

[39] Certain information is taken from the HAI Model, copyright (c) 1998 HAI Consulting, Inc., AT&T Corporation, and MCI Telecommunications Corporation, and/or the BCM-Plus Model copyright (c) 1996, MCI Telecommunications Corporation. Used by permission. Certain information is taken from the Benchmark Cost Proxy Model, copyright (c) 1998 BellSouth, Indetec, Sprint and U S WEST. Used by permission. Note the Hatfield Model was recently renamed as the HAI Model.

rock and soil type, water depth, and the area of the service territory were obtained from the proxy model sponsors. Finally, regression analysis was used to identify factors that explain the variation in unit costs.

The econometric models found herein varied depending on the type of facility being analyzed. The basic specification of the cost relationship was as follows: investment per 1,000 feet = β_1 * number of pairs +β_2 * rock hardness + β_3 *soil type + β_4 * water depth + β_5 * line density + β_6 * shared installation + ϵ

Where:

β_1 = The incremental investment for each 1,000 pair feet of cable

β_2 = The incremental placement investment when rock raises the cost of installation

β_3 = The incremental placement investment when soil type raises the cost of installation

β_4 = The incremental placement investment when water raises the cost of installation

β_5 = The fixed cost for each 1,000 feet for placing the cable in a given line density zone

β_6 = The reduction or increase in cost for placing one or more cables at the same location

ϵ = random error

With the exception of shared installation, all the variables list above have a direct linkage to the proxy models. The proxy models use soil type, rock hardness, density, water depth, and the size of cable to determine the level of investment. The last explanatory variable, shared installation, is not explicitly included in the models. Rather, the economies from placing two or more cables along the same route are reflected in the estimation of the structure costs. For example, once a trench is dug for the first cable, the proxy models assume that the hole can be used by additional cables.

With the parameter estimates, the cost of placing the cable should be reduced by the variable *colocate* wherever there is a second cable sharing the same trench.

The regression results provided below reflect the use of the Hatfield terrain and line density data. Use of the HM should not be seen as an endorsement of that model relative to the other two proxy models, the BCPM or the FCC Staff Model, Hybriel Proxy Cost Model (HPCM). It was elected to report only the regression results from the HM in order to limit the length of this chapter.

Identical set of regressions were run using inputs from the BCPM and the HM. The interested reader can obtain the estimates associated with the BCPM inputs by reading the STATA output file "bcpm regression log cables & poles".

This report contains the results from the econometric analysis of the data. These estimates provide a useful way of obtaining input estimates for the proxy models. Rather than relying on the opinion of experts regarding the cost and mix of different installation activities, *actual* construction expenditures are used to estimate how cost varies by the factors identified above.

This data set will not end the controversy about the appropriate value of inputs. This report contains a limited number of econometric specifications of the cost function. Others will, no doubt, propose different specifications that will, arguably, have superior statistical properties, make better economic/engineering sense, or result in higher/lower cost estimates.[40] It is accepted *a priori* that these regressions can be improved upon. Nevertheless, the authors believe that these estimates are reasonable on the following grounds. First, based on familiarity with cost data, many of the parameter estimates appear to be reasonable. Second, almost all the models have F values that are highly

[40] For example, an analyst could add a variable that controls for variation in regional labor rates.

statistically significant.[41] The high statistical significance indicates that the models are doing a good job of explaining the variation in the dependent variables.[42]

Special Cases

All regression results were obtained using STATA. If the reader looks at the STATA files, it will be noted that the cost data from some projects were excluded from this regression. For example, in the buried copper data analysis, the observations from projects NM 512-K and MT 529 were excluded. If the data from these two projects had not been excluded, the regression estimates would not have made as much sense. The parameter estimates would have suggested that the cost of installing buried cables in low-density areas was greater than in more concentrated areas.

The data analysis highlights the fact that there are factors that account for variation in unit costs that are not accounted for by the proxy models or the regression analysis reported below. For one of these two RUS companies, Clark Fork Telecommunications of Montana, the unit costs are quite high for its population density and soil conditions. According to Joel Shifman of the Maine Public Utilities Commission, the costs are unusually high, because the company provides services in the Glacier Mountain National Park, which discourages the use of aerial cables; therefore, when facilities need to be installed, the road often needs to be ripped open. Furthermore, since two-lane roads are found throughout the territory, a flagman is used to control the flow of automobile traffic. The combination of opening the road and controlling traffic flow, causes the costs to be quite high in this service territory.

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[41] The F test is a measure of the overall significance of the estimated regression.

[42] Conducting a statistical test of the overall explanatory power of a model is much more meaningful than a claim that R^2, the coefficient of determination, is "high" or "low." What constitutes a high or low value for R^2 is subjective. This subjectivity is largely removed when statistical tests are conducted.

Some, limited areas of the country, such as Clark Fork, merit exemption from the use of proxy models default inputs. For example, in areas surrounding observatories, a telephone company may not be permitted to use electronic transmission equipment on its cables. It is not possible for the proxy models to anticipate these special conditions. Therefore, the States and the FCC might establish a process whereby a firm can make a showing that, due to special conditions, the proxy model default inputs should not be used to model the company's costs. Requests for such exceptions should be granted with great caution, and companies should be required to furnish adequate support for claims that they face unique installation conditions.

Illustration

Regression analysis was used to estimate the cost of installing different types of facilities. This analysis allows the analyst either to identify the impact of individual cost drivers or predict the cost of installing facilities when all cost drivers are considered simultaneously. This report was more interested in predicting the total cost of installing facilities, rather than determining the influence of individual cost drivers. Stated differently, the primary objective is to have a specification of the cost function that provides a statistically significant explanation in the variation of the labor and material costs associated with installing facilities. Although it would be useful to have statistically significant parameter estimates for individual cost drivers, this was not the primary goal.[43]

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[43] If individual t-tests are conducted on each parameter estimate, caution should be taken in the construction of the confidence intervals. The hypothesis testing must reflect that if multiple hypothesis are tested, the standard Student t-level of confidence intervals are no longer applicable. Rather, the analyst should consider using the Bonferroni test.

To illustrate the regression process, the graph in figure 2-1, below, identifies the cost of installing two-pair buried drop wires. The circles represent the costs reported in the contracts for 1,000 feet of buried drop wire. The X axis variable, "*combine*," identifies the soil and rock conditions.[44] A zero value for the variable combine implies that neither difficult soil or rock conditions exits that increase the cost of placing the drop wire. The line running through the graph is the regression line estimated in Table 2-6, below.

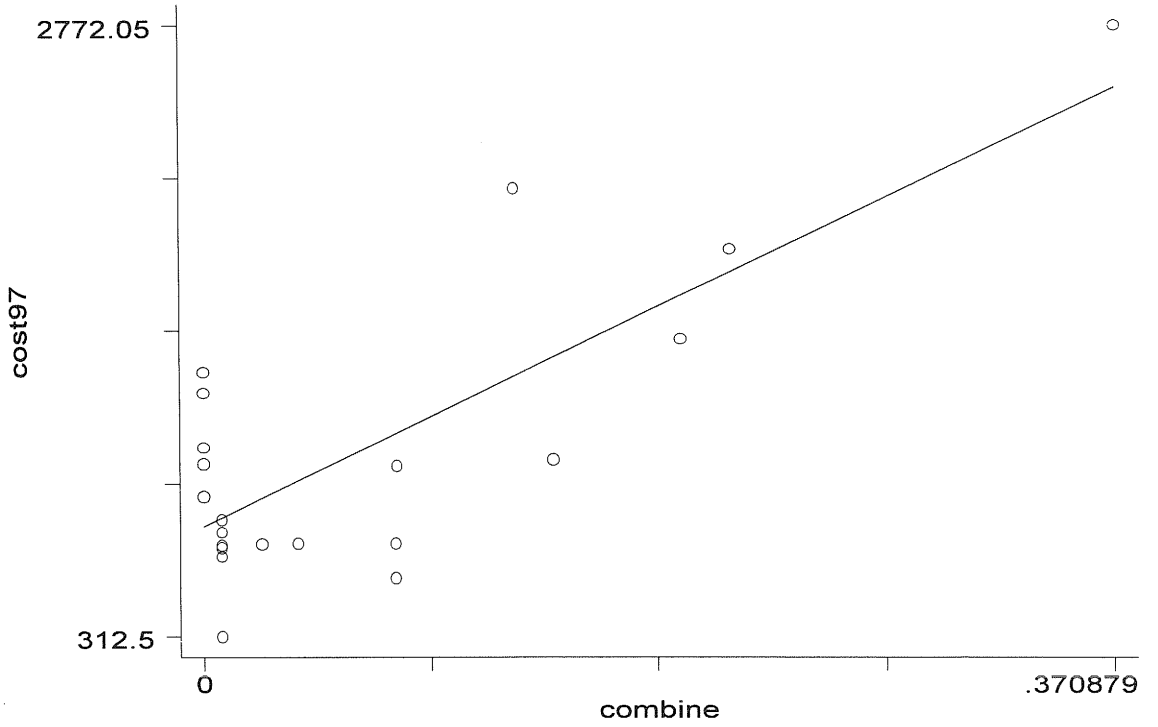

Figure 2-1: Cost of installing buried two-pair drops.
Source: Author's construct.

[44] The variable *"combine"* is defined in Table 2-8 below.

Table 2-6

Regression Results: Cost of Installing Two-Pair Buried Drops

Source	SS	df	MS	Number of obs =	26
				F(1, 24) =	37.33
Model	4578329.18	1	4578329.18	Prob > F =	0.0000
Residual	2943842.18	24	122660.091	R-squared =	0.6086
				Adj R-squared =	0.5923
Total	7522171.36	25	300886.854	Root MSE =	350.23

cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
combine	4768.784	780.5591	6.109	0.000	3157.789	6379.779
_cons	755.3235	80.87741	9.339	0.000	588.4007	922.2463

Source: Authors' construct.

This regression result was obtained by regressing the cost of two-pair buried cable on a constant term, _cons, and "*combine*," a variable that represents soil and rock conditions.

The regression analysis did not control for other factors, such as water depth and line density per square mile, that may affect the cost of installation. If these other variables are added to the specification of the model, the explanatory power of the model may increase. In the results reported in the following sections, other explanatory variables are included. This example illustrates how regression analysis can be used to identify variations in the cost of installing facilities.

Buried Copper Cable

Table 2-7 provides the results from a regression analysis of buried copper cable. This represents the results from only one model estimate. Parameter estimates associated with other model specifications can be found in the file "HM regression log cables & poles." Variable definitions are found in Table 2-8.

Table 2-7

Regression Results: Cost of Installing Buried Copper Cable

Source	SS	df	MS		Number of obs =	1131
					F(6, 1125) =	996.44
Model	4.6588e+10	6	7.7647e+09		Prob > F =	0.0000
Residual	8.7665e+09	1125	7792442.79		R-squared =	0.8416
					Adj R-squared =	0.8408
Total	5.5355e+10	1131	48943037.9		Root MSE =	2791.5

cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
number_o	11.8932	.2477075	48.013	0.000	11.40718	12.37922
colocate	-1101.283	208.6911	-5.277	0.000	-1510.751	-691.8157
combine	1349.091	432.9728	3.116	0.002	499.5661	2198.616
watlin15	229.6622	189.3575	1.213	0.225	-141.8713	601.1958
dens0	1932.864	570.1793	3.390	0.001	814.1294	3051.598
dens1	2427.494	155.1588	15.645	0.000	2123.061	2731.927

Source: Authors' construct.

Note that the F value for the model is highly significant.[45] This suggests that, at any standard level of significance, the hypothesis that all of the coefficient estimates are equal to zero can be rejected.

These parameter estimates can be used to estimate the cost of installing buried cables. To see how this could be done, assume the following:

Cable size: 400 pairs
presence of a second cable: no
bedrock indicator value in Hatfield Model: 1.2
Soil type indicator value in Hatfield Model: 1.1
Water indicator value in Hatfield Model: 1.0
Population density: 4 lines per square mile

[45] The variable for the depth of the water table (watlin15) is not statistically significant at any standard level of significance. The regression results from dropping this variable are found in file "HM regression log cables, drops & poles". The log file does not contain regression results from rerunning each model after dropping statisticly insignficiant variables. As mentioned at the outset, the objective of this study was to estimate a regression function that provided a statistically significant explanation of the variation in the value of the dependent variable.

Using these assumed inputs and the results of the regression, the following estimate would result.

Estimated investment per thousand feet:

11.8932*400 - 1,101.283*0 + 1,349.091 * (1.2 - 1 + 1.1 - 1) + 229.6622 * (1 - 1) + 1,932.864 = $7,094.87.

On a per-foot basis, the estimated investment is $7.09 per foot for the 400 pair cable.

If the soil, water and rock type was normal, and all the other inputs remained unchanged:

Cable size: 400 pairs
presence of a second cable: no
bedrock indicator value in Hatfield Model: 1.0
Soil type indicator value in Hatfield Model: 1.0
Water indicator value in Hatfield Model: 1.0
Population density: 4 lines per square mile

Using these assumed inputs and the results of the regression, the following estimate would result.

Estimated investment per thousand feet:

11.8932*400 - 1,101.283*0 + 1,349.091 * (1 - 1 + 1 - 1) + 229.6622 * (1 - 1) + 1,932.864 = $6,690.14.

On a per-foot basis, the estimated investment is $6.69 per foot for the 400 pair cable.

If the soil, water and rock type was normal, a 25-pair cable was placed, and all other inputs remained unchanged:

Cable size: 25 pairs
presence of a second cable: no
bedrock indicator value in Hatfield Model: 1.0
Soil type indicator value in Hatfield Model: 1.0
Water indicator value in Hatfield Model: 1.0
Population density: 4 lines per square mile

Using these assumed inputs and the results of the regression, the following estimate would result.

Estimated investment per thousand feet:

11.8932*25 - 1,101.283*0 + 1,349.091 * (1 - 1 + 1 - 1) + 229.6622 * (1 - 1) + 1,932.864 = $2,230.19.

On a per-foot basis, the estimated investment is $2.23 per foot for the 25 pair cable.

The dependent variable in this regression was cost97; when using these parameter estimates in a proxy model, there is a need to add the cost of splicing, as well as LEC engineering.

Table 2-8

Definitions of Regression Variables

Variable	Definition
bdens0	0 to 5 lines per square mile. Calculated by dividing BCPM lines by BCPM area.
bdens1	6 to 100 lines per square mile. Calculated by dividing BCPM lines by BCPM area.
bdens2	101 to 200 lines per square mile. Calculated by dividing BCPM lines by BCPM area.
bdens3	200 to 650 lines per square mile. Calculated by dividing BCPM lines by BCPM area.
bdens4	3.5 to 4.5 lines per square mile. Calculated by dividing BCPM lines by BCPM area.
bdens5	4.6 to 5 lines per square mile. Calculated by dividing BCPM lines by BCPM area.
bed24a15	Hatfield 5.0 rock hardness indicator value at 24 inch depth - 1. CBGs weighted by area.
bed24a1b	BCPM rock hardness indicator value at 24 inch depth - 1. CBGs weighted by area.
bed24l15	Hatfield 5.0 rock hardness indicator value at 24 inch depth - 1. CBGs weighted by lines.
bed24l1b	BCPM rock hardness indicator value at 24 inch depth - 1. CBGs weighted by lines.
bed36a15	Hatfield 5.0 rock hardness indicator value at 36 inch depth - 1. CBGs weighted by area.
bed36a1b	BCPM rock hardness indicator value at 36 inch depth - 1. CBGs weighted by area.
bed36l15	Hatfield 5.0 hardness indicator value at 36 inch depth - 1. CBGs weighted by lines.
bed36l1b	BCPM rock hardness indicator value at 36 inch depth - 1. CBGs weighted by lines.
bed48a15	Hatfield 5.0 rock hardness indicator value at 48 inch depth - 1. CBGs weighted by area.
bed48a1b	BCPM rock hardness indicator value at 48 inch depth - 1. CBGs weighted by area.
bed48l15	Hatfield 5.0 rock hardness indicator value at 48 inch depth - 1. CBGs weighted by lines.
bed48l1b	BCPM rock hardness indicator value at 48 inch depth - 1. CBGs weighted by lines.
BFC	buried filled copper cable.
BFO	buried fiber optic cable.
bm3dens	BCPM line density per square mile.
colocate	two cables simultaneously placed at the same location

Table 2-8 (Continued)

Definitions of Regression Variables

Variable	Definition
combine	bedrock + soil indicator = bed36l15 + sstlin15 Hatfield value. 36 inches is used for copper and fiber because this depth appeared most frequently in the contracts.
combineb	bedrock + soil indicator = bed36l1b + sstlin1b BCPM value
_cons	constant term in STATA regressions
cost1997	cost of facilities including appropriate loadings. For cables, splicing costs are included.
cost97	cost of facilities including appropriate loadings, with one exception. For cables, splicing costs are excluded.
CO	aerial fiber optic cable.
CW	aerial copper cable.
dens0	0 to 5 lines per square mile. Calculated by dividing Hatfield lines by Hatfield area.
dens1	6 to 100 lines per square mile. Calculated by dividing Hatfield lines by Hatfield area.
dens2	101 to 200 lines per square mile. Calculated by dividing Hatfield lines by Hatfield area.
dens3	201 to 650 lines per square mile. Calculated by dividing Hatfield lines by Hatfield area.
dens4	3.5 to 4.5 lines per square mile. Calculated by dividing Hatfield lines by Hatfield area.
dens5	4.6 to 5 lines per square mile. Calculated by dividing Hatfield lines by Hatfield area.
gauge	gauge of copper cable
hm5dens	Hatfield line density per square mile
labor	labor cost of installing facility
material	material cost of installing facility
number_o	number of copper pairs or fiber strands in cable sheath
POLE 30-5	30 foot class 5 pole
POLE 40-4	40 foot class 4 pole
rus_code	Rural Utility Service Code for various types of facilities. The codes are defined in the appendix of this chapter (Table: RUS Engineering Symbols--Outside Plant)

Table 2-8 (Continued)

Definitions of Regression Variables

Variable	Definition
sstare15	Hatfield 5.0 soil surface indicator value - 1. CBGs weighted by area.
sstare1b	BCPM soil surface indicator value - 1. CBGs weighted by area.
sstlin15	Hatfield 5.0 soil surface indicator value - 1. CBGs weighted by lines.
sstlin1b	BCPM soil surface indicator value - 1. CBGs weighted by lines.
UF	underground filled copper cable
UO	underground fiber optic cable
watare15	Hatfield 5.0 water indicator value -1. CBGs weighted by area..
watere1b	BCPM water indicator value -1. CBGs weighted by area..
watlin15	Hatfield 5.0 water indicator value -1. CBGs weighted by lines.
watlin1b	BCPM water indicator value -1. CBGs weighted by lines.

Source: Authors' construct.

Material Costs

An earlier version of this data set was recently provided to parties in a proceeding before the Maine Public Utilities Commission. The Hearing Examiners in an unbundled network element case asked the parties to comment on the outside plant costs. A Bell Atlantic (BA) witness submitted a comparison of the material costs and material and labor costs from the RUS data with the comparable cost inputs used in BA's link (loop) study. His principal conclusion was "that the material costs used by the

Company in the TELRIC Study are less, for all cable types, when compared with the RUS data."[46] The comparison of material costs are illustrated in Table 2-9 below.

Bell Atlantic's material cost comparison suggests that, where this data is used to estimate the forward looking costs of a large firm, it may be appropriate to adjust the material costs downward.

The data in Table 2-9 suggests that it may be appropriate to adjust the material prices downward by the following amounts:[47]

Underground Copper	16.3%
Aerial Copper	15.2%
Underground Fiber	27.8%
Aerial Fiber	33.8%

These discounts could be applied to the material component of the data base, and the regressions could be rerun. Alternatively, the discount can be applied to the parameter estimate for the variable number_o. This parameter identifies how the cost of a facility varies as the number of copper pairs or fibers in a cable increases.

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[46] Rebuttal Testimony of Stanley Baker, Bell Atlantic, Docket No. 97-505, December 22, 1997, p. 4, and Attachment 1. Baker also found (at pp. 4-5) "[i]n contrast with the comparison of material costs which showed that the Company's studied costs were lower than the RUS data, the comparison of labor and material costs between the RUS data and the Company's data shows just the opposite." Ibid. Among other factors, Baker notes that "[o]ne item causing this result is the labor component associated with fiber splices in the independent company data is inordinately low." Baker also stated (at pp. 5-6) that BA's underground copper costs were high relative to the RUS values because "The Company's costs for underground copper cable reflect only the relatively short lengths deployed in the TELRIC study."

[47] The calculations are found in file "ba table on rus v. ba osp.xls". The difference in material prices were calculated by calculating the percentage difference in price for each type of cable. The individual percentage changes were then assigned a weight based on the number of observations for each type of facility.

No adjustment has been calculated for poles because, among other reasons, the data provided by Bell Atlantic does not allow control for the class of the pole. Furthermore, the Bell Atlantic material price includes the cost of "associated materials such as anchors and guys." Baker, p. 3. These items are excluded from the RUS material prices.

Table 2-9

Comparison of RUS Data and Bell Atlantic Material Cost Inputs

RUS DATA:			BELL ATLANTIC LINK STUDY INPUTS:		
Underground Copper			Underground Copper		
Pairs	Observations	$ Per foot	Urban	Suburban	Rural
200	135	$1.99			$1.60
400	93	$3.83			$3.34
600	94	$5.62	$4.86		
900	58	$8.04		$6.70	
1200	34	$11.45	$9.15	$9.30	
1800	20	$16.04		$13.08	
Aerial Copper			Aerial Copper		
Pairs	Observations	$ Per foot	Urban	Suburban	Rural
200	28	$2.03			$1.62
400	24	$3.92	$3.30	$3.30	
600	17	$5.15	$4.86		
900	8	$7.64		$6.39	
Underground Fiber			Underground Fiber		
Strands	Observations	$ Per Foot	Urban	Suburban	Rural
12	136	$0.87	$0.62	$0.62	$0.62
72	33	$3.04	$2.24		$2.24
144	5	$5.53	$4.98	$4.98	
Aerial Fiber			Aerial Fiber		
Strands	Observations	$ Per Foot	Urban	Suburban	Rural
24	24	$1.35		$0.82	$0.82
48	6	$2.12			$1.64
72	4	$2.72		$2.24	$2.24
Poles			Poles		
Height	Observations	$ Per Foot	Urban	Suburban	Rural
35	53	$162	$266	$266	$266
40	41	$203	$354	$354	$354
45	17	$250	$401	$401	$401

Source: Authors' construct from RUS and Bell Atlantic data.

Because this is largely a material cost, adjustment of the parameter estimate for number_o is a quick way of making the adjustment. The adjustment is not perfect, however, because some of the material cost is reflected in the fixed cost of installing a cable.

None of the regression estimates reported in this chapter reflects an adjustment for the difference between RUS and large LEC material input prices.

Buried Fiber Optic Cable

Table 2-10 provides the results from a regression analysis of buried fiber optic cable. Results are reported for only one of model. Parameter estimates associated with other model specifications can be found in the file "HM regression log cables, drops & poles."

Table 2-10

Regression Results: Cost of Installing Buried Fiber Optic Cable

Source	SS	df	MS		Number of obs =	707
					F(6, 701) =	589.26
Model	1.0212e+10	6	1.7019e+09		Prob > F =	0.0000
Residual	2.0246e+09	701	2888212.72		R-squared =	0.8345
					Adj R-squared =	0.8331
Total	1.2236e+10	707	17307154.4		Root MSE =	1699.5

cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
number_o	36.58157	1.909966	19.153	0.000	32.83163	40.33151
watlin15	121.8819	155.8343	0.782	0.434	-184.0759	427.8397
combine	593.2549	296.9037	1.998	0.046	10.32789	1176.182
dens0	1850.096	347.5987	5.323	0.000	1167.637	2532.555
dens1	2316.261	124.1455	18.658	0.000	2072.52	2560.003
colocate	56.43567	146.5545	0.385	0.700	-231.3027	344.1741

Source: Authors' construct.

In order to see how to use these parameter estimates, consider the following assumptions:

Cable size: 16 tubes (fibers)
presence of a second cable: no
bedrock indicator value in Hatfield Model: 1.0
Soil type indicator value in Hatfield Model: 1.0
Water indicator value in Hatfield Model: 2.0
Population density: 25 lines per square mile

Using these assumed inputs and the results of the regression, the following estimate would result.

Estimated investment per thousand feet:

36.58157*16 + 56.43567*0 + 593.2549 * (1.0 - 1 + 1.0 - 1) + 121.8819 * (2 - 1) + 2,316.261 = $3,023.45.

On a per-foot basis, the investment is $3.02 per foot for the 16-fiber cable. As with all cable regression estimates, there is a need to add the cost of LEC engineering and splicing.

Poles

The data base contains information on the cost of various sizes and classes of poles. Table 2-11 provides descriptive statistics for some of the different sizes. The average investment value, stated in 1997 dollars, reflects both material and installation cost.[48]

[48] Only observations for which the data base indicates that the cost of both the material and the labor values are greater than zero are included.

Table 2-11

Average Investment Cost for Poles Contained in the RUS Access Database

Height (Feet)	Class	Average Material Price	Average Total Investment	Std. Dev. Total Investment	Observations
30	3	129.82	$245.13	29.28	6
30	4	122.62	$277.48	99.37	18
30	5	115.28	$263.23	90.51	27
30	6	142.19	$317.93	164.63	6
35	2	205.32	$350.11	20.15	4
35	3	164.42	$302.98	25.63	8
35	4	157.93	$315.86	99.21	16
35	5	139.69	$295.56	90.87	23
40	2	236.11	$422.51	68.00	4
40	3	222.68	$368.34	7.09	4
40	4	213.94	$395.93	91.14	19
40	5	178.02	$413.55	151.65	13
45	2	314.8	$537.11	51.05	2
45	3	296.44	$460.10	86.09	4
45	4	249.88	$474.12	125.89	9

Source: Authors' construct.

Table 2-12 indicates that LECs install a wide variety of size poles. For the most part, Table 2-12 also shows that the better classes of poles, such as class two, have higher material costs than the higher-numbered class poles.

Thirty foot, class 5 poles appear most frequently in the data set. Although data analysis of this size pole has been undertaken, the results are not reported here. Rather, Table 2-12 provides estimates for a 40-foot, class 4 pole, because this is the size pole that the HM assumes. The authors were unable to identify from the BCPM documentation the assumed pole size, but they believe the model uses 45-foot, class 5 poles.

Table 2-12

Regression Results: Investment per Pole

Source	SS	df	MS		Number of obs =	19
					F(3, 15) =	3.51
Model	61704.4186	3	20568.1395		Prob > F =	0.0415
Residual	87822.3628	15	5854.82419		R-squared =	0.4127
					Adj R-squared =	0.2952
Total	149526.781	18	8307.04341		Root MSE =	76.517

cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
sstare15	49.99036	244.7599	0.204	0.841	-471.703	571.6837
watlin15	112.5506	50.40416	2.233	0.041	5.116637	219.9845
bed48a15	66.07799	31.45088	2.101	0.053	-.9579629	133.1139
_cons	310.645	33.64669	9.233	0.000	238.9288	382.3612

Source: Authors' construct.

All of the 40-foot, class 4 observations appear in the Hatfield density band of 5 to 100 lines per square mile. Consequently, the regressions below do not include dummy variables for different density zones. Note that in neither the BCPM nor the HM do the model sponsors contend that the cost of a pole is a function of the population density.[49] With the buried cables, the rock hardness data at the 36-inch depth level was used. For poles, the data for 48 inches was used.[50]

In order to see how to use these parameter estimates, consider the following assumptions:

Soil type indicator value in Hatfield Model: 1.0
Water indicator value in Hatfield Model: 2.0
Bedrock indicator value in Hatfield Model: 1.0

[49] HM 5.0 Inputs, Assumptions, and Default Values, B12--Pole Investment, December 11, 1997; and BCPM 2.0, file loopint.xls, folder Structure Inputs.

[50] The statical significance of the equation is 4.15 percent. The significance increases to 1.45 percent if the variable "sstare15" is dropped from the regression.

Using these assumed inputs and the results of the regression, the following estimate would result.

Estimated investment per pole:

49.99036*(1.0-1) + 112.5506 * (2.0 - 1) + 66.07799 * 1.0 - 1) + 310.645 = $423.20.

If the water depth indicator value was also one, the cost of the pole would be $310.645.

Note that the pole costs do not include the cost of guys, cross arms, grounding wires, anchors, or other miscellaneous items. Also, as with all of the RUS outside plant data, LEC engineering is not included. As shown in Table 2-13, The RUS Access database contains the following items which are associated with the cost of placing poles. This list of miscellaneous pole-related items, their cost, and the number of times they appeared in the database was faxed to several experts in the area of outside plant engineering,[51] who were asked to provide an opinion as to how these miscellaneous items should be factored into pole costs. Based on the comments of the experts, the loading calculation shown in Table 2-14 was devised.[52]

[51] The recipients were Wally Budsberg, a former employee of U S West and the Washington Transportation and Utilities Commission, Ed Cameron, a current employee of the Rural Utilities Service Bureau, and Harry Clinton, a current employee of the New York Public Service Commission.

[52] The calculations supporting this table may be found in the *Pole Loadings Calculation Workbook.xls* file, which accompanies this paper.

Table 2-13

RUS Pole Loader Descriptions

RUS Code Prefix	Description
PE	Guy Assembly Units
PF	Anchor Assembly Units
PM	Ground and Misc. Assembly Units
PM1	Pole Lightning Protection Assembly
PM11	Guy Guard
PM12	Sidewalk guy arm
PM14	Push Brace assembly
PM2	Pole ground assembly
PM2-1	Auxiliary ground rod assembly
PM2A	Ground wire assembly
PM4	Cable extension arm
PM4A	Cable extension arm
PM5	Pole stepping assembly
PM52-1	Pole marking, per pole, route and pole numbering
PM6	One wood pole key
PM7	Two wood pole keys
PM8	One wood key and one metal key
PM9	Two wood keys and one metal key

Source: Authors' construct.

Table 2-14

RUS Pole Loading Calculations

RUS Code Prefix	Total Number of Unites in Data Base	Average Unit Cost	Probability Rural	Probability Suburban	Probability Urban	Loading Rural	Loading Suburban	Loading Urban
PE	10430	36.53	0.17	0.17	0.17	6.210613	6.210613	6.210613
PF	6104	86.18	0.17	0.17	0.17	14.65033	14.65033	14.65033
PM11	5508	9.71	0.05	0.6	0.8	0.485505	5.826058	7.768077
PM12	24	79.97	0	0.08	0.1	0	6.3975	7.996875
PM14	5	138.65	0.001	0	0	0.138646	0	0
PM4, 4A	33	92.90	0	0.02	0.05	0	1.854061	4.635152
PM, PM2, PM2-1, PM2A	7858	$13.82	0.25	0.5	0.8	3.454548	6.909096	11.05455
PM52-1	7968	7.91	1	1	1	7.912707	7.912707	7.912707
Subtotal						32.85	49.76	60.23
Total for Loading With Miscellaneous Items						32.98	49.96	60.47

Authors' construct.

From Table 2-14 it can be seen that, given the cost data in the database, the suggested pole loadings for rural, suburban, and urban areas are: $32.85, $49.96, and $60.23 per pole, respectively. It should be noted that there was some disagreement around the issue of ground wire assembly and pole grounding units.[53] One expert felt that the probability estimates for these units was too low. It was his opinion that, especially in high-lightening areas, each pole would have a pole ground assembly unit attached to it, and that there would be commensurate increase in the number of other grounding units. Although the authors believe that the percentages used in the table are reasonable, analysts may change these percentages either to reflect the conditions which exist in their specific area of the country or to conform with the engineering practices employed by the companies under consideration.

Aerial Copper Cable

Table 2-15 presents analysis of the cost of installing aerial cable. The Hatfield line and area data suggest that few of these companies have average line density less than five lines per square mile. Therefore, parameter estimates for only two density zones, 6 to 100 and 201 to 650 lines per square mile.[54]

This aerial regression does not include explanatory variables for soil, rock, or water depth, because the cost of hanging the cables on the poles is independent of these factors. Rather, the cost impact of these factors is reflected in the pole placement costs.

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[53] These values should not be interpreted as the view of any one individual, or an average of the three solicited view points. Rather, it is based on the authors' summary of the comments provided by each of the three parties.

[54] The BCPM STATA log, contained in file "bcpm regression log cables and poles log", suggests that there are many companies whose average line density is less than five lines per square mile.

Table 2-15

Regression Results: Cost of Installing Aerial Copper Cable

Source	SS	df	MS		Number of obs =	255
					F(4, 251) =	515.06
Model	3.9990e+09	4	999750313		Prob > F =	0.0000
Residual	487201119	251	1941040.32		R-squared =	0.8914
					Adj R-squared =	0.8897
Total	4.4862e+09	255	17592950.5		Root MSE =	1393.2

cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
number_o	9.67289	.363424	26.616	0.000	8.957141	10.38864
dens1	1377.202	110.3447	12.481	0.000	1159.882	1594.522
dens3	661.9934	354.7366	1.866	0.063	-36.64617	1360.633
colocate	-206.9393	336.7909	-0.614	0.539	-870.2355	456.357

Source: Authors' construct.

These parameter estimates suggest that the cost of installing aerial cable decreases as density increases. This could be due to two factors: (1) there was data for only one company in this density range, North Pittsburgh Telephone Company, and there is something that makes its costs lower than what one would expect for this density range; or (2) there may be less traveling time involved in this density zone, and therefore their costs are lower.

An alternative view is that the cost of placing aerial cables is independent of population density. At the 1 percent level of significance, the hypothesis that there is no statistically significant difference in the cost of placing cables in the two density zones can be accepted. In the regression results below in Table 2-16, the density variables have been dropped.

Table 2-16

Regression Results: Cost of Installing Aerial Copper Cable (with density variables dropped)

Source	SS	df	MS	Number of obs =	255
Model	1.4766e+09	2	738308059	F(2, 252) =	375.44
Residual	495555262	252	1966489.14	Prob > F =	0.0000
				R-squared =	0.7487
				Adj R-squared =	0.7467
Total	1.9722e+09	254	7764454.25	Root MSE =	1402.3

cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
number_o	9.425349	.345521	27.279	0.000	8.744872	10.10583
colocate	-120.3254	336.3768	-0.358	0.721	-782.7934	542.1427
_cons	1361.593	110.8073	12.288	0.000	1143.367	1579.819

Source: Authors' construct.

These results suggest that, if only one 50-pair cable is placed for 1,000 feet, hence colocate=0, the labor and material cost would be 1,361.593 + 50 * 9.425349 = $1,832.86. This is equivalent to a placement cost of $1.83 per foot. If a second 3600 pair cable were placed on the pole, the labor and material cost would be 1,361.593 + 3,600 * 9.425349 - 120.3254 = $35,172.52. This is equivalent to a placement of $35.17 per foot.

Aerial Fiber Cable

For aerial cable (as shown in Table 2-17), parameter estimates are provided for density zones 1 and 3. Because there was only one observation available for the lowest density zone, no parameter estimate is provided for that density zone.

Table 2-17

Regression Results: Cost of Installing Aerial Fiber Cable

Source	SS	df	MS		Number of obs =	168
					F(4, 164) =	262.14
Model	989517410	4	247379352		Prob > F =	0.0000
Residual	154763246	164	943678.331		R-squared =	0.8648
					Adj R-squared =	0.8615
Total	1.1443e+09	168	6811194.38		Root MSE =	971.43
cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
number_o	39.04649	2.874812	13.582	0.000	33.37007	44.7229
dens1	1100.807	105.226	10.461	0.000	893.0347	1308.579
dens3	477.2315	456.3785	1.046	0.297	-423.9036	1378.367
colocate	948.2939	443.2426	2.139	0.034	73.09607	1823.492

Authors' construct.

At any standard level of significance, the hypothesis that the cost of placing aerial fiber cables in density zones one and three are identical can be accepted. Thus, the density variables have been dropped from the regression reported in Table 2-18.

Table 2-18

Regression Results: Cost of Installing Aerial Fiber Cable (with density variables dropped)

Source	SS	df	MS		Number of obs =	169
					F(2, 166) =	101.48
Model	201138633	2	100569316		Prob > F =	0.0000
Residual	164508790	166	991016.808		R-squared =	0.5501
					Adj R-squared =	0.5447
Total	365647423	168	2176472.76		Root MSE =	995.50
cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
number_o	36.99432	2.599294	14.232	0.000	31.86238	42.12625
colocate	922.6949	454.1476	2.032	0.044	26.04512	1819.345
_cons	1147.749	105.8191	10.846	0.000	938.8239	1356.673

Source: Authors' construct.

These results suggest that if a single 16-fiber cable is placed for 1,000 feet, and hence colocate=0, the labor and material cost would be:

1,147.749 + 16 * 36.99432 = $1,739.66.

This is equivalent to a placement cost of $1.74 per foot.

The parameter estimate for the variable colocate is positive. This suggests that when a fiber cable is placed on the same pole as a second copper or fiber cable, the cost of placement increases.

Underground Copper

The data for underground copper are concentrated in the density zone 1, 6 to 100 lines per square mile. There is only one observation for density zone 0, no observations in density zone 2, and four observations for density zone 3. In the regression results below, only data from density zone 1 was used. If the other five observations are included, the parameter estimates fall in the 95 percent confidence intervals identified in Table 2-19.

Table 2-19
Regression Results: Cost of Installing Underground Copper Cable

Source	SS	df	MS		Number of obs =	81
					F(2, 78) =	128.62
Model	3.0603e+09	2	1.5301e+09		Prob > F =	0.0000
Residual	927943770	78	11896715.0		R-squared =	0.7673
					Adj R-squared =	0.7614
Total	3.9882e+09	80	49852668.9		Root MSE =	3449.2

cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
number_o	10.14025	.6393398	15.860	0.000	8.86742	11.41308
colocate	-2064.739	3492.651	-0.591	0.556	-9018.072	4888.594
_cons	3568.458	572.6589	6.231	0.000	2428.381	4708.534

Source: Authors' construct.

These parameter estimates suggest that if one 1,000-foot cable is placed in the conduit, the material and labor of a 100-pair underground cable is 3,568.458 + 10.14025 * 100 - 2,064.739 * 0 = $4,582.483. This is equivalent to a cost of $4.58 per foot.

Underground Fiber Optic Cable

Here too, the data is limited, as there are only five observations outside density zone 1. The parameter estimates for 1,000 feet of underground cable placed in density zone 1 are shown in Table 2-20.

Table 2-20

Regression Results: Cost of Installing Underground Fiber Optic Cable

Source	SS	df	MS		Number of obs =	128
Model	290952479	2	145476240		F(2, 125) =	111.56
Residual	163009245	125	1304073.96		Prob > F =	0.0000
					R-squared =	0.6409
					Adj R-squared =	0.6352
Total	453961724	127	3574501.77		Root MSE =	1142.0

cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
number_o	34.73169	2.32929	14.911	0.000	30.12174	39.34165
colocate	14.61047	444.7638	0.033	0.974	-865.6323	894.8532
_cons	2120.411	144.4419	14.680	0.000	1834.543	2406.28

Source: Authors' construct.

These parameter estimates suggest if one 16-fiber underground fiber-optic cable is placed in conduit, the material and labor is 34.73169*16 + 14.61047*0 + 2,120.411 = $2,676.12. This is equivalent to a cost of $2.68 per foot.

Buried Drop Wire

The following regression results in Table 2-21 are for buried drop wires. Unlike the previous analysis for copper cables, consideration was not limited to 24-gauge wire. Due to the fact that there are a limited number of observations, and the majority are for 22-gauge wire, this analysis includes both types of drop wires.

Table 2-21

Regression Results: Cost of Installing Buried Drop Wire

Source	SS	df	MS		Number of obs =	64
					F(5, 59) =	106.80
Model	104492243	5	20898448.7		Prob > F =	0.0000
Residual	11545244.3	59	195682.106		R-squared =	0.9005
					Adj R-squared =	0.8921
Total	116037488	64	1813085.75		Root MSE =	442.36

cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
number_o	21.50047	4.261105	5.046	0.000	12.97402	30.02692
dens0	1176.476	271.6398	4.331	0.000	632.9266	1720.026
dens1	850.7703	85.58887	9.940	0.000	679.5074	1022.033
watlin15	348.7825	125.6024	2.777	0.007	97.45272	600.1122
combine	545.8288	210.1838	2.597	0.012	125.2521	966.4056

Source: Authors' construct.

To illustrate the use of these parameter estimates, assume:

Drop size: 3 pair
bedrock indicator value in Hatfield Model: 1.0
Soil type indicator value in Hatfield Model: 2.0
Water indicator value in Hatfield Model: 1.0
Population density: 25 lines per square mile

Given the assumptions above, the parameter estimates suggest that the cost of installing 1,000 feet of three-pair drop wire is 21.50047*3 + 850.7703 + 348.7825 * (1-1) + 545.8288 * (2-1 + 1 - 1) = $1,461.10. On a per-foot basis, this is equivalent to a labor and material cost of $1.46. As with other regressions reported above, this excludes

LEC engineering and splicing. Furthermore, it reflects the cost of materials paid by small telephone companies.

An argument could be made that the regression analysis should be limited to situations where a large number of drops are installed. This may correspond with observations where the length of drop wire installed is greater than 2,000 feet. The following regression results in Table 2-22 were obtained by including only those observations where the length of facility installed was in excess of 2,000 feet.

As one would expect, in this regression, the cost of installing a drop is lower in the less populated density zone. On the other hand, the t-statistics are not as good. But, as stated above, the overall fit of the regression model is of greater concern. As with the first regression for buried drops, the parameter estimates are statistically significant.

Table 2-22

Regression Results: Cost of Installing Buried Drop Wire (greater than 2000 feet)

Source	SS	df	MS		Number of obs =	26
					F(5, 21) =	39.18
Model	35785652.3	5	7157130.46		Prob > F =	0.0000
Residual	3836577.74	21	182694.178		R-squared =	0.9032
					Adj R-squared =	0.8801
Total	39622230.1	26	1523931.93		Root MSE =	427.43

cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
number_o	98.90271	57.64768	1.716	0.101	-20.98219	218.7876
dens0	477.7867	540.3371	0.884	0.387	-645.9059	1601.479
dens1	633.0441	213.6676	2.963	0.007	188.698	1077.39
watlin15	227.0326	211.4119	1.074	0.295	-212.6225	666.6877
combine	435.0132	264.7588	1.643	0.115	-115.5829	985.6092

Source: Authors' construct.

To illustrate the use of these parameter estimates, assume:

Drop size: 3 pair
bedrock indicator value in Hatfield Model: 1.0
Soil type indicator value in Hatfield Model: 2.0
Water indicator value in Hatfield Model: 1.0
Population density: 25 lines per square mile

Given the assumptions above, the parameter estimates suggest that the cost of installing 1,000 feet of three-pair drop wire is 98.90271*3 + 633.0441 + 227.0326 * (1-1) + 435.0132 * (2-1 + 1 - 1) = $1,364.77. On a per-foot basis, this is equivalent to a labor and material cost of $1.36. As with other regressions, this excludes LEC engineering and splicing. Furthermore, it reflects the cost of materials paid by small telephone companies, rather than the apparently larger discounts received by the larger companies.

Aerial Drop Wire

All of the 22- and 24- gauge aerial drop wires fall into the density zone 1, 6 to 100 lines per square mile. The results are shown in Table 2-23.

Table 2-23

Regression Results: Cost of Installing Aerial Drop Wire

Source	SS	df	MS		Number of obs =	13
Model	324549.385	1	324549.385		F(1, 11) =	2.20
Residual	1621444.96	11	147404.087		Prob > F =	0.1659
Total	1945994.35	12	162166.196		R-squared =	0.1668
					Adj R-squared =	0.0910
					Root MSE =	383.93

cost97	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
number_o	44.44383	29.952	1.484	0.166	-21.48008	110.3677
_cons	584.7457	178.1694	3.282	0.007	192.5976	976.8939

Source: Authors' construct.

For this regression, the hypothesis that the parameter for number_o, the number of pairs, is equal to zero cannot be rejected. This disappointing result may be due to the fact that were only 13 observations.

Other Outside Plant Facilities

The data base contains cost data for other outside plant facilities, including information on such items as pedestals, serving area interfaces, network interface devices, and conduit. The interested analyst can access the data by using MS Access. Also, much of the data is also available in the Excel spreadsheets.

Appendix 2-A

RUS Engineering Symbols — Outside Plant

RUS Code Prefix	Equipment Type	Description
BA	Cable loading, buried	Buried plant housing stub pole units
BC	Buried cross connect	Cross-connecting assembly units
BCV	Coaxial cable, buried	Cable TV
BD	Buried pedestal	Buried plant pedestal units
BDA	Buried pedestal loading	Buried plant pedestal assembly units
BDS	SAI--buried	Serving area interface
BDV	Buried pedestal--coaxial cable	Buried pedestal--Coaxial Cable
BDX	SAI--buried loading	Serving area interface frame
BFC	Cable, buried copper	Buried filled cable assembly units
BFG	Loading coil, buried fiber	Buried plant loading coil units, fiber
BFO	Cable, buried fiber	Buried filled fiber optic cable units
BG	Loading coil, buried copper	Buried plant loading coil units, copper
BG15-1	Cable loading, buried	Buried plant terminal block. Consists of a 1 pair station protector mounted on a pole with the required length of a 6 pair filled wire to connect the protector to a cable pair. Used to connect existing drop wires to new buried cable or wire
BG15-6	Drop loading	Buried plant terminal block. Consists of a 6 pair station protector mounted on a pole with the required length of a 6 pair filled wire to connect the protector to a cable pair. Used to connect existing drop wires to new buried cable or wire
BM	Cable loading	Miscellaneous assembly units
BM1	Cable loading	Miscellaneous assembly units
BM100	Cable loading, buried	Rebonding and grounding of existing cables in a new buried plant housing
BM101	Cable loading, buried	Unknown
BM102	Cable loading, buried	Unknown
BM103	Cable loading, buried	Unknown
BM109	Cable loading, buried	Unknown
BM10M	Cable loading, aerial or buried	Suspension strand assembly unit
BM12	Cable loading	Unknown
BM13	Cable loading	Unknown
BM14	Cable loading	Unknown
BM15	Cable loading	Unknown
BM16	Cable loading	Suspension strand assembly unit

Appendix 2-A (Continued)

RUS Engineering Symbols — Outside Plant

RUS Code Prefix	Equipment Type	Description
BM171	Cable loading	Unknown
BM192	Cable loading	Unknown
BM2	Cable loading	Housing ground assembly unit
BM20	Cable loading	Unknown
BM200	Cable loading, buried	Installation of new buried cable in an existing buried cable terminal housing
BM21	Cable loading	Cost of constructing a concrete pad for a DLC Unit
BM22	Cable loading	Cost of placing 6 16 foot ground rods and 00 conductor as specified by the engineer.
BM25	Cable loading	Unknown
BM26	Cable loading	Unknown
BM2A	Cable loading	Housing auxiliary ground assembly unit
BM2A-1	Cable loading	Housing auxiliary ground assembly unit
BM2B	Cable loading	Housing ground assembly unit
BM2C	Cable loading	Existing facility bonding assembly unit
BM2D	Cable loading	Existing cable rebonding assembly unit, includes bonding harness and a single bonding connector
BM2E	Buried pedestal loading	Locator wire assembly unit
BM2G	Cable loading	Connects new cable grounding shields in an existing terminal housing
BM2P	Buried pedestal loading	Adds a bare number 6 AWG ground wire between tow or more pedestals
BM3	Cable loading	Unknown
BM36	Cable loading	Repeater housing assembly unit, stub/pole mounted
BM3G	Cable loading	Connects an existing cable grounding shield in a new terminal housing
BM4	Cable loading	Unknown
BM4311	Cable loading, buried	Reenforced filter fabric fence assembly unit
BM5	Cable loading	Unknown
BM50	Cable loading, aerial or buried	Splicing of aerial drop wire to buried cable
BM50-12	Cable loading, aerial or buried	Splicing of aerial drop wire to buried cable
BM50-6	Cable loading, aerial or buried	Splicing of aerial drop wire to buried cable
BM51	Cable loading	Unknown
BM52	Buried pedestal loading	Pedestal post number assembly unit
BM52-1	Buried pedestal loading	Route and pedestal markers for existing pedestals

Appendix 2-A (Continued)

RUS Engineering Symbols — Outside Plant

RUS Code Prefix	Equipment Type	Description
BM53	Cable loading, buried	Buried cable warning sign assembly unit
BM55	Cable loading	Splice location assembly unit
BM56	Buried pedestal loading	Pedestal renumbering
BM57	Cable loading, buried	Cable splice locating and grounding unit
BM58	Cable loading, buried	Pole mounted warning sign
BM60	Cable loading, buried	Underground pipe crossing assembly unit
BM61	Cable loading, buried	Underground non-pipe crossing assembly unit
BM62	Cable loading, buried	Unknown-conduit assembly unit
BM63	Cable loading, buried	Underground pipe crossing assembly unit placed in an open trench
BM64	Cable loading, buried	Underground non-pipe crossing assembly unit
BM65	Cable loading, buried	Labor and material to install split-pipe with a diameter of 2 inches. Unit includes excavation and backfilling.
BM66	Cable loading	Bridge attachments
BM67	Cable loading, buried	Innerduct
BM6M	Cable loading, aerial or buried	Suspension strand assembly unit
BM70	Cable loading	Unknown
BM71	Cable loading, buried or underground	Rock excavating unit
BM72	Cable loading, buried or underground	Asphalt assembly unit
BM73	Cable loading, buried or underground	Concrete assembly unit
BM74	Cable loading, underground	Rock excavation duct unit
BM75	Cable loading	Warning tape unit
BM76	Cable loading, buried or underground	Ripping unit
BM78	Cable loading	Unknown
BM8	Cable loading	Pigtail
BM80	Cable loading	Riser guard
BM81	Cable loading	Riser guard
BM82	Cable loading	Riser guard
BM83	Cable loading	Buried service guard
BM84	Drop loading	Mobile home post assembly unit
BM85	Cable loading	Unknown

Appendix 2-A (Continued)

RUS Engineering Symbols — Outside Plant

RUS Code Prefix	Equipment Type	Description
BM86	Cable loading	Unknown
BM89	Cable loading	Unknown
BM90	Cable loading, buried	Compartmental core cable carrier stub assembly unit
BM91	Cable loading, buried	Labor necessary to figure eight out 1 lineal foot of fiber optic cable.
BM93	Cable loading	Unknown
BM95	Drop--aerial from buried	Cost of providing connection from new buried plant terminal housing to existing aerial drop wire via a vertical run of BFC2-22 wire. Max Distance from pole is 20 feet.
BM96	NID loading	36 inch mobile home post for an nid
BM97	Cable loading	Unknown
BM98	Cable loading, buried	Labor and material required to backhoe new cable to required depth
BM99	Cable loading	Unknown
BMCC	Cable loading	Labor and material required to cut and repair an existing telephone facility of 25 pairs or less. Splice case and splicing included in this unit.
BMCP	Cable loading, buried	Labor and materials required to cut and repair an existing galvanized or plastic pipe
BMDB	Cable loading, buried	Directional bore unit which places a 3 inch steel pipe under a highway
BMPB	Cable loading, buried fiber	Labor required to place 1 foot of buried fiber under an existing obstacle or through BM60, 61, or 66 and reroll cable back onto reel to avoid cutting the facility.
BMPD	Cable loading, buried	Plow duct assembly unit 1 lineal foot of HDPE plow duct
BMPLOW	Cable loading, buried	Buried plow unit
BMRC	Cable loading, buried	Remove and replace required sections of culvert to place cable in order to prevent cutting of proposed facilities
BMRT	Cable loading, buried	Repeater housing mounting unit
BMSEED	Cable loading, buried	Seeding right of way
BMSS-2	Manhole unit, loading	Manhole/bore pit safety shoring
BMTR	Cable loading, buried	Trenching unit
BMTSS	Cable loading, buried	Trench safety shoring unit
BMUD	Cable loading, buried	Innerduct used to pull buried cable through

Appendix 2-A (Continued)

RUS Engineering Symbols — Outside Plant

RUS Code Prefix	Equipment Type	Description
BMWT	Cable loading, buried fiber	Warning tape assembly unit
C	Cable, aerial copper-nonfilled	Aerial nonfilled cable units
CF	Cable loading, aerial	Aerial figure 8 cable unit
CFL	Cable loading, aerial	Figure 8 cable assembly unit
CO	Cable, aerial fiber	Aerial filled fiber optic cable units
COINN	Cable loading, aerial	Innerduct, 1.25" orange, lashed to strand and used to pull Aerial cable through
CW	Cable, aerial copper-filled	Aerial filled cable units
E	Cable loading, buried	Cost of burial of 1000 feet of cable
EHS	Cable loading, fiber	Unknown 5/16 type of strand
FO	Cable loading, fiber	Fiber optic splice closures and organizers
HA	Cable loading, aerial	Aerial splice closure unit
HBF	Cable loading, buried	Buried filled splice closure
HC	Cable loading, copper	Copper cable splicing unit
HO	Cable loading, fiber	Fiber optic cable splicing unit
HU	Cable loading, underground	Underground splice closure units
INN	Innerduct	Innerduct
K&B	Cable loading, buried	K&B brand vault splice closure
MUL	Innerduct loading	Muletape
NID	NID	Network interface device, no housing protectors
NIP	NID	Network interface device, has housing protectors
NPE	Guy assembly units-existing poles	Guy assembly units-existing poles
OPF	Cable loading, fiber	Fiber optic splice cabinets
OV	Cable loading, buried fiber	Moore surface entry optivault fiber optic vault
P1	NID loading	Outside station protector assembly units
PC	Aerial cross Connect	Cross-connecting assembly units
PDS	SAI--aerial	SA interface cabinet units
PE	Pole loading	Guy assembly units
PF	Pole loading	Anchor assembly units
PG	Loading coil, aerial	Aerial plant terminal/loading coil units
PM	Pole loading	Ground and misc. assembly units
PM1	Pole loading	Pole lightning protection assembly
PM11	Pole loading	Guy guard

Appendix 2-A (Continued)

RUS Engineering Symbols — Outside Plant

RUS Code Prefix	Equipment Type	Description
PM12	Pole loading	Sidewalk guy arm
PM14	Pole loading	Push brace assembly
PM15	Pole loading	Unknown
PM2	Pole loading	Pole ground assembly
PM2-1	Pole loading	Auxiliary ground rod assembly
PM21	Cable loading	Central office cable entrance
PM22	Cable loading	Central office ground system
PM2A	Pole loading	Ground wire assembly
PM30	Cable loading, aerial	Unknown
PM4	Pole loading	Cable extension arm
PM4A	Pole loading	Cable extension arm
PM5	Pole loading	Pole stepping assembly
PM52-1	Pole loading	Pole marking, per pole, route and pole numbering
PM6	Pole loading	One wood pole key
PM7	Pole loading	Two wood pole keys
PM8	Pole loading	One wood key and one metal key
PM9	Pole loading	Two wood keys and one metal key
PM90	Cable loading, aerial	Compartmental core cable carrier stub assembly unit
PM91	Cable loading, aerial	Compartmental core cable carrier stub assembly unit
Pole	Poles	Pole units
R	Cable loading, aerial	Right-of-way clearing units
REP	Repeater housing	Repeater for T1 cables
RM	Right-of-way clearing units	Reclearing of existing right of ways
SC	OTHER	Unknown
SEA	Drop--aerial	Aerial service entry assembly units
SEB	Drop--buried	Buried service entry assembly units
SEK	Drop--aerial from buried	Aerial from buried service entry assembly units
Sli	Slick	Slick units
Str	Cable loading, aerial	Support strand
U	Cable, underground copper-nonfilled,	Underground nonfilled cable units
UCV	Coaxial cable, underground	Coaxial cable
UD	Conduit	Underground conduit assembly unit
UDL	Conduit loading	Pre-cast collars

Appendix 2-A (Continued)

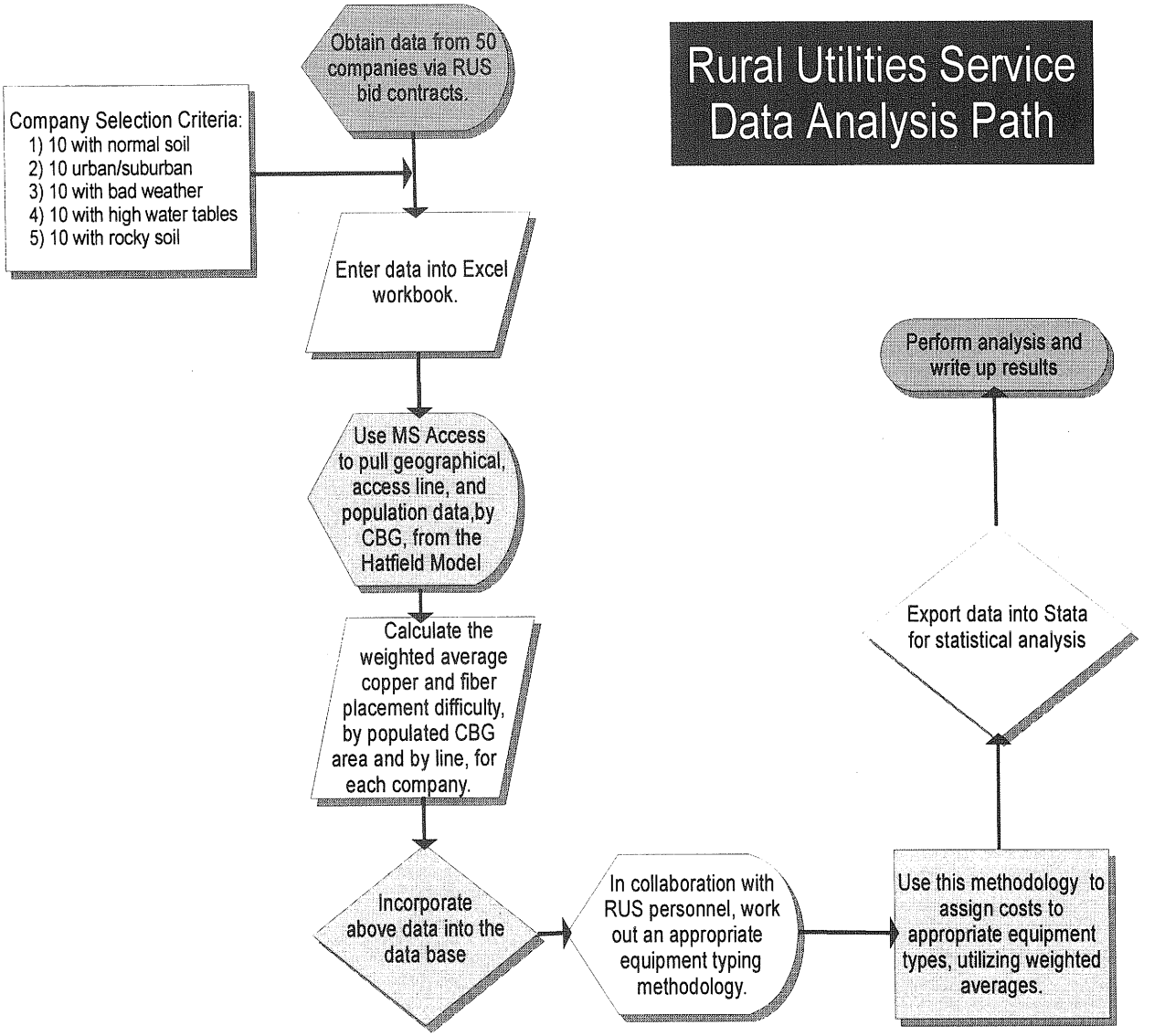
RUS Engineering Symbols — Outside Plant

RUS Code Prefix	Equipment Type	Description
UF	Cable, underground copper-filled	Underground filled cable units
UG	Loading coil, underground	U/G cable loading coil units
UH	Handhole unit	Handhole assembly unit
UM	Manhole unit	Manhole assembly units
UO	Cable, underground fiber	Underground filled fiber optic cable

Source: Authors; construct.

Appendix 2-B

Rural Utilities Service Data Analysis Flow Chart



Appendix 2-C

Impact of Surface Texture, Water Depth and Rock Hardness on Cost Estimates in BCPM 3.0, Hatfield 4.0 and Hatfield 5.0

The cost proxy models assume that there are different costs for installing cable and structures depending on surface texture, water depth, and rock hardness. The purpose of this appendix is to describe how the BCPM 3.0 and the Hatfield 4.0 and 5.0 models adjust installation costs to take into account varying geological conditions.

Terrain Factor Usage in BCPM 3.0

Water Depth and New Terrain Factor

Table 2-C below indicates how water depth is factored into the cost of outside plant. If the water depth is less than or equal to the critical water depth of 3 feet, the cost of installation is increased by 30 percent.

> As for the New Terrain Variable, from the BCPM documentation comes the following "This field is (and will be) empty in the data as delivered ... Note that the last character of each of these records will be a comma, indicating that a field is logically present but actually missing at the end."[55] Currently the NewTerrainFactor multiplier is set to 1. The logic has been included in the model in order to accommodate a future variable that will be used to identify extraordinary terrain conditions.[56]

---

[55] Benchmark Cost Proxy Model; Model Methodology, p. 33. Note: This is from the documentation for BCPM 2.5. The table referred to is the same in BCPM 3.0 with the same default values. Since no documentation on the NewTerrainFactor was found in the BCPM 3.0 documentation, it is assumed that the quotes above are still valid. In fact, in runs of the BCPM 3.0 these factors do not appear in the Miscellaneous Inputs tab of loop analysis files generated by the review option.

[56] Benchmark Cost Proxy Model; Algorithms, Attachment 8, p. 4. Note: This is from the documentation for BCPM 2.5. The table referred to is the same in BCPM 3.0 with the same default values. Since no documentation on the NewTerrainFactor was found in the BCPM 3.0 documentation, it is assumed that the quotes above are still valid.

Table 2-C

Terrain Inputs and Surface Impacts

Critical Water Depth	3	Depth in feet at which water impacts placement costs
Water Factor	30.0%	Percent cost increase for presence of water within critical depth
New Terrain Trigger	5	Value that triggers new terrain variable multiplier
New Terrain Factor	1	Cost multiplier when new terrain variable exceeds trigger point
Min Slope Trigger	12	Point at which minimum slope effects placement distance
Min Slope Factor	1.100	Change in distance due to increased average slope
Max Slope Trigger	30	Point where presence of very high slope causes yet more cable
Max Slope Factor	1.0500	Change in distance due to a maximum-only slope presence
Combination Slope Factor	1.200	Secondary change in distance due to substantial slope

Source: Miscellaneous Inputs tab of the BCPM 3.0.

Rock Hardness and Soil Surface Texture

The rest of this section of this appendix is devoted to explaining how U.S. Geological Survey (USGS) data on soil structures are used in the cost calculations of the BCPM 3.0 model. All the formulas discussed below may be found in the *Loop* module of BCPM 3.0. A copy of this, with ouput from a New Hampshire wire center, is included with this Appendix for purposes of illustration. The file name is *BCPM 3.0 Loop*.

There are several columns in the *Grid Data* tab of the *BCPM 3.0 Loop* workbook that contain USGS data which are used in the BCPM 3.0 cost algorithms. These are:

column E *Depth to Bedrock* (Inches)
column F *Rock Hardness*, designates the hardness of the bedrock
column G *Soil Surface Texture*
column H *Water Table Depth (feet)*
column I *Minimum Soil Slope,* and
column J *Maximum soil slope.*

The data from these columns is used to derive the values found in the following columns of the *Grid Demographics* tab of the workbook:

column W *Copper Depth Condition*
column X *Fiber Depth Condition*
column Y *Water Cost Multiplier*, and
column Z *Surface Indicator.*

Column Z--*Surface Indicator*, cell Z3 contains the following formula:

```
=IF(ISBLANK(SurfaceSoilTexture),0,If(ISERROR(VLOOKUP(SurfaceSoil
Texture,SurfaceTextureTable,2))=TRUE,0,VLOOKUP(SurfaceSoilTexture,
SurfaceTextureTable,2))).
```

The *Surface Texture Table* is found in the Fixed Tables tab of the workbook. This table is a lookup table which contains all the USGS soil surface texture symbols and their associated impact code. This impact code is either 0 or 1.

The above formula for *Surface Indicator* says that: If cell G3 of the *Grid Data* tab is blank, Z3 = 0, if G3 contains a symbol which is not found in the *Surface Testure Table* then Z3 = 0, if neither of these conditions hold then the value for Z3 is an impact code, 0 or 1, which is found by matching the USGS symbol in cell G3 to the corresponding USGS symbol in the *Surface Texture Table* lookup table and returning the appropriate impact code to cell Z3. As this discussion illustrates the value of column Z-- *Surface Indicator* can ONLY be 0 or 1.

This value of Z3 is used to help determine the values of column W--*Copper Depth Condition* and column X--*Fiber Depth Condition*. For example, column W--*Copper Depth Condition,* cell W3, contains the following formula:

```
IF(AND(DepthtoBedrock<= NormalUGBuriedCover ,
RockHardness="HARD"), 1,
IF(AND(DepthtoBedrock>NormalUGBuriedCover,SurfaceIndicator=0),3,2)
```

Column E of the *Grid Data* tab, is the *DepthtoBedrock* column. This column contains data on the depth to bedrock measured in inches. Column F, *RockHardness*, indicates the hardness of the bedrock and contains the values HARD or SOFT, or is blank. *NormalUGBuriedCover* is the normal underground depth for copper and is found in C5, of the *Miscellanous Inputs* worksheet. The default value is set at 24 inches. Column Z, the *Surface Indicator* column, was discussed above.

The formula for *Copper Depth Condition* states that, IF *DepthtoBedrock*, is less than or equal to the *NormalUGBuriedCover* of 24 inches and IF the value for *RockHardness* is equal to "Hard" THEN the *Copper Depth Condition* value for cell W3 = 1(Hard Rock). However, IF *DepthtoBedrock* is greater than the *NormalUGBuriedCover* of 24 inches, and IF the value of Z3, *SurfaceIndicator* is = 0, THEN the *Copper Depth Condition* value for cell W3 = 3 (Normal). IF neither of the above two conditions is true, THEN the *Copper Depth Condition* value for cell W3 = 2 (Soft Rock). A similar formula is found in column X--*Fiber Depth Condition*. In the formula for fiber, *NormalUGBuriedCover* is changed to *NormalFiberCover* and is set at a default depth of 36 inches.

Section 6.11 from the December 11, 1997 edition of the BenchMark Cost Proxy Model Release 3.0; Model Methodology document states that

> U.S.G.S. and Soil Conservation Service data for four terrain characteristics that impact the structure and placement cost of telephone plant are included as inputs to BCPM 3.0 by CBG and assigned to an ultimate grid. These terrain variables include depth to water table, depth to bedrock, hardness of bedrock, and surface soil texture. Combinations of these characteristics determine one of four placement cost levels.

Placement Cost Levels (increasing placement difficulty)

- (Normal) Neither water table depth nor depth to bedrock is within placement depth for copper or fiber cable, and surface soil texture does not interfere with plowing.
- Either soft bedrock is within cable placement depth or surface soil texture interferes with plowing.
- Hard bedrock is within cable placement depth.
- Water table is within cable placement depth."[57]

Several conclusions about the role of the *Surface Indicator* variable may be drawn from this quotation. The values of 0 and 1 found in the *Impact* Column of the Surface Texture Table, located in the *Fixed Tables* tab, can be said to be 0 = Normal, and 1 = Causes interference with plowing. So, the wealth of Soil types available in the Surface Texture Table is reduced to a two-code classification scheme, with 0 denoting Normal Soil and 1 denoting soil that interferes with plowing or Soft Rock.

These values are then used in conjunction with the following variables:

NormalFiberCover 36 inches
NormalUGBuriedCover 24 inches
DepthtoBedrock
RockHardness

to determine the values found in the *Copper Depth Condition* and the *Fiber Depth Condition* columns. As stated earlier, these values are 1 for Hard Rock, 2 for Soft Rock, and 3 for Normal. For example, if the value in cell W3 of the *Copper Depth Condition* column is equal to 1, then the formula in cell AO3 in the *Main Feeder Buried Copper Structure $* column of the *MainFeeder* tab will be directed to use the structure costs from the *HardRockStructure* table in its cost determination algorithm.

---

[57] BenchMark Proxy Model Release 3.0; Model Methodology, December 11, 1997, section 6.11, p. 47.

The effect of a high water table is taken into account in column Y -- *Water Cost Multiplier* which contains the formula:

=IF(WaterTableDepth<CriticalWaterDepth,1+(WaterFactor/100),1)

The formula for *Water Cost Multiplier* states that IF the value of cell H3 -- *Water Table Depth (feet)* in the *Grid Data* tab is less than the *CriticalWaterDepth* of 3 feet, found in cell C16 of the *Miscellaneous Inputs* tab, THAN Y3 = 1+(*WaterFactor*/100), or 1+(30%/100)=1.3. However, IF the value in H3 is greater than the *CriticalWaterDepth* than Y3 = 1, and costs are not affected.

One of the ways in which these terrain values are used in the cost algorithms is illustrated by examining the formula found in cell AO3 in the *Main Feeder Buried Copper Structure $* column of the *MainFeeder* tab, reproduced below.

=IF(MainFdrSegmentBurDistance=0,0,CopperMainFdrStructureRatio*WaterCostMultiplier*MainFdrSegmentBurDistance*IF(FiberTestColumn="None",VLOOKUP(Density,CHOOSE(CopperDepthCondition,HardRockStructure,SoftRockStructure,NormalStructure),4),VLOOKUP(Density,CHOOSE(FiberDepthCondition,HardRockStructure,SoftRockStructure,NormalStructure),4))).

This formula uses the terrain values in two ways. If the *MainFdrSegmentBurDistance* is greater than 0, then a value is created by multiplying the *Water Cost Multiplier*, the *CopperMainFdrStructureRatio*, and the *MainFdrSegmentBurDistance* together. This value is then multiplied by a cost value drawn from the Buried Feeder Cost Column of either the *HardRockStructure*, *SoftRockStructure*, or the *NormalStructure* tables, found in the *Density by Unit Tables* tab. The cost value chosen is determined by the value in R3 -- *Density-Total HH/Sqmi* of the *Grid Demographics* tab and by the values found in either the *Copper Depth Condition Column* or the *Fiber Depth Condition* column, depending on whether BCPM 3.0 has determined fiber or copper to be the lowest cost feeder option.

The various cost values found in the *HardRockStructure*, *SoftRockStructure*, and the *NormalStructure* tables are either the BCPM 3.0 default values or user-determined input values.

Appendix 2-D

The Calculation of Weighted Geological Factors in the RUS Access Database

This report includes data on the cost of installing outside plant facilities. This data was derived from contracts between RUS companies and private vendors. Pursuant to RUS requirements, the prices were established through a competitive bid process. Vendors that submitted winning bids are required to abide by the engineering standards established by the RUS.

The contract data is available in a form that does not permit an activity to be connected with a specific CBG. It is possible to match the contract cost data only with composite geological information for each company. This Appendix describes how the geological code information for each CBG was aggregated into a single factor for each of the companies. Geological information was extracted from the Hatfield 4.0, 5.0 and the BCPM 3.0 cost proxy models.

The following example uses data extracted from Hatfield Model 4.0 as a proxy. Data from BCPM 3.0 and Hatfield 5.0 were treated in a similar fashion.

The composite geological code data derived from the Hatfield 4.0 Model is found in the MS Access *RUS Outside Plant* database in the *Hat 4-1 Weighted Placement Difficulty* query.

Columns whose titles start with the phrase, "Soil Type Indicator Weighted by Pop," are concerned with the following data:

The soil type indicator for a CBG: 1=normal; 2=soft rock; and, 3=hard rock.

Populated area of a CBG.

In this case the weighted, or composite, average soil type indicator for a company is determined by weighting the soil type indicator for each of the company's CBGs by the populated area for each CBG. For example, in Table 2-D, this figure is calculated by

summing the product of Difficulty level times the Populated area per CBG for all CBGs served by a company and dividing this Total by the Sum of the Populated area for all the CBGs:

196.6189/142.7860=1.377018293.

Table 2-D

Calculating the Weighted Average Soil Type Indicator

Company	CBG	Area	Populated Area-sq Miles	Difficult Level	Difficulty Times Pop Area	Weighted Placement
Zippy	420979	22.20	20.6648	2	41.3295	
Zippy	420979	11.59	4.3874	2	8.77475	
Zippy	420979	22.15	16.2145	2	32.4290	
Zippy	420979	41.48	39.2460	1	39.2459	
Zippy	420979	15.95	12.4095	1	12.4095	
Zippy	420979	20.14	19.4209	1	19.4209	
Zippy	420979	22.62	17.8767	1	17.8766	
Zippy	421070	13.08	12.5662	2	25.1324	
TOTAL			142.7860		196.618	1.3770182

Source: Authors' construct.

Columns whose titles start with the phrase, "Soil Type Indicator Weighted by Total Lines," are concerned with the following data:

The soil type indicator for a CBG; 1=normal; 2=soft rock, and; 3=hard rock.

Total Number of Lines per CBG.

In this instance, the weighted average soil type indicator for a company is determined by using the total number of lines per CBG. The weighting is done according to a procedure similar to that outlined in Table 2-D, above.

The column titled, "Weighted High Water Indicator Pop," concerns itself with the following:

> The high water indicator value per CBG; 1=no high water table, 2=a high water table.
>
> Populated area of a CBG.

The Weighted high water indicator is a weighted average indicator of the presence of a high water table in a company's area of operation. For the column discussed here the weighting is done by Populated Area per CBG. The weighting calculations performed are similar to those in Table 2-D, above.

The column titled, "Weighted High Water Indicator Lines," concerns itself with the following:

> The high water indicator value per CBG; 1=no high water table, 2=a high water table.
>
> Total Number of Lines in a CBG.

The Weighted high water indicator is weighted average indicator of the presence of a high water table in a company's area of operation. For the column discussed here the weighting is done by Total Number of Lines per CBG. The weighting calculations performed are similar to those in Table 2-D above.

Columns beginning with the phrase, "Placement Difficulty Level Weighted," use both the Weighted high water indicator and the soil-type indicator to come up with a Placement Difficulty Level, which is weighted first by populated area and then by Total number of lines.

Appendix 2-E

Formulas from Access Queries used in Cable Weighting Calculations

Formulas from the *cable loadings to cable ratios* query

Total Cable ratio: Nz([RUS Cross-tab by cable loading type]![Cable Loading])/Nz([RUS Cross-tab by cable Type]![SumOfExtended Cost1])

Aerial Ratio: Nz([RUS Cross-tab by cable loading type]![Cable Loading, Aerial])/(Nz([RUS Cross-tab by cable Type]![Cable, Aerial Copper-filled])+Nz([RUS Cross-tab by cable Type]![Cable, Aerial Copper-nonfilled])+Nz([RUS Cross-tab by cable Type]![Cable, Aerial Fiber]))

Aerial or Buried Ratio: nz([RUS Cross-tab by cable loading type]![Cable Loading, Aerial or Buried])/(nz([RUS Cross-tab by cable Type]![Cable, Aerial Copper-filled])+nz([RUS Cross-tab by cable Type]![Cable, Aerial Copper-nonfilled])+nz([RUS Cross-tab by cable Type]![Cable, Aerial Fiber])+nz([RUS Cross-tab by cable Type]![Cable, Buried Copper])+nz([RUS Cross-tab by cable Type]![Cable, Buried Fiber]))

Buried or Underground Ratio: nz([RUS Cross-tab by cable loading type]![Cable Loading, Buried or Underground])/(nz([RUS Cross-tab by cable Type]![Cable, Buried Copper])+nz([RUS Cross-tab by cable Type]![Cable, Buried Fiber])+nz([RUS Cross-tab by cable Type]![Cable, Underground Copper-filled])+nz([RUS Cross-tab by cable Type]![Cable, Underground Copper-nonfilled])+nz([RUS Cross-tab by cable Type]![Cable, Underground Fiber]))

Buried Ratio: NZ([RUS Cross-tab by cable loading type]![Cable Loading, Buried])/(Nz([RUS Cross-tab by cable Type]![Cable, Buried Copper])+Nz([RUS Cross-tab by cable Type]![Cable, Buried Fiber]))

Buried Fiber Ratio: NZ([RUS Cross-tab by cable loading type]![Cable Loading, Buried Fiber])/NZ([RUS Cross-tab by cable Type]![Cable, Buried Fiber])

Copper Ratio: Nz([RUS Cross-tab by cable loading type]![Cable Loading, Copper])/(Nz([RUS Cross-tab by cable Type]![Cable, Aerial Copper-filled])+Nz([RUS Cross-tab by cable Type]![Cable, Aerial Copper-nonfilled])+Nz([RUS Cross-tab by cable Type]![Cable, Buried Copper])+Nz([RUS Cross-tab by cable Type]![Cable, Underground Copper-filled])+NZ([RUS Cross-tab by cable Type]![Cable, Underground Copper-nonfilled]))

Fiber Ratio: Nz([RUS Cross-tab by cable loading type]![Cable Loading, Fiber])/(Nz([RUS Cross-tab by cable Type]![Cable, Aerial Fiber])+Nz([RUS Cross-tab by cable Type]![Cable, Buried Fiber])+Nz([RUS Cross-tab by cable Type]![Cable, Underground Fiber]))

Underground Ratio: Nz([RUS Cross-tab by cable loading type]![Cable Loading, Underground])/(Nz([RUS Cross-tab by cable Type]![Cable, Underground Copper-filled])+NZ([RUS Cross-tab by cable Type]![Cable, Underground Copper-nonfilled])+Nz([RUS Cross-tab by cable Type]![Cable, Underground Fiber]))

Formulas from the *Weighted Cable Costs With Geological and Line Data* query

Total Weighted Unit Cost: [Weighted Cost of Aerial Copper Filled Loading]+[Weighted Cost of Aerial Copper Non- Filled Loading]+[Weighted Cost of Aerial Fiber]+[Weighted Cost of Buried Copper]+[Weighted Cost of Buried Fiber]+[Weighted Cost of Underground Copper-Nonfilled]+[Weighted Cost of Underground Copper-filled]+[Weighted Cost of Underground Fiber]

Weighted Cost of Aerial Copper Filled Loading: IIf([RUS Engineering Codes]![Equipment Type]="cable, aerial copper-filled" And [RUS Outside Plant Data]![Number of Units]>0,[RUS Outside Plant Data]![Total Unit Cost]+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Total Cable ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Aerial Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Aerial or Buried Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Copper Ratio]),0)

Weighted Cost of Aerial Copper Non- Filled Loading: IIf([RUS Engineering Codes]![Equipment Type]="cable, aerial copper-nonfilled" And [RUS Outside Plant Data]![Number of Units]>0,[RUS Outside Plant Data]![Total Unit Cost]+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Total Cable ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Aerial Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Aerial or Buried Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Copper Ratio]),0)

Weighted Cost of Aerial Fiber: IIf([RUS Engineering Codes]![Equipment Type]="cable, aerial fiber" And [RUS Outside Plant Data]![Number of Units]>0,[RUS Outside Plant Data]![Total Unit Cost]+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Total Cable ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Aerial Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Aerial or Buried Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Fiber Ratio]),0)

Weighted Cost of Buried Copper: IIf([RUS Engineering Codes]![Equipment Type]="cable, Buried Copper" And [RUS Outside Plant Data]![Number of Units]>0,[RUS Outside Plant Data]![Total Unit Cost]+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Total Cable ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Buried Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Buried or Underground Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Aerial or Buried Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Copper Ratio]),0)

Weighted Cost of Buried Fiber: IIf([RUS Engineering Codes]![Equipment Type]="cable, Buried Fiber" And [RUS Outside Plant Data]![Number of Units]>0,[RUS Outside Plant Data]![Total Unit Cost]+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Total Cable ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Buried Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Buried or Underground Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Aerial or Buried Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Fiber Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Buried Fiber Ratio]),0)

Weighted Cost of Underground Copper-Nonfilled: IIf([RUS Engineering Codes]![Equipment Type]="cable, Underground Copper-nonfilled" And [RUS Outside Plant Data]![Number of Units]>0,[RUS Outside Plant Data]![Total Unit Cost]+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Total Cable ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Underground Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Buried or Underground Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Copper Ratio]),0)

Weighted Cost of Underground Copper-filled: IIf([RUS Engineering Codes]![Equipment Type]="cable, Underground Copper-filled" And [RUS Outside Plant Data]![Number of Units]>0,[RUS Outside Plant Data]![Total Unit Cost]+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Total Cable ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Underground Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Buried or Underground Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Copper Ratio]),0)

Weighted Cost of Underground Fiber: IIf([RUS Engineering Codes]![Equipment Type]="cable, Underground Fiber" And [RUS Outside Plant Data]![Number of Units]>0,[RUS Outside Plant Data]![Total Unit Cost]+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Total Cable ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Underground Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Buried or Underground Ratio])+([RUS Outside Plant Data]![Total Unit Cost]*[cable loadings to cable ratios]![Fiber Ratio]),0)

CHAPTER 3

DIGITAL SWITCHING COST

This chapter provides estimates of investment cost estimates for digital switching. The analysis begins with a discussion of data for small telephone companies. Next, the chapter addresses the cost of switches acquired by large telephone companies. The conclusion of this chapter identifies how these findings can be incorporated into a cost proxy model.

Switch Acquisitions of Small Telephone Companies

The sponsors of the proxy cost models have provided estimates of the cost of switches used by large LECs. This section of the report provides an estimate of the payments made by small telephone companies.

Many small telephone companies receive financing assistance from RUS, which requires telephone companies to report the payments made for new switches. RUS provided data on the cost of digital switches acquired in the past three years. The data is found in the Excel worksheet **rus central office data.xls.** That file contains the purchase price for 181 switching machines. Of the 181 data points, 139 involve the acquisition of new switches; the remaining observations are associated with augmenting an existing switch.

The equipment prices recorded in the file exclude the LECs' engineering costs. Based on data analysis undertaken by RUS, it is recommended that a loading of 8 percent be added to the costs to reflect telephone company engineering by small companies.[1] The prices do reflect the vendor's cost of installing the equipment.

Model Specification

In the regressions below, the following functional form is used to estimate how investment per switch varies as the number of equipped lines increases:

$$\text{investment per switch} = \beta_1 + \beta_2 * \text{lines} + \epsilon$$

Where:

β_1 = The fixed cost of a switch
β_2 = The investment per equipped line
ϵ = random error

This linear specification of the investment function is widely used for modeling costs in the telecommunications industry. For the purposes of this exercise, there is an important limitation of the model specification. There was no data on the number of busy-hour messages or busy-hour minutes-of-use, both of which measurements of usage affect the level of investment. Because there is no publicly available data on the level of usage by switch location, these variables were not included in the analysis.

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[1] Comments of the Rural Utilities Service, *In the Matter of Forward-Looking Mechanism for High Cost Support for Non-Rural LECs*, CC Docket No. 97-160, August 8, 1997, p. 2. This value is slightly higher than the 7 percent engineering loading factor used in the benchmark cost model 2 (BCM2). Folder Table Inputs, Cell B36. BCM2 was sponsored by U S WEST and Sprint in 1996.

The models have an input for telephone company engineering. In BCPM, this input is found in folder "Cost Table Inputs," cells F107 through F109.

The data points have been classified as either "host" or "remote switches."[2] The classification is based on information contained in the RUS contracts. The distribution of lines on these two types of switches are shown on Table 3-1.

Table 3-1

Descriptive Statistics: RUS Switches

Percent Distribution	Line Size on Remote Switching Machines	Line Size on Host Switching Machines
1%	20	350
5%	73	350
10%	109	412
25%	201	500
50%	300	1069
75%	717	1920
90%	1334	2561
95%	1587	17020
99%	2480	17020
Mean	552	2258
Standard deviation	597	4314
Observations	125	14

Source: Authors' construct from RUS data.

[2] BCPM 1.1 identified if a switch was a host or a remote. The *Local Exchange Routing Guide* (LERG) data base, produced by BELLCORE, was the primary source for this information. The LERG data base also identifies the host that serves each remote switch.

The actual specification of the model is a little more complicated than suggested by the above equation. In recognition that the "getting started" cost is greater for a host switch than for a remote, a dummy variable was included for the host switches (5ESS, EWSD, DMS-100, and DMS-10). The investment per equipped line is also allowed to differ for host and remote switches. Taking into account that investment for remote and host switches differ, the following functional form resulted:

investment per switch =

$\beta_1 + \beta_2 *$ host_indicator $+ \beta_3 *$remote_lines $+ \beta_4 *$ host_lines $+ \epsilon$

Where:

β_1 = The fixed investment for a remote switch = _cons

β_2 = The incremental fixed investment for a host switch = host

β_3 = The incremental investment per line termination on a remote switch = remoline

β_4 = The incremental investment per line termination on a host switch = hostline

ϵ = random error

Note that β_2 is the incremental fixed investment for a host switch. The total fixed investment for a host switch is $\beta_1 + \beta_2$.

Cost of Software Upgrades

The data set includes information on the cost of upgrades to existing switches. For example, LECs periodically purchase new software or processors. The data from the upgrades have not been included in the reported regressions, because, for most of the

upgrades, the contracts do not indicate the number of lines associated with the upgrade. The cost of the upgrades varies greatly, and without data on the number of lines, it is difficult to explain the variation in cost. Furthermore, the focus of the universal service funding and unbundled network element modeling has, arguably, been the cost of installing new switches.[3]

Arguably, the cost of upgrades should be included in the life-cycle analysis of switches. An official with RUS suggested to the authors that, historically, software upgrades occurred on average every five years. The very limited data available suggests that this is a reasonable estimate of the historical practices of the industry.[4]

For ten observations in the data set, the cost of the software upgrade could not be isolated.[5] For these ten cases, the average cost was $95,810. If a discount rate of 10.05 percent and a 14-year depreciation life for switching machines are assumed, the fixed cost of a host switch is increased by $196,649.[6]

During the life-cycle of the switch, the level of traffic and the number of subscribers is likely to increase. Therefore, it would be inappropriate to increase the getting started cost of a host switch by $196,649, unless the level of demand was

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[3] Considering the cost of a new switch is consistent with the approach taken when modeling the cost of the loop. When modeling the cost of the loop, parties have estimated the cost of constructing an new loop network. The cost estimates for the loop have not been based on a mix of new installations and expanding the capacity of existing facilities.

[4] The five-year cycle for upgrades may not be appropriate, prospectively. Due to such changes as IntraLATA pre-subscription and local number portability the life-cycle of the software may be shorter in the coming years.

[5] In the contracts, the cost of the upgrades are reported as being incurred only at the host switch.

[6] The cost of money and depreciation life values were obtained from the State Members' Second Report on the Use of Cost Proxy Models, FCC CC Docket No. 96-45, April 21, 1997.

The derivation of the $196,649 is found in the excel worksheet that contains the switch investment data.

increased simultaneously.[7] Quantifying the long-term demand for telecommunications services is notoriously difficult.[8] Therefore, rather than becoming embroiled in such an undertaking, it is recommended that commissions focus on working with current demand and cost.

For two of the software upgrades, the number of lines that benefitted from the upgrade is known. For these two installations, the software upgrade cost $20.78 per line. If it is assumed that software upgrades are required every five years, that the switch has a fourteen year life, and that the cost of money is 10.05 percent, the present discounted value of the upgrades increases to approximately $25.25 per line.

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[7] To illustrate the need to consider more than just the increased cost of software upgrades or equipment acquired after the initial installation, consider the following data from a sensitivity run for the State of Pennsylvania. When the number of lines was increased by 3 percent, the model, based on the default input values, reported a decline in the monthly cost of $0.20. The costs decline because many quasi-fixed costs, such as poles, would be recovered from a larger number of subscribers.

The authors believe it is reasonable to assume that the additional investment per line will cost approximately $20 to $50 more than the initial cost of switching equipment and that the annual charge factor for switching equipment is approximately 25 percent. For the 3 percent additional lines, the incremental cost per line, not identified by a static proxy model, would be approximately $0.0125 ($35 incremental investment * .25 annual charge factor * .03 line growth / 12 months). This numerical example suggests that economies of density can be greater than the additional costs associated with acquiring additional equipment for existing switching machines.

The assumption that added lines cost 20 percent more than initially-equipped lines is based on information provided by the RUS to the FCC. "Comments of the Rural Utilities Service," *In the Matter of Forward-Looking Mechanism for High Cost Support for Non-Rural LECs*, CC Docket No. 97-160, August 8, 1997, p.3.

[8] During a proceeding before the FCC, this view was expressed by the LECs. The FCC had proposed that LEC usage forecasts be used to allocate the cost of new investments between regulated and non-regulated services. The allocation of common equipment was to be based on relative use during the period when non-regulated use was at its highest occupancy rate during the equipment's life cycle. After public notice, the FCC chose to base cost allocations only on three-year demand forecasts, a period significantly less than the economic life of most outside-plant and central-office facilities. The suppliers of the new services informed the FCC "that they cannot [reliably] forecast relative non-regulated and regulated usage over the lengthy depreciation lives of most network plant." The FCC accepted the LECs' position and remarked that long-term forecasts are closer in method to "fortune-telling...[than] reasoned analysis." See, "Separation of Costs of Regulated Telephone Service From Costs of Nonregulated Activities," CC Docket no. 86-111, 2 Federal Communications Commission Record 6283, 6285 (first quote), 6288 (second quote).

Terminating a Remote on a Host Switching Machine

The RUS contracts indicate the number of equipped lines associated with the investment. For eleven observations, there are no equipped lines and no software upgrade was ordered. For these offices, the reported investment levels are the additional costs incurred at the host when it terminates the umbilical DS1 links between the host and the remote. Because the purpose of this analysis is to identify the total switch investment, the incremental host investments have been excluded from the data set used for regression analysis.

The cost of terminating the remote on the host should be included in the proxy models. Table 3-2 indicates the incremental investment associated with terminating a remote on a host switch.[9] The cost varies due to the lumpy nature of the equipment. DS1 connections between the host and remote are terminated on modules that can handle a discrete number of DS1 links.[10] The getting started cost of the module provides capacity for up to 20 DS1 links. If a new remote is terminated on the host, the effective cost of terminating the remote on the host depends on the extent to which a new module must be acquired. If there is sufficient capacity on the existing modules, the incremental cost will be low. If, on the other hand, a new module must be acquired, the effective cost is much higher.

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[9] The incremental investment was calculated by dividing the investment associated with the terminations on the remotes by the number of in-service remote switches supported by the investment.

[10] The number of DS1 links between the host and remote is largely a function of the amount of busy-hour CCS traffic.

Table 3-2
Incremental Investment Associated with Terminating a Remote on a Host Switching Machine

Mean	27,598.29
Standard Deviation	26,455.61
Minimum	4,298.4
Maximum	98,655
Number of Host Switching Machines	11

Source: Authors' construct.

Table 3-2, above, indicates that the *average* cost of terminating a remote on a host switch is $27,598.29.[11] The incremental cost of these links are not included in the regression results reported below. When the models are run, it is recommended that the $27,598 for the host termination be added to the getting started cost of the remote switch.

Many of the remotes included in the data set are line frame units that have varying numbers of line cards. These line units are dependent on the host for originating and terminating calls. Nevertheless, these remote line units can operate on a stand-alone basis. For example, Siemens Stromberg-Carlson provides the following description of the capabilities of its remote line switches that terminate 360, 450, or 1,000 lines:

> When communications with the host office are lost, the RLS [remote line switch] enters the ESS [emergency switching system] mode (if provided). The intranodal switch option is a prerequisite for the ESS feature. While in optional ESS mode, all call processing functions required for line-to-line calls within the RLS are performed by the RLS instead of by the host office. Host office operations assumed by the RLS include the following:

[11] This value excludes the 8 percent LEC engineering cost.

- Provides call progress tones (dial tone, ringback tone, busy tone, etc.).
- Collects either DTMF or rotary-dial pulses.
- Provides call routing for off-hook service and after one, three, or seven digits have been dialed.
- Provides features and enforces restrictions defined by the line class of service.
- Records number of call originations and terminations
- Recognizes call release.
- Provides coin control for paystation lines.
- Provides multiline hunting.

Two 5-line hunt groups can be provided for emergency outgoing service. These connections are separate from the normal RLS-to-host links. Lines in these groups can be reached by dialing 1-,3-, or 7-digit numbers defined by the operating company. [12]

Regression Results for RUS Companies

The following parameter estimates shown in Table 3-3 were obtained from the RUS data set:

Table 3-3

Regression Results: Switching Machine Costs

```
Regression with robust standard errors                Number of obs =     139
                                                      F(  3,   135) = 1030.89
                                                      Prob > F      =  0.0000
                                                      R-squared     =  0.7860
                                                      Root MSE      =  1.0e+05
------------------------------------------------------------------------------
             |               Robust
       total |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        host |   518307.7   88431.19     5.861   0.000     343418.1    693197.4
    hostline |   43.68767   7.11571      6.140   0.000     29.61499    57.76036
    remoline |   140.3432   11.94662     11.748   0.000     116.7164    163.9699
       _cons |   54681.67   5523.894      9.899   0.000      43757.1    65606.23
------------------------------------------------------------------------------
```

Source: Authors' construct.

[12] *Remote Line Equipment: Remote Line Switches 360, 450, and 1000,* Siemens Stromberg-Carlson Publication No. 00-300-04, Issue 8, December 1994, p. 12-13.

In the regression shown above, the parameter estimates suggest that the investment per switch = $\beta_1 + \beta_2$ * host_indicator + β_3 *remote_lines + β_4 * host_lines = 54,681.67 + 518,307.7 * host_indicator + 140.34*remote_lines + 43.69 * host_lines. These results can be used as follows within the proxy models (assuming that the 8 percent engineering loading factor is taken into account elsewhere):[13]

> Investment per host switch = 54,681.67 + 518,307.7 * host_indicator + 43.69 * host_lines = 572,989.4 + 43.69 * host_lines
> Investment per remote switch = 54,681.67 + 140.34*remote_lines exclusive of the host/remote termination

The RUS companies buy switches through either a competitive bidding or a negotiated contract process. If the company is already using a particular type of digital switch, it may decide that it has no choice but to buy the new switch from the same vendor. For example, if the sub-tending host switching machine is manufactured by Lucent Technologies, the LEC must also install a Lucent switch at the remote office. In those situations where the LEC is able to buy a switch from *any* vendor, RUS regulations require the LEC to issue a request for proposals (RFP). The bid selected through the RFP process is referred to as a "competitive bid contract."

The data set indicates whether the switch was purchased as a result of competitive bidding or is a negotiated price. Table 3-4 indicates the cost for the host and remotes when the supplier is selected through a competitive bidding process:

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[13] The data set indicates the number of equipped lines, rather than the number of working lines. Therefore the incremental investment per line termination, $43.69 and $140.34, are the estimates for an additional line of capacity. Digital switches do not operate at full capacity; consequently, where these parameter estimates are used to estimate the cost of providing universal service or unbundled network elements, the values must be divided by the line switch utilization. There is no need to adjust the fixed cost of the switches for utilization, since, by definition, the fixed cost is independent of the level of utilization.

Table 3-4

Regression Results: Switching Machine Costs - Competitive Bid

Regression with robust standard errors

Number of obs	=	48			
F(3, 44)	=	65.15			
Prob > F	=	0.0000			
R-squared	=	0.9172			
Root MSE	=	63367			

total	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
host	517192.7	115740.2	4.469	0.000	283933.6	750451.9
hostline	65.57482	64.4569	1.017	0.315	-64.32953	195.4792
remoline	86.41505	11.79285	7.328	0.000	62.64813	110.182
_cons	45886.07	5054.224	9.079	0.000	35699.95	56072.19

Source: Authors' construct.

The parameter estimates suggest that the competitive bid price for a remote switching machine was 45,886.07 + 86.42*remote_lines. For a host switch, the regression analysis suggests that the cost function was (45886.07. + 517192.7) + 65.57 * host_lines = 563,078.8 + 65.57 * host_lines.

Table 3-5 indicates the cost for the host and remote switches when the price is established through negotiations:

Table 3-5

Regression Results: Switching Machine Costs - Negotiated Bid

Regression with robust standard errors

Number of obs = 91
F(3, 87) = 3738.01
Prob > F = 0.0000
R-squared = 0.7443
Root MSE = 1.1e+05

total	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
host	484971	172216.8	2.816	0.006	142671.4	827270.6
hostline	44.30757	11.32993	3.911	0.000	21.7881	66.82703
remoline	148.4643	15.42105	9.627	0.000	117.8133	179.1153
_cons	67263.28	7805.485	8.617	0.000	51749.03	82777.53

Source: Authors' construct.

The parameter estimates suggest that the negotiated bid price for a remote switching machine was 67,263.28 + 148.46*remote_lines. For a host switch, the regression analysis suggests that the cost function was (67,263.28 + 484,971) + 44.31 * host_lines = 552,234.3 + 44.31 * host_lines.

Discussion of Regression Results

The data set has been used to estimate the price of installing new switches. For this group of purchases, parameter estimates have been made using data on either all purchases, competitive bid purchases, or negotiated bid purchases. Use of the first regression results is recommended, since they reflect the actual mix of acquisitions. These parameter estimates may be used to estimate the cost of providing voice-service, unbundled network elements, or for establishing the cost of providing universal service.

Prior to undertaking this research, the authors held the hypothesis that the price for a negotiated bid would be *higher* than for a competitive bid, because the LEC was

already tied to a supplier. Since the buyer would have little leverage with the seller, the negotiated price was expected to be higher than the competitive bid.

This hypothesis is consistent only with the parameter estimates for the remote switching machines. In those situations, the negotiated price is greater than the amount paid in a competitive bid. This may be because a remote switching machine must be acquired from the manufacturer of the tending host machine. But with regards to the acquisition of a host switching machine, if the existing supplier requests too high a price, the LEC can buy equipment from another vendor. Hence, the buyer has more leverage when negotiating the price for a host switching machine.

Regardless of which estimates are used within the proxy models, the data set provides a good indication of the cost of a host switching machine. In the regression runs, the fixed and per-line investment for the host switch were approximately $560,000 and $50 respectively.

For remote switching machines, the fixed investment is in the neighborhood of $55,000. This represents the getting started cost for a small remote switching machine. Per-line investment for a remote switching machine exhibits a great deal of variance: there is a great deal of difference in the investment per line depending on whether the price is negotiated ($148) or established through a competitive bidding process ($86). The $86 value is lower, in part, because the price is established through a competitive bidding process.[14]

Unfortunately the contracts do not indicate the level of traffic that will be handled by these switches, and busy-hour calling volume and holding times have a significant impact on the design of switching machines. Since usage is positively correlated with the number of lines, the cost impact of usage is effectively included in the per-line investment estimates. Both of the proxy models arbitrarily split the per-line investment between usage and the port cost. As discussed in the monograph *Improving Cost*

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[14] Other factors could be contributing to the lower price in competitive situations. For example, usage could be lower on the switches acquired through the competitive process.

Proxy Models, the appropriate split depends largely on the treatment of the central processor.[15]

Arguably, the investment estimates for RUS companies provided above should be interpreted as being greater than the prices paid by large LECs. The larger LECs have greater buying power than the RUS companies and, therefore, are likely to obtain equipment at lower prices. The magnitude of the differential between the price paid by large and small companies is not clear, and the authors are not aware of any publicly available data that indicates the magnitude of the discount provided to one group of companies versus the other.

There is a second factor that can make the getting-started cost of a switch higher for a large LEC than for a small LEC. Typically, the capacity of the switches produced by large LECs is greater than that of switches purchased by small LECs. Therefore the larger LECs' switches tend to be more expensive. Nevertheless, the capacity of the switches used by the independent telephone companies should not be inferred from the data provided above. Table 3-1 indicates that the largest host and remote switches included in the RUS data base was 2,480 and 17,020 remote and host line terminations respectively.[16] Some RUS companies deploy the DCO switch, which can serve up to 32,400 lines in an end-office configuration.[17] When configured as a network host, the DCO switch can serve up to 70,000 lines and can be connected to various types of remote switches, the largest of which, the RLS-4000, can support up to 4,500 lines.

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[15] David Gabel, *Improving Cost Proxy Models for Use in Funding Universal Service* (Columbus, OH: NRRI, 1996) pp. 31-33.

[16] The data set is not exclusively switches with comparatively small capacity. For example, the data set includes information on the Lucent 5ESS switching machine.

[17] An end office configuration would mean that the entire customer base interfaces with the DCO system via direct wire connections.

Switching Investments: Large Companies

Unlike the RUS companies, large LECs do not release the terms of their contracts with vendors. Fortunately, fairly useful data is available through depreciation report data compiled by the FCC and the Bureau of Economic Analysis (BEA) of the Commerce Department.

The data set includes the following information for each switch: the location of the office in which the switch is installed; the model designation of the switch; the year the switch was first installed; the lines of capacity; the installed cost of the switch; and the switch's cost per line. In a Public Notice, the FCC provided the following description of the data:

> Large incumbent LECs file depreciation rate reports with the Commission pursuant to 47 C.F.R. section 43.43. Prior to filing these reports, companies generally submit depreciation rate studies that include data for each digital switch in operation. The switches in this data set consist of all of the RHCs' digital switches that were reported as installed between 1983 and 1995 in the states specified, with certain exceptions. To increase the reliability of analyses using these data, the following switches were removed from the data set: (1) switches for which there were no lines of capacity, such as those functioning solely as tandem switches; (2) switches with fewer than 1000 lines of capacity; and (3) switches that were deemed to be "outliers" because of unusually high or low per-line

costs.[18] The data set contains at least one state from the area served by each RHC.[19]

Some modifications have been made to the data set; these are documented in the data files accompanying this report.[20] Some of the data classifications did not seem reasonable, and therefore, the type of switch was reclassified. For example, the data set identified as DMS-100 or 5ESS switches certain wire centers that terminated less than 2,000 customers and cost in the neighborhood of $500,000. Based on the authors' past reviews of cost data, it seemed more reasonable to assume that these locations were remote switching machines.

Embedded costs have been converted to 1997 values by using the Turner Price Indexes, which are available by region of the country. For digital switching machines, there is no variation in the index between areas.

The LECs regularly use telephone plant indexes to convert embedded to current cost data. For example, many companies use this methodology to construct annual maintenance charge factors, which are typically expressed as the ratio of current maintenance costs divided by current investment. The denominator, current

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[18] The following procedures were used to identify outliers: (1) if there was a gap of 20 percent or more between the per-line cost of a switch and the next lower, or higher, cost switch, that switch and any others with lower, or higher, per-line cost were excluded; (2) a low-priced switch that failed test 1 was nevertheless retained in the data set if a lower per-line cost switch would have passed test 1 in a previous year; (3) a high-priced switch that failed test 1 was retained in the data set if a higher per-line cost switch would have passed test 1 in a subsequent year. These rules removed about 40 outliers from a data set containing per-line cost data for nearly 3600 switches. In addition, a small number of switches associated with apparent inconsistencies in the studies were not included in the set. In particular, for several locations in California, switches that were at the same location, but had different capacities, types, and years of installation, were reported as having the same per-line costs. These anomalies were judged to be the results of averaging by the respondent, and the switches in these locations were excluded from the data set.

[19] "Spreadsheet of Digital Switching Data from Depreciation Rate Studies Available," CC Dockets Nos. 96-45 and 97-160, Released: August 4, 1997, DA 97-1663.

[20] See file: new log with corrected data.

investment, is estimated by multiplying the yearly net investments by telephone plant indexes.

The accounting records identify the book investment for each switch. In less densely populated regions, remote switching machines are used to terminate customer lines. Remote switching machines are dependent on a host switching machine for interoffice traffic and for setting up and taking down calls. Therefore, part of the cost of the host switching machine should be attributed to customers on the remote switching machine. Because the data in the depreciation reports do not permit identification of the portion of investment on the host switching machine that is attributable to customers on the remote, the econometric cost estimates understate the cost of a serving a rural customer.

The authors do not believe that this understatement causes a large distortion. The incremental cost of handling remote traffic on a host switching machine is often not large. There are costs associated with terminating the trunks, processing the calls, and using the network on the host switch, but in terms of the investment per subscriber, these activities do not require large investments.

Two sets of regression results are presented. First, data from years 1985 forward were used.[21] Prior to the divestiture of AT&T, the Bell Operating Companies purchased almost all of their equipment from their sister company, Western Electric. Because this arrangement impeded development of competitive pricing in the switching market, pre-divestiture data has been excluded. Data from 1984 has also been excluded on the grounds that it was a transitional year, and, therefore, the market prices were not reflective of the competitive conditions that emerged in later years.

For the years 1985 through 1995, there are 3,394 observations in the data base. 2,848, or 84 percent, of these observations are either DMS-100, DMS-100 remotes,

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[21] Limiting the scope of years to the post-1984 era is consistent with the approach taken by the FCC Staff in their own analysis of the data. The Staff's Analysis is discussed in the *Further Notice of Proposed Rulemaking*, CC Docket No. 96-45, July 18, 1997, Par. 130.

5ESS, 5ESS remotes, or EWSD switching machines. The analysis focused on these machines, because the extent to which the other observations are host or remote switching machines is not clear. Furthermore, by limiting the analysis to a few families of products, it possible to obtain more precise parameter estimates.

The number of lines terminated on the RBOC switches is considerably greater than for the RUS companies. Many of the large LECs' host switches are located in urban areas; therefore, it makes economic sense to terminate a large number of lines on these switches. Somewhat surprisingly, there is also a large difference in the number of lines terminated on a remote switch. Some of this difference is attributable to the way the RBOC data set was created. The data set excludes switches with less than 1,000 lines. Hence, the average number of lines reported in Table 3-6, below, is greater than the population mean value.

Table 3-6
Descriptive Statistics: RBOC Lucent and Nortel Switches Used In Regressions (1985-1995)

Percent Distribution	Remotes	Hosts
1%	1,024	3,584
5%	1,208	6,400
10%	1,280	8,960
25%	1,920	13,162
50%	3,072	21,856
75%	5,147	36,928
90%	7,616	55,422
95%	9,243	67,429
99%	13,376	98,490
Mean	3,958	27,845
Standard deviation	3,397	20,716
Observations	1,409	1,439

Source: Authors' construct from FCC data.

A second set of regressions based on data from 1993 through 1995 was also estimated. There is merit in limiting the data analysis to these more recent years, because the technology is more homogeneous, and the conversion from embedded to current costs is done for a shorter time period. By limiting the data set to three years, the results are less affected by the telephone plant indexes used to convert embedded to current dollars.

At least one State has used data from a similar time period to evaluate the reasonableness of the switching investment values: The New York Public Service Commission recently used data from the 1995 New York Telephone depreciation report to judge the reasonableness of the Hatfield and *Switching Cost Information System* (SCIS) values. The Commission limited its consideration to data from switches installed during 1993 and 1994.[22]

For the years 1993 through 1995, there are 406 observations in the data base. 356, or 87 percent of these observations, are either DMS-100, DMS-100 remotes, 5ESS, 5ESS remotes, or EWSD switching machines.

Table 3-7 provides the distribution of line sizes for the Nortel and Lucent switches included in this second set of regressions.

The data set excludes switches with fewer than 1,000 lines of capacity. As a matter of sound econometrics, caution must be exercised when parameter estimates from a data set are used to forecast for instances for which the data set has no similar observations. To the extent to which the offices with less than 1,000 lines are or would be using the same type of switches as offices with more than 1,000 lines, the analysts feel comfortable using the parameter estimates from the regressions. To the extent to which wire centers with less than 1,000 lines use different types of switches, the parameter estimates for the RUS companies may be substituted.

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[22] "Opinion and Order Setting Rates for First Group of Network Elements," in *Joint Complain of AT&T Communications of New York, et al.,* Case No. 95-C-0657, Opinion No. 97-2, April 1, 1997, slip op. at 84-86.

Table 3-7

Descriptive Statistics: RBOC Lucent and Nortel Switches Used In Regressions (1993-1995)

Percent Distribution	Remotes	Hosts
1%	1,020	4,320
5%	1,040	7,648
10%	1,208	9,616
25%	1,540	13,349
50%	2,070	30,329
75%	3,840	52,369.5
90%	6,912	68,158
95%	8,714	82,017
99%	13,760	112,974
Mean	3,170	35,875
Standard deviation	2,814	25,127
Observations	162	192

Source: Authors' construct from FCC data.

Regression Results for Large Companies

The parameter estimates shown in Table 3-8 were obtained from the data set for the years 1985 through 1995. The parameter estimates were derived by using data for Lucent, Nortel, and Siemens EWSD switching machines.

Table 3-8

Regression Results: Large Company Switching Investment (1985-1995)

Regression with robust standard errors

Number of obs = 3023
F(3, 3019) = 2520.84
Prob > F = 0.0000
R-squared = 0.7994
Root MSE = 1.1e+06

cost1997	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
hostdm10	746170.7	69455.02	10.743	0.000	609986.8	882354.6
hsdm10li	107.2468	3.326741	32.238	0.000	100.7239	113.7697
relinexp	94.47673	6.513561	14.505	0.000	81.70527	107.2482
_cons	199412.8	24131.39	8.264	0.000	152097.2	246728.4

Source: Authors' construct.

In the regression shown in Table 3-8, the parameter estimates suggest that investment per switch = $\beta_1 + \beta_2$ * host_indicator + β_3 *remote_lines + β_4 * host_lines = 199,412.8 + 746,170.7 * host_indicator + 94.48*remote_lines + 107.25 * host_lines These results can be used as follows within the proxy models:

Investment per host switch = 99,412.8 + 746,170.7*host_indicator + 107.25*host_lines
= 945,583.5 + 107.25 * host_lines

Investment per remote switch = 199,412.8 + 94.48*remote_lines exclusive of host/remote termination on host

The data set indicates the number of equipped lines, rather than the number of working lines. Therefore the incremental investment per line termination, $94.48 and $107.25 for remote and host lines, respectively, are the estimates for an additional line of capacity. As noted earlier, digital switches do not operate at full capacity. Consequently, where these parameter estimates are used to estimate the cost of

providing universal service or unbundled network elements, the values must be divided by line switch utilization, which typically runs in the range of 90 to 95 percent.[23]

The parameter estimates shown in Table 3-8 should not be used to estimate the cost of terminating an ISDN line on a switch. During the years covered by this data set, the overwhelmingly majority of the lines were for voice service.[24] Therefore, to a large extent, the per-line investment estimates do not reflect the additional costs associated with providing ISDN lines on a digital switching machine. On the other hand, to the extent that embedded switching investment includes the cost of packet switching, or other non-POTS activities, the data will overstate the cost of providing POTS.

These parameter estimates suggest that, contrary to the claims of the sponsors of BCPM 1.1 and Hatfield 3.1, the fixed cost of a host and remote switch differ significantly. Furthermore, the point estimates for the incremental investment for terminating a line on a remote and host switch differ. The difference in the line termination investment estimates may be due to the higher per-line traffic on host switching machines. Relative to remotes, host switching machines are more likely to be located in urban areas, which have higher busy-hour traffic usage.[25] Due to the high correlation between the number of lines and total busy-hour usage, the traffic-sensitive cost is likely being picked-up by β_3 and β_4, the coefficients for the number of lines.

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[23] The level of utilization on a digital switch is higher than in the loop because of the modularity of the plant. For example, in the Nortel family of products, the DMS-10 and DMS-100 switching machines, one line card is dedicated to each customer.

[24] Federal Communications Commission, Statistics of Communications Common Carriers, 1994/1995 Edition, U.S. Government Printing Office (1995), Tables 2.4, 2.5, and 2.6.

[25] See, for example, Bridger M. Mitchell, *Incremental Costs of Telephone Access and Local Use*, RAND/R-3909-ICTF (Santa Monica, CA: Rand Corporation, July 1990), p.47.

Alternative Estimation of the Investment Function

The results reported in the prior section included the DMS-10 as a host switch. The DMS-10 has much a much smaller capacity than the DMS-100 or the 5ESS.[26] Like the larger switches, the DMS-10 can both terminate lines and act as a host switch. However, the busy-hour capacity of the DMS-10 is much lower than that of the other two switches, and its getting started cost is less, because it can process fewer calls, so the cost of the central processor that controls these operations is less than for the larger machines.

Since the cost structure of the DMS-10 is different than for the other two host switches, the cost proxy models could be explicitly designed to take into account the lower fixed cost. Such a course is not recommended for three reasons. First, the parameter estimate for the fixed cost of the DMS-10 switch was not statistically significant.[27] Second, some of the larger LECs are no longer installing new DMS-10 switch.[28] Third, the proxy models do not identify the manufacturer of the switch installed at the different wire centers.

Instead, it is recommended that proxy models reflect the cost of the DMS-100, 5ESS, their remotes, and EWSD switches. The parameter estimates from these types of switches are reported in Table 3-9.

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[26] David Gabel and Mark Kennet, *Estimating the Cost Structure of the Local Telephone Exchange Network* (Columbus, OH: NRRI, 1991), p.30.

[27] See file: new log with corrected data.

[28] On the other hand, the DMS-10 continues to be installed by some Independent telephone companies.

Table 3-9

Regression Results: Switching Investment for DMS-10, 5ESS, and EWSD Switches

Regression with robust standard errors — Number of obs = 2848; F(3, 2844) = 2644.93; Prob > F = 0.0000; R-squared = 0.8012; Root MSE = 1.1e+06

cost1997	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
hostexp	962905.2	80917.07	11.900	0.000	804243.2	1121567
holinexp	102.5551	3.52579	29.087	0.000	95.6417	109.4684
relinexp	94.47673	6.513826	14.504	0.000	81.70443	107.249
_cons	199412.8	24132.37	8.263	0.000	152094.1	246731.5

Source: Authors' construct.

These results can be used as follows within the proxy models:

Investment per host switch = 199,412.8 + 962,905.2 * host_indicator + 102.56* host_lines = 1,162,318 + 102.56 * host_lines

Investment per remote switch = 199,412.8 + 94.48*remote_lines exclusive of termination on host

As with the prior estimates, the incremental cost of the line must be adjusted upward to reflect utilization, because digital switches do not operate at full capacity. Consequently, where these parameter estimates are used to estimate the cost of providing universal service or unbundled network elements, the values must be divided by the line switch utilization, typically in the range of 90 to 95 percent.[29]

[29] There is no need to adjust the fixed investment for the switches. The fixed investment is the cost incurred as the number of lines asymptotically approaches zero. Since the fixed cost is independent of the level of traffic or the number of lines, it is independent of the level of utilization.

Parameter Estimates Based on Data from 1993 to 1995

This section provides parameter estimates using only data from 1993 to 1995. As stated previously, there is merit is considering data from this shorter time period because the technology is more homogeneous. Also, by considering the more recent time period, analysis is limited to switches that have more similar architecture. Furthermore, there has been a continuous downward trend in the price of digital switches. By considering only more recent acquisitions, a smaller adjustment must be made to the embedded cost in order to reflect current cost.

The following parameter estimates in Table 3-10 were obtained using 1993-1995 data for the Lucent, Nortel, and Seimens EWSD switching machines:

Table 3-10
Regression Results: Cost of Lucent, Nortel, and Seimens EWSD Switches (1993-1995)

Regression with robust standard errors — Number of obs = 356; F(3, 352) = 196.58; Prob > F = 0.0000; R-squared = 0.6828; Root MSE = 1.9e+06

cost1997	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
hostdm10	295776.4	218971.3	1.351	0.178	-134880.1	726432.9
hsdm10li	108.2438	8.375581	12.924	0.000	91.7713	124.7162
relinexp	110.4922	9.493131	11.639	0.000	91.82184	129.1626
_cons	193962.1	26068.91	7.440	0.000	142691.7	245232.5

Source: Authors' construct.

If the data from the DMS-10 switches is dropped, there is a small change in the parameter estimate for the per-line cost of the host switch (see Table 3-11). On the other hand, since the getting started cost of a DMS-10 is considerably different than for a 5ESS or DMS-100, there is a sizeable decrease in the getting started cost of the host. Parenthetically, note that only two observations are lost when the DMS-10 data is:

Table 3-11

Regression Results: Cost of Lucent, Nortel, and Siemens EWSD Switches Without DMS-10 Switches (1993-1995)

Regression with robust standard errors

Number of obs	= 354
F(3, 350)	= 196.90
Prob > F	= 0.0000
R-squared	= 0.6826
Root MSE	= 1.9e+06

cost1997	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
hostexp	319121.7	222573.7	1.434	0.153	-118628.4	756871.9
holinexp	107.861	8.418804	12.812	0.000	91.30321	124.4188
relinexp	110.4922	9.493435	11.639	0.000	91.82087	129.1636
_cons	193962.1	26069.75	7.440	0.000	142689	245235.2

Source: Authors' construct.

excluded; this reflects that the RBOCs have phased out their acquisition of these machines.

The coefficient for the host switches is not statistically significant in either of these regressions. The reason for this can be seen by decomposing this variable into three parts: the fixed cost of a 5ESS, DMS-100, and EWSD machines. The results are reported below in Table 3-12.

The parameter estimates suggest that the statistically insignificant variable for the host is due to the large variation in the price of a DMS-100 and EWSD switching machines.

If the objective is to obtain statistically significant parameter estimates, the data set could be limited to the Lucent switches. Such a course is not advised, however, because obtaining statistically significant coefficient estimates is but one of many goals of statistical analysis. Another goal is to explain the variation in the dependent variable. The models reported in this section do a good job of explaining the variation in the

dependent variable, as reflected in the F statistics. Therefore, it is recommended that the parameter estimates be used in the cost proxy models.[30]

Table 3-12

Regression Results: Cost of Lucent, Nortel, and Siemens SWSD Switches (1993-1995), Host Variable Decomposed

Regression with robust standard errors — Number of obs = 354; F(5, 348) = 156.92; Prob > F = 0.0000; R-squared = 0.6904; Root MSE = 1.9e+06

cost1997	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
d5ess	999252.1	388057.6	2.575	0.010	236018.7	1762485
ddms100	358713.6	278831.3	1.286	0.199	-189692.9	907120.2
dewsd	-177207.7	272458.9	-0.650	0.516	-713080.9	358665.5
holinexp	103.0944	8.686104	11.869	0.000	86.01058	120.1783
relinexp	110.4922	9.520676	11.606	0.000	91.76692	129.2175
_cons	193962.1	26144.55	7.419	0.000	142540.9	245383.3

Source: Authors' construct.

Use of These Parameter Estimates

The Hatfield and Benchmark Cost Proxy Models contain information on the nature of the existing switch nodes. The databases for these models include information on the extent to which each existing switch is either a host or a remote switching machine. Neither Hatfield 3.1 or BCPM 1.1 currently use this data because their current switching cost functions do not distinguish between the cost of a host and remote switch.

[30] The proxy model data bases indicate whether a switch is a host, remote, or stand-alone. Because the data sets do not indicate the manufacturer of the switch, there is little to be gained by obtaining estimates for each type of machine.

The parameter estimates reported herein provide support for the proposition that the getting started cost of a remote and a host are considerably different. In order to use this information, the code within the models must be changed.

Essentially the algorithm uses the LERG data base to determine whether the current switch is a host, stand-alone, or remote switch. After making this determination, the investment parameter estimates reported in the final section of this report are used by the program.

It is assumed that the investment function for a host and stand-alone switch are the same. A stand-alone and host machine are similar, but not identical. They both provide multiple direct interoffice routes to other wire centers, but the host switch has a function that the stand-alone office does not: assisting one or more remote switches with the set-up and disconnection of calls. Furthermore, its trunks carry interoffice traffic that is destined for other wire centers.

The umbilical links between the host and remote switching machines are terminated on a digital trunk frame. These frames are similar to the frames used for the termination of integrated subscriber line carrier and interoffice trunks. In all three cases, the trunks typically are terminated on the switch at the DS-1 level. Because the cost of these terminations is not large relative to the total cost of the switch, assuming that the cost of a host and a stand-alone switch are equal should not cause a large error.

Use of Embedded Data

The FCC data set indicates the year in which a digital switch was first installed. Subsequent to the initial installation, equipment may have been modified to provide new services or functions. For example, in the late 1980s and early 1990s, the hardware of both the Nortel and Lucent family of switches was modified due to the

technical requirements of the System Signaling Seven (SS7) and the Custom Local Area Signaling Services (CLASS).[31]

It is assumed implicitly that all investments recorded in the data set were made in the year in which the switches were installed. To the extent that this is not true, the treatment of the data results in an understatement of the current cost of the switches. This is because embedded investment has been converted to current investment by multiplying it by the ratio of the 1997 telephone plant index divided by the index for the year in which the switch was installed. Since the cost of digital switching has been declining over time, this effectively deflates the embedded dollars too much. Unfortunately, this problem can not be corrected using publicly available data, because the LECs do not report the additions and retirements made at each switching machine.

The FCC data has also been used by the BEA. Perhaps in response to this concern, a BEA analyst tested to see whether the year a digital switch was installed had a statistically significant impact on cost. The analyst concluded that the year of installation did not have a statistically significant impact.

The analysis in this study has taken a different approach to this issue. Every three years, a LEC's depreciation report indicates the book investment of each switch and the number of equipped lines. The Bell Atlantic data included in the BEA data set is based on the Company's Pennsylvania 1995 depreciation study. The authors also had access to Bell Atlantic's Pennsylvania 1992 depreciation study. A data set was constructed that included switches installed between the 1989 and 1992 depreciation studies. The 1992 and 1995 depreciation report had book investment data for 39 switches installed between 1989 and 1991, which was the last year covered by the 1992 report.

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[31] Gabel, *Improving Cost Proxy Models*, pp. 50-53.

Tests were performed to see whether there was a statistically significant difference in the parameter estimates depending on whether data for these 39 switches were obtained from the 1992 or the 1995 report. Using either a Chow or a dummy variable structural stability test, there was not a statistically significant difference. The results from this test provide support for using the *entire* data set.

There is a second factor to be considered that would cause the estimate of the cost of plain old telephone service (POTS) to be overstated. The investment data is drawn from the books of the regional bell operating companies (RBOCs) and includes more than just the cost of switching voice calls. For example, the data includes the cost of the main distribution frame, packet switching and ISDN equipment. Because the cost of the main distribution frame is explicitly accounted for in the proxy models, this cost is reflected a second time in the RBOC switching investment data base. Also, since the cost of ISDN and other non-POTS switching investments are in the data set, costs included that are not associated with providing basic telephone service are included.

It is not possible to tell *a priori* which of the two effects discussed in this section, over deflating book investments or excluding non-switch related costs, dominate. Fortunately, the estimates from the RUS data are not contaminated in this fashion, and, therefore, they provide a validity check on the parameter estimates provided in this chapter.

Comparison of Econometric Estimates with Other Studies

Publicly available data has been used to obtain the estimates reported in this chapter. In a typical rate proceeding, a large LEC relies on an engineering process model, such as SCIS, to estimate its switching investments. It is not possible to compare the parameter estimates in this report with the SCIS values, because Bellcore,

the developer of SCIS, prohibits public disclosure of SCIS estimates and the methods used to obtain those estimates.

Estimates of the cost of new switching equipment can be made from public reports of the RBOCs, but the data are not very useful. For example, it is possible to identify the yearly incremental investment in digital switching and the number of additional working lines on the digital switches. However, the quotient of these two values provides a poor estimate of the average investment per line, because it is not possible to determine the extent the which the values used in such a calculation are associated with adding capacity to existing switches, versus the installing new switching machines. Furthermore, the year in which certain expenses are capitalized can differ from the year in which the additional lines are reported.

Switching Investment: Medium Size Companies

This report has used data from small and large companies to estimate the investment function for digital switching. The authors are not aware of a publicly available data set for medium size companies and have not attempted to construct one.

It is reasonable to use the estimated investment functions from either the RUS or RBOC data to estimate the investment levels for the medium size firms. When the results from the RUS and the RBOCs are compared, there is sufficient similarity in the parameter estimates, given the difference in technology and demand levels, that either investment function, or some combination of the two, can be used to approximate the investment level of the medium size firms.

Conclusion

In this chapter two data sets have been used to obtain estimates for the cost of acquiring digital switching. Based on this data analysis, the numbers shown in Table 3-13 can be used to estimate the investment in digital switching.

Table 3-13

Suggested Switching Investment Values

	Small Companies	Medium and Large Companies
Getting Started Cost for a Remote Switch	$ 27,598 + $ 54,681 = $ 82,279	$ 193,962
Additional Cost Per-Line on a Remote Switch	$ 140.34	$ 110.49
Getting Started Cost for a Host Switch	$ 518,307 + $ 54,681 = $ 572,988	$193,962 + $ 319,122 = $ 513,084
Additional Cost Per-Line on a Host Switch	$ 43.69	$107.86

Source: Authors' construct.

These input values can easily be put into the proxy models. The models have fields for the getting started (fixed) and per-line cost of a host and a remote switching machine.

APPENDIX

DESCRIPTION OF THE SWITCHING COST AND OUTSIDE PLANT DATABASE FILES

The NRRI commissioned the authors to collect and analyze data on the cost of installing outside telephone plant and digital switching. Zip files contain the data that was collected and used to obtain estimates of the current cost of installing digital switching machines (switch.zip) and outside plant (OSP1.zip, OSP2.zip, and OSP3.zip).

Two sources of data were used in the report. The RUS provided copies of recent switching contracts for digital switching purchases made by small telephone companies. Data for large telephone companies was obtained from the FCC. The FCC data set included the embedded cost of over 3,500 switching machines. This embedded investment was converted to current values using the Turner Price Index.

The data analysis was done with the statistical package STATA. In order to make the data portable to other application programs, the data is being provided as an Excel file. The zip file also contains the "log" files that were used to record the work done in STATA.

Contents of switch.zip

File Name	Format	Description
allswitch data corrected.xls	Excel--STATA data set exported to Excel	RBOC depreciation data
allswitch data corrected.dta	STATA	RBOC depreciation data
new log with corrected data.log	Text	Log of regressions run in STATA with RBOC data
rus switching log for new switches & upgrades.log	Text	Log of regressions run in STATA with RUS data
rus central office data.xls	Excel	Switching Investment data for RUS companies.

Contents of OSP1.zip

File Name	Format	Description
nrri rus outside plant.mdb	Access [*NOTE: you will need MS Access 97* to open this file]	Data base of contract cost data; Hatfield and BCPM line, rock, soil, area, water depth data

Contents of OSP2.zip

File Name	Format	Description
conduit, drop, poles, cables.xls	Excel	STATA data file conduit, drop, poles, cables exported from STATA

Contents of OSP3.zip

File Name	Format	Description
ba table on rus v. ba osp.xls	Excel	Comparison of RUS material costs with Bell Atlantic material costs
bcpm regression log cables, drops & poles.log	STATA log file	Results of running file BCPM regression poles, cable, do
bcpm regression poles, cable.do.txt	STATA do file.	Contains various regression commands using the BCPM rock, soil, line and water data
cable, pole tpi do file.txt	STATA do file	STATA commands for converting cost data to 1997 values
conduit, drop, poles, cables.dta	STATA data file	STATA data file used in regression analysis
hm regression poles, cable.do.txt	STATA do file	Contains various regression commands using the HM rock, soil, line and water data
hm regression log cables, drops & poles.log	STATA log file	Results of running file hm regression poles, cable.do
pole and pole loading average unit costs.xls	Excel	This workbook provides the calculations used to derive the pole loading factors.
splicing.xls	Excel	Splicing expenditures for various contracts
tpi log.log	STATA log file	Converting cost data to 1997 values
variable creation log.log	STATA log file	Creating new variables for regression analysis

Contents of OSP3.zip (continued)

File Name	Format	Description
variable creation do file.do.txt	STATA do file	Creating new variables for regression analysis
weighted cable cost comparison.xls	Excel	This Workbook provides a comparison of the Total Extended Weighted Cable Cost by contract produced by the MS Access algorithms with the Sum of the Total Extended Cost of Cables and Cable Loading Units by contract.