96 access line system."[23] Splitting the $51,000 between both ends of the circuit, the cost of the electronics declined 82% [ln(11248/25500)] during the period 1986 to 1992.

The second order impact is suggested by NET's description of the SLC technology. The SLC system requires fewer pairs of either copper or fiber cable than does a dedicated copper line to each household. Therefore the reduction in electronic costs also leads to considerable savings in cable investments.

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[23] New England Telephone, Incremental Cost Study, Book 1 of 3, page 4 of 23, Attachment Loop 2, Massachusetts Department of Public Utilities Docket 86-33.

Note that New England Telephone is not talking about fiber-optic multiplexers, just the analog/digital bank.

Data Inputs: A Review

In this section of the paper, I raise some concerns I have regarding the inputs and organization of BCM2 and HM2.2.2.[24] In addition, I propose remedies for dealing with the concerns that are identified.

Issue I: Model Organization. Both BCM2 and Hatfield have been constructed as Excel spreadsheets. Their programs have a extremely large number of calculations. For example, BCM2 has approximately 168 columns in which calculations are made, but no documentation is provided within the model that explains the nature of these computations. Neither have I seen any external records that chronicle the basis for the calculations. Without some reasonable documentation, it is difficult, if not impossible, to understand the essence of the model. The Hatfield model also lacks adequate documentation to explain the gist of the large number of calculations embedded in the model. Neither model should be used to set the USF until their developers provide a column-by-column description of the formulas in the spreadsheets.

Proposed Remedy: The models should be held to the same standard that some State Commissions have imposed on model developers. For example, the Colorado Public Utilities Commission has established the following rule:

> When a provider submits a cost estimate to the Commission, it must simultaneously file a complete set of supporting work papers and source documents. . ..The work papers must clearly and logically present all data used in developing the estimate and provide a narrative explanation of all formulas or algorithms applied to these data. These work papers must allow others to replicate the methodology and calculate equivalent or alternative results using equivalent or alternative assumptions. . ..
>
> The work papers must be organized so that a person unfamiliar with the study will be able to work from the initial investment, expense, and demand data to the final cost estimate. Every

[24] To the extent that this paper is more critical of the BCM2 than the Hatfield model, this is only because I have found it easier to audit the BCM2 model.

number used in developing the estimate must be clearly identified in the work papers as to what it represents.[25]

The Joint Board should require that all parties who submit cost studies satisfy the requirement established by the Colorado Commission. Not only should the program algorithms be explained, but the source data should be identified and provided.

Issue II: Structural Investment. BCM2 and the Hatfield model treat structural investment, that is poles and conduit, in significantly different ways. BCM2 assumes that the poles and conduit are not shared with the cable and electric companies. Hatfield assumes that the telephone company should only pick up one-third of the cost of poles and conduit, the remaining two-thirds being the responsibility of the electric and cable companies.[26] The Hatfield model also assumes that only one-third of the cost of trenching is recovered from telephone operations.[27]

Proposed Remedy: Based on my experience with installing cables, rarely are buried cables installed in the same trench as facilities used by cable, electric, or water companies. Therefore I disagree with the Hatfield proposition that only one-third of the trenching cost is picked-up by telephone companies. Some value less than 100% may be appropriate, but one-third is unreasonable. I

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[25] In the Matter of Proposed Rules Regarding the Costing and Pricing of Telephone Services, Rule 6, Docket 92R-596T, June 1, 1993.

A similar standard has been established by the Connecticut Department of Public Utility Control: "SNET must submit sufficient documentation so that every step of the analysis can be replicated and all source data used must be provided and documented to the degree that an audit trail is readily discernible." Application of the Southern New England Telephone Company for Approval to Offer Unbundled Loops, Ports and Associated Interconnection Agreements, p.77, December 20, 1995.

[26] The Hatfield model assumes a pole investment of $450, a value that seems reasonable for an "average" installation. For installations made in 1993, the Rural Electrical Administration reported an average installed cost of $288.92 per pole for its Northeast Region. This REA value excludes guy units, but they typically ran to only $41 per guy wire. On the other hand, I have seen data for rocky terrain which suggests costs in the neighborhood of $850 per installed pole.

BCM2 does not indicate which cost levels are built into its model. They may be handled through the structure multiplier.

[27] Hatfield Model: Model Description, Version 2.2, Release 2, September 4, 1996, p. C-6.

suggest that the Hatfield model be modified to reflect that most buried cable is plowed, an operation that is less expensive than trenching.

Determining through physical inspection the extent to which conduit and poles are shared with other suppliers is difficult to establish. Thus, rather than basing the sharing of structural investment on a visual examination of the local exchange companies' operations, the cost estimates should reflect the suppliers' practices.

The FCC's Statistics of Communications Common Carriers, as well as some internal LEC data, can be used to develop an estimate of the structural investment per sheath or cable mile. The FCC document provides both embedded investments and physical counts of equipment. The embedded investment can be converted to a current investment through the application of current/book investment ratios, a method that has been used by the industry for a number of years. Below, I provide a loading that would be applied to each cable sheath foot. It is based largely on publicly available data.[28]

Let:

A = the embedded investment in conduit (Table 2.9 of the FCC Statistics of Communications Common Carriers)

B = the embedded investment in poles (Table 2.9 of the FCC Statistics of Communications Common Carriers)

C = the sheath miles of underground cable (Table 2.10 of the FCC Statistics of Communications Common Carriers)

D = the sheath miles of aerial cable (Table 2.10 of the FCC Statistics of Communications Common Carriers)

E = current/book ratio for Poles

F = current/book ratio for Conduit

adjustment factor = 90% (explained below)

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[28] It may be appropriate to adjust the formula to reflect the revenue and expenses associated with conduit and pole rentals. The cash flow can be converted for embedded investments by dividing the revenue by the appropriate annual charge factor. If rent revenue is obtained, the dollars would then be divided by the annual charge factor. This quotient would provide an estimate of the portion of structural investment rented to others. The quotient would be subtracted from the embedded investment.

Loading per sheath foot of aerial cable = (B * E) / (D * adjustment factor)

Loading per sheath foot of underground cable = (A * F) / (C * adjustment factor)

The formulas' logic is simple. First, the embedded structural investment is converted to current dollars. This operation takes place in the numerator of each formula. The current investment is then distributed among the quantity of underground or aerial sheath miles.

The formula may understate the effective future-loading per sheath foot, because with the current widespread deployment of fiber, the sheath miles will likely decline. Fiber cables require fewer sheath miles than copper cables do. This would suggest a need to decrease the denominator in each model by some arbitrary amount. I recommend starting with a value of 10%.[29, 30]

Issue III: Do the Models Accurately Capture Cost Variations Due to Topography. Traditionally, cost models have explicitly captured variations in loop costs that are due to loop length and customer density. U.S. West developed such a proxy model a few years ago and was criticized for failing to take into account the topography of the area being modeled.[31]

HM 2.2.2 has eliminated the BCM1's practice of varying the cost, which depended on "the degree of difficulty of structure placement under various soil types, bedrock depth, and water table conditions." The Hatfield makes an adjustment for rocky

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[29] The number of sheath miles will also be reduced because the models size cables to meet total, rather than incremental, demand. To meet incremental demand, a carrier might sequentially deploy two 100-pair cables. In order to meet the total demand, the carrier might deploy just one 200-pair cable. In the later case, the sheath miles would be reduced by a factor of two. On the other hand, because of its reduced size, more fiber cable sheaths could fit on a pole or inside conduit. Also, the embedded investment might reflect past operating inefficiencies.

[30] I am in the process of collecting data from various companies that will allow me to make this calculation. When the data is assembled, I will post the information on the ERMIS bulletin board.

[31] Joel Shifman and Ron Choura, "Universal Service: Existing Proxy Models, What can they be used for?" (Presented at the NRRI / NARUC *Biennial Regulatory Information Conference*, Columbus, Ohio, September 1996): p. 17.

terrain by increasing the loop length by 20%, in order "to accommodate the routing of facilities around difficult placement conditions."[32] Based on my own experience with installing cables, this is not a reasonable assumption. Cables typically run along the side of a road, there is little opportunity to route cables around rocky terrain.

AT&T and MCI, the sponsors of the Hatfield model, correctly point out that where BCM adjusted installation costs to reflect the difficulty of constructing facilities, the cost factors were based on assumptions that were hard to audit. This leaves the Joint Board with the dilemma of how to use a forward-looking model that reflects surface variations. HM 2.2.2 largely ignores the impact of soil types, bedrock depth, and water table conditions, and when it does consider these factors, the 20% adjustment factor is not reasonable unless: (1) the base case cost levels are reasonable and; (2) the cost impact of rock adds an increase in installation costs of approximately 20%, relative to the baseline costs.

Auditing the Hatfield model is difficult and, therefore, conclusions cannot be reached at this time regarding the reasonableness of its cable investment values.

BCM2, on the other hand, takes into consideration variations in topographical conditions, but the reasonableness of the adjustments are hard to evaluate. The sponsors of the BCM2 have provided me with their estimates of how installation costs vary by method and soil condition. The Appendix provides a comparison of the BCM2 data with some publicly available data. These data lead to the conclusion that the majority of these cost elements appear to be reasonable, but the weighted cost of the same activities is too high. This suggests that the model is using the wrong mix of operations for installing facilities.

Issue IV: Maintenance Cost Loading Factors. There are three types of cables installed in the network: aerial, underground, and buried. The latter two are combined by the BCM2 into one category, below-ground. The proportion of underground cable appropriately increases proportionately with population density. The investment in

[32] AT&T's and MCI's responses to the Federal-State Joint Board's request for information, submitted August 19, 1996, CC Docket No. 96-45, p.2 (second quote), 7 (first quote).

buried cable, as well as aerial cable, is converted to a yearly cost by applying an annual charge factor that is independent of the population density and the type of cable.

Normally the annual cost factor for below-ground cable varies depending on the type of cable and its construction. The Table provided below illustrates that not only is copper more expensive to maintain than fiber, but underground cable is less expensive to maintain than aerial or buried cable.[33] The failure of BCM2 to distinguish between the costs of maintaining fiber and copper is especially problematic because the future mix of fiber and copper differs significantly from the current embedded base of facilities.

Table 2: Cable Carrying Charge Factors: Bell Atlantic

Cable Type & Placement		
Placement	**Fiber**	**Copper**
Aerial	.0127	.0561
Underground	.0103	.0237
Buried	.0103	.0643

Proposed Remedy: The maintenance factors provided in the previous Table can serve as benchmarks for judging the reasonableness of the maintenance factors used in forward-looking cost studies.[34]

Problem I: Inappropriate Facility Mix. The models make assumptions regarding the mix of below-ground and aerial facilities that, in some instances, have little to do with the actual construction of an area's network. For example, aerial cable constitutes 89% of New England Telephone's sheath miles. The number of Massachusetts' households

[33] "Bell Atlantic's Direct Case" CC Docket No. 94-97, Phase II, Exhibit 2 p. 3 of 4, October 19, 1995. Pennsylvania data is used because these are the state Bell Atlantic characterized as typical during the case. (p. 16).

[34] Pacific Bell's factors for underground cable (0.031) and buried cable (0.068) are in the same range as the Bell Atlantic values. Testimony of R.L. Scholl, Pacific Bell, April 17, 1996, p.9, in *Rulemaking on the Commission's Motion into Universal Service,* R.95-01-020.

per square miles is 37. BCM2 assumes that with this population density, 28% of the cable would be aerial. The Hatfield model is a bit more on target, it assumes 50% of the cable to be aerial.

Proposed Remedy: When a model is used at the State level, this problem can easily be remedied by changing the mix of facilities through the Table Inputs Folder. But if the model were being used at the FCC, it would be difficult for the Staff to make these adjustments. The models' developers should be encouraged to substitute, on a per-company basis, the outside plant statistics located in Table 2.10 of the FCC's Statistics of Communications Common Carriers. Also, whenever available, they should use the outside plant statistics found in the internal reports of the local exchange companies. For example, many of the companies produce a report that shows the facility mix on a state-by-state basis (e.g., report QR7A, Plant Mileage).

The models' sponsors should also take into account that the future mix of facilities may change. For instance, in areas served by REA companies, aerial cable is rarely deployed today. The government agency has determined that borrowers should use buried, not aerial, cable. Nevertheless, in some areas, such as the rocky terrain of Maine, aerial cable will remain the primary mode of delivery.

Problem II: Non-Investment Related Expenses. Non-facility-based costs are added on as a non-plant-related expense factor (i.e.: expenditures unrelated to depreciation, return, taxes, and maintenance of the facilities). Using data from ARMIS, the developers of BCM2 summed up the costs for non-plant-related expenses (customer operations—marketing, customer operations—services, corporate operations, and miscellaneous depreciation expenses), and divided this value by the number of lines. The quotient was $133.39 annually, or $11.12 per month. They then assumed that 75% of this expense, that is $8.34 per month, was related to providing universal service.

This is a very poor assumption to make. For example, it is absurd to assume

that 75% of the marketing costs are related to providing universal-service-related products. The Hatfield Model includes a monthly line charge of $1.37 for billing, billing inquiries, and directory listing.

The following Table lists some of the TSLRIC expenses identified by Pacific Bell in a recent universal cost study presented to the California Commission. The largest cost, customer service, is associated with billing, collections, and billing inquiries. Pacific Bell argued that non-recurring costs are arguably part of the cost of universal service because of the California Commission's decision to set the price of installation below-cost.[35] The Administrative Law Judge found that Pacific Bell's non-investment-related expenses allocated an inappropriately large share of common and shared costs, particularly customer service expenses, to universal-service-related products. The

[35] Testimony of R.L. Scholl, Pacific Bell, April 17, 1996, p. 11-12, in *Rulemaking on the Commission's Motion into Universal Service*, R.95-01-020. I have excluded from the Table, the cost of switch maintenance ($0.50), loop maintenance ($2.48), and network operations ($1.91) since these expenses are estimated elsewhere in the BCM2 and Hatfield models.

The directory assistance cost of $0.93 presumably represents the monthly cost based on the typical number of calls made by residential subscribers.

Judge reduced the expenses by $2.00 per line. The Table reflects this change.[36] The Judge also decreased Pacific Bell's estimate of the cost of non-recurring costs and directory assistance estimates by $1.13 and $0.42 per line, respectively.[37]

Table 3: Non-Investment Related Expenses: California

Non-Investment Related Expense Item	**California Cost Proxy Model**
Directory Assistance	$0.93 @$0.33 per call
Directory White Pages	$0.31
Customer Services	$3.39
"Operator Minus"	$0.11
Non-recurring costs	$1.51
General and Administrative	$1.90
ALJ adjustment for Customer Services	-$2.00
ALJ adjustment for non-recurring costs	-$1.13
ALJ adjustment for Directory Assistance	-$0.42
Total	$4.59

[36] *Rulemaking on the Commission's Motion into Universal Service*, R.95-01-020, August 5, 1996, p.141.

[37] Ibid., p. 144.

The Pacific Bell data, as modified by and administrative law judge, suggests a non-investment related expense somewhere in between the levels used in BCM2 and HM2.2.2. I am in the process of collecting data from other jurisdictions. When the data is assembled, I will post the information on the ERMIS bulletin board.

Problem III: Use of Census Block Group Data. A common criticism of both the BCM2 and Hatfield models is that they match census block groups with inappropriate wire centers. Furthermore, census block groups, the fundamental units of analysis in the models, cover territory that has little or no relationship to the carrier and serving areas that are the fundamental building blocks in telephone networks. Currently, none of the models, CPM, Hatfield, or BCM2, use serving-area configurations that comport with the way telephone systems are engineered. In rural areas, some of their census block groups are too large and lead to improper assumptions regarding the length of the distribution portion of the network. In more densely populated areas, their census block groups can be too small and lead to an overstatement of the cost-of-service. The cost is inflated because the models deploy more fiber-optic multiplexers than are economically sensible. In short, the current modeling procedures misrepresent the layout of the network and these errors cause a significant distortion in the cost-of-production.

Proposed Remedy. More appropriate matching has been accomplished in some work that Mark Kennet and I have done for the consulting firm, JSI. We have developed a program that combines data bases to provide wire-center boundaries, as well as census block data. (The Cost Proxy Model also uses a data base that provides wire center boundaries. This type of data should be employed in future versions of the model.) The use of this information would not only ensure that customers are attached to the appropriate wire center, but also that the size of the serving area could be modified to better reflect the engineering practices of the telephone companies. Because they are smaller than census block groups, census blocks could be combined or split to better comport with the size of the serving areas.

Problem IV: Traffic Sensitive Proportion of Switch: The Hatfield model assumes that 70% of the cost of a digital switch is traffic sensitive. BCM2 assumes that 30% of the switch is traffic sensitive. Neither model provides documentation on how these values were derived. I have created the following Table to clarify how cost data could be used to support either position. In 1986, New England Telephone presented a study to the Massachusetts Department of Public Utilities that identified the central processor, line, and CCS investment for both the #5ESS and DMS-100 host switches. I have used these data to estimate the investment for a switch that has 13,057 lines and a 3.55 busy-hour CCS per line.[38]

Table 4: Cost Components of DMS-100 and #5ESS Switching Machines

Switch Type	Total	Line	CCS	Central Processor
#5ESS	$4,457,421	$1,462,384 (32%)	$1,715,037 (38%)	$1,280,000 (29%)
DMS-100	$3,967,701	$2,023,835 (51%)	$1,297,865 (33%)	$646,000 (16%)

The portion of the switch that is characterized as non-traffic sensitive is dependent on the treatment of the central processor. For instance, the central processor could be characterized as non-traffic sensitive because once a switch is constructed, the cost of the central processor may not change when additional CCS are carried. In this scenario, only the CCS column would be characterized as a traffic-sensitive investment. I will call this the "BCM2 view." On the other hand, central processors can not handle an unlimited number of calls. Digital switches have been deloaded at times because the central processor could not process all of the calls. This

[38] See, New England Telephone, Incremental Cost Study, Book 1 of 3, Tab 2, page 3 of 15, Docket 86-33.

would suggest that the central processor *is* a traffic-sensitive investment. Under this approach, the CCS and central processor dollars are TS investments. This could be the "Hatfield Model view" of the world.

If the DMS-100 data are used as the model office, the "BCM2 approach" would suggest that 33% of the investment is TS. If the "Hatfield argument" is accepted, and the #5ESS switch is used as the model technology, then the TS percent is 67% (38 + 29).

Proposed Remedy: The principal task of the central processor is to process calls. The monitoring for an off-hook signal is done by the line equipment, not the central processor. Therefore, the central processor could be characterized as a traffic-sensitive investment. On the other hand, a minimum size central processor is needed at each central office, regardless of the level of traffic. Therefore the central processor can be characterized as non-traffic sensitive investment. Non-traffic sensitive equipment is not synonymous with line related investment. The cost of the smallest sized central processor is in a sense a fixed cost, but this cost is not caused by lines, rather it is incurred in order that multiple tasks can be carried out.

When the central processor is enlarged for processing of additional calls, this incremental cost should be classified as traffic sensitive. For the fixed, or getting started cost of a central processor, I recommend that the cost be split in one of two ways. Either the getting started cost of the central processor should allocated evenly to lines and calls, or assume that 58% of the switch investment is traffic sensitive. This value was derived by assuming: (a) that the central processor is a traffic-sensitive investment; and (b) that there is an equal likelihood that a #5ESS or DMS-100 switch would be deployed.[39]

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[39] 58% = ½ * (38 + 29) + ½ * (33 + 16). If the model sponsors can provide more current or representative data, these values should be reevaluated.

Table 4, above, reflects my arbitrary assumptions regarding CCS usage and the number of lines on the switch. The models' developers should feel free to provide data that do a better job of identifying the number of lines and typical busy-hour usage on a switch. These data could then be used to recalculate the TS ratio.

For the development of unbundled rates, the models should move toward assigning the cost of the central processor on the basis of the time that the computer spends carrying out different tasks (e.g., the number of milliseconds spent processing local and toll calls, vertical services, etc.).

Problem V: Switching Technology Used in Rural Areas

Neither BCM2 nor HM 2.2.2 include cost algorithms that are appropriate for the small switches that are used by the Independents. In rural areas, many Independents use switches that have cost characteristics which are much different than the values used in BCM2 or the Hatfield model.

Proposed Remedy: The models should be modified to reflect the cost of the type of technology that is used in low-density areas. The models should consider use these algorithms, or developing their own cost estimates that reflect the technology used in low density markets.

Appendix

An Evaluation of the Installation Costs Used in BCM2 and HM 2.2.2

This Appendix discusses the reasonableness of some of the data used in the models.

Much of the data used for this analysis were obtained from Heavy Construction Cost Data: 1996, published by Means (800 448 8182). Means provides construction companies and buyers of services with an independent estimate of the construction's cost.

Included in the total cost estimate of Means is an allowance for a 10% profit by the contractor (p.3), material, labor, equipment, and overhead. The installation costs reflect the labor costs of urban areas (p. vi).

Manholes

HM 2.2.2 assumes that the price of an installed manhole is $3,000. Means (p. 78) reports that the cost varies from $2,750 for a 4' x 6' x 6' to $5,775 for a 8' x 14' 7' utility vault. Therefore, the reasonableness of the HM 2.2.2 value depends on what constitutes a typical installation. If manholes larger than the minimum size are installed, the $3,000 value will be less than the typical cost. The REA reported that for 1993, the average installed cost of a manhole unit was $5,925. This suggests that the $3,000 estimate is on the low side.

Conduit

HM 2.2.2 assumes that the cost of installing conduit varies from $25 to $75 per foot, depending on the population density.[40] Means provides the following cost for conduit, exclusive of trenching (pp. 264-65). The variation in conduit cost is largely driven by the cost of the material, not the installation.

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[40] AT&T's and MCI's responses to the Federal-State Joint Board's Request For Information, submitted August 19, 1996, CC Docket No. 96-45, p. 17. BCM2 uses a constant value of $40 per foot for conduit regardless of the population density.

Table 5: Conduit Installation Costs

Rigid Galvanized Steel Conduit--Size	Investment Per Foot
2"	$6.70
2.5"	11.10
3"	$14.20
4"	$17.50

If the conduit is placed in area that can be trenched, and then backfilled by hand, the additional investment per foot is no more than $2.00 per foot (Means, p. 53). Significant additional costs are incurred when asphalt must be removed and then reinstalled. The cost of installing asphalt can be in the range of $7.50 to $9.00 per square foot (Means, p. 72), but it often runs considerably higher. Additional expenses will be incurred ripping out the old asphalt and digging through the compact dirt and rocks. The overall range of $25 to $75 per foot therefore seems reasonable.

Variation in Installation Costs by Soil Type

The beauty of the BCM2 model is its modeling of how installation costs vary depending on the type of activity. The models' sponsors have collected data which suggest that the cost of installing below-ground cable can vary from as little as 70¢ per foot for a straight plow, to over $12 a foot for boring cable (see Table below). This is potentially a very important contribution of the model, it can help explain variations in installation costs that are independent of density and loop length. The data presented below are my attempt to judge the reasonableness of the values proposed by the models' developers.

Table 6: The Cost-of-Service in a Densely Populated State

BCM2 Metro Weighting Multiplier for Normal Soil and Density of 650 - 850 per Square Mile

Activity	Cost	% of Activity	Weighted Cost
Plow	$0.7		$0.00
Rocky Plow	$1.15		$0.00
Trench & Backfill	$1.95	25.00%	$0.49
Rocky Trench	$2.23		$0.00
Backhoe Trench	$2.04	5.00%	$0.10
Hand Dig Trench	$2.23	5.00%	$0.11
Bore Cable	$12.12	20.00%	$2.42
Push Pipe & Pull Cable	$9.8	5.00%	$0.49
Cut & Restore Asphalt	$8.23	10.00%	$0.82
Cut & Restore Concrete	$10.84	10.00%	$1.08
Cut & Restore Sod	$2.06	20.00%	$0.41
Subtotal		100.00%	$5.93
Conduit	$40	0.50%	$0.20
Total			**$6.13**

This Table suggests that for normal soil, with a density range of 650 to 850 lines, the cost of installing below-soil cables is $5.93, exclusive of the cost of conduit. For soft and hard rock, the cost of installation, exclusive of conduit, is $7.61 and $14.27, respectively.

In 1990, Massachusetts had a population of 6,016,425 spread over 8,257 squares miles. This works out to roughly 724 persons per square mile.[41] The State is served by one telephone company, New England Telephone (NET). In 1986, NET provided the State Commission with data for the cost per foot of installing buried and underground cable. The following Table provides the fixed and marginal cost per foot for the various gauges of copper wire used in the loop. I have followed the convention of estimating a linear cost function from broad-gauge cost data.[42] The cost of different

[41] The actual telephone density is higher than this because some areas do not receive service (e.g. forests, farms), and the calculation excludes business lines. If these adjustments were taken into account, the density would be higher than 724, but this would have no effect on the conclusions that I reach below.

[42] See, for example, Rural Electrical Administration, "Design Techniques of Feeder-Distribution Cable Engineering," Telecommunications Engineering and Construction Manual, section 231, February 1986, p.B-41; New England Telephone, Massachusetts Department of Public Utility, Docket 86-33, Work

size cables was the dependent variable, and the size of the cables, along with the intercept term, were the explanatory variables. The estimated coefficient of the intercept measures the per-foot, fixed cost of installing a cable.

Table 7: Fixed and Marginal Investment per Foot of Copper Cable

Fixed and Marginal Investment per Foot of Copper Cable Data Year: 1987			
Gauge of Wire	Fixed Investment per Foot	Marginal Investment per Pair Foot	Cable Capacity
26			
Underground	$1.68	$.0075	3600
Buried	2.17	0099	3600
24			
Underground	1.91	.0097	2400
Buried	2.41	.012	2400
22			
Underground	1.74	.013	1800
Buried	2.23	.016	1800
19			
Underground	2.58	.013	400
Buried	3.06	.015	400

Source: New England Telephone, work papers, book 1, tab 1, p. 1-2, attachment 1, in Massachusetts D.P.U. Docket 86-33.

The BCM2 model works with 24-gauge wire. Since the data in the above Table were collected, the price index for installing cable has increased only slightly. The Table suggests that the per-foot cost of installing cable in Massachusetts is in the range of $2 to $3, not the $6 to $14 suggested by the data used in BCM2.

The difference between the values suggested by BCM2 and the forward-looking costs identified by NET are likely due to an inappropriate mix of activities that the cost levels for the individual activities are too high. In order to try to isolate the importance of each of these factors, in the next section I use data from the REA to evaluate the reasonableness of the BCM2 cost levels.

Papers, Book 1, tab 1, p.20 of Attachment 4; and Response of Bell Atlantic-Pennsylvania to Set VI, Interrogatory No. 7(F) of the Office of the Consumer Advocate Dated June 23, 1995, Docket M-00940587 ("Competitive Safeguards").

Cost of Service in a Rural Area

For the least densely populated areas, zero to five customers, BCM2 uses the following costs for installing a foot of cable in normal, soft rock, and hard rock, respectively:

Table 8: BCM2 Rural weighting Multiplier development for Normal Soil

0- 5 Normal			
Activity	**Cost**	**% of Activity**	**Weighted Cost**
Plow	$0.70	88.00%	$0.62
Rocky Plow	$1.15		$0.00
Trench & Backfill	$1.95		$0.00
Rocky Trench	$2.23		$0.00
Backhoe Trench	$2.04		$0.00
Hand Dig Trench	$2.23		$0.00
Bore Cable	$12.12		$0.00
Push Pipe & Pull Cable	$9.80		$0.00
Cut & Restore Asphalt	$8.23	5.00%	$0.41
Cut & Restore Concrete	$10.84	5.00%	$0.54
Cut & Restore Sod	$2.06	2.00%	$0.04
Subtotal		100.00%	$1.61
Conduit	$40.00	0.10%	$0.04
Total			**$1.65**

Table 9: BCM2 Rural weighting Multiplier development for Soft Rock

0-5 Rock Soft			
Activity	**Cost**	**% of Activity**	**Weighted Cost**
Plow	$0.70	5.00%	$0.04
Rocky Plow	$1.15	40.00%	$0.46
Trench & Backfill	$1.95		$0.00
Rocky Trench	$2.23	8.00%	$0.18
Backhoe Trench	$2.04	10.00%	$0.20
Hand Dig Trench	$2.23	5.00%	$0.11
Bore Cable	$12.12	10.00%	$1.21
Push Pipe & Pull Cable	$9.80	10.00%	$0.98
Cut & Restore Asphalt	$14.23	5.00%	$0.71
Cut & Restore Concrete	$16.84	5.00%	$0.84
Cut & Restore Sod	$4.10	2.00%	$0.08
Subtotal		100.00%	$4.82
Conduit	$40.00	0.10%	$0.04
Total			$4.86

Table 10: BCM2 Rural weighting Multiplier development for Hard Rock

0-5 Rock Hard			
Activity	**Cost**	**% of Activity**	**Weighted Cost**
Plow	$0.70		$0.00
Rocky Plow	$1.15		$0.00
Trench & Backfill	$1.95		$0.00
Rocky Trench	$10.23	38.00%	$3.89
Backhoe Trench	$2.04		$0.00
Hand Dig Trench	$10.23	20.00%	$2.05
Bore Cable	$12.12	10.00%	$1.21
Push Pipe & Pull Cable	$14.80	10.00%	$1.48
Cut & Restore Asphalt	$16.50	10.00%	$1.65
Cut & Restore Concrete	$19.20	10.00%	$1.92
Cut & Restore Sod	$11.15	2.00%	$0.22
Subtotal		100.00%	$12.42
Conduit	$40.00	0.10%	$0.04
Total			$12.46

The Tables show, not surprisingly, that as the soil becomes more rocky, the cost of trenching increases.

I have used data from the northeastern region served by REA companies to identify the cost of plowing and trenching cable. The REA data include the price of materials, something that is not included in BCM2 cost estimates provided on the Figures.

Table 11: Cost Per Foot of Installing Buried Cable in Rural Areas: REA Competitive Bid Data

SUMMARY OUTPUT – 24 Gauge Wire – Labor and Materials

Investment Per foot

Regression Statistics	
Multiple R	0.96979316
R Square	0.94049877
Adjusted R Square	0.938447
Standard Error	0.73646556
Observations	61

ANOVA

	df	*SS*	*MS*	*F*
Regression	2	497.238993	248.6194965	458.384894
Residual	58	31.45812827	0.542381522	
Total	60	528.6971213		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.37243791	0.138359472	2.691813582	0.00927179
pairs	0.01044202	0.000345353	30.23582308	3.355E-37
trenching	1.04628261	0.215620792	4.852419856	9.5609E-06

The regression results based on REA data suggest that the BCM2 plowing cost of $0.70 is high. The Table indicates that the investment per foot for installing copper cable is 37¢. When trenching is required, the installation cost increases by $1.05 to a total of $1.42 per foot (.37 + 1.05). Both REA's plowing and trenching costs are lower than the values used in the BCM2.[43]

The REA data also includes some useful information regarding the cost of installing cable in more congested areas. Their account system has a field code of P which stands for difficult. P is defined in the organization manual as follows:

[43] To the extent that the REA data do not include engineering costs, outside plant engineering costs should increase costs by approximately 5%, a suggestion made to me by a LEC. The BCM2 data that appears on the tables above exclude engineering costs.

> Predesignated buried filled cable which will, in the judgment of the Engineer, be much [original emphasis] more difficult to install than normal for this project because of the presence of underground facilities or severe right-of-way restrictions.[44]

As Table 12, below, indicates, when obstacles are encountered in more densely populated areas, the cost of plowing increases dramatically. When there are no impediments, the cost of installing a foot of buried is $0.37 per foot. Where obstacles are incurred, the cost increases to $1.61 per foot.[45] Therefore the models should reflect that the cost of installing a foot of cable increases with population density, all else equal.

Table 12: 24 Gauge Wire--Buried Cable--Investment Per Foot--Difficult Placement

Regression Statistics	
Multiple R	0.954843839
R Square	0.911726756
Adjusted R Square	0.90857414
Standard Error	0.824786169
Observations	30

ANOVA

	df	*SS*	*MS*	*F*
Regression	1	196.7326243	196.7326	289.1969
Residual	28	19.04762229	0.680272	
Total	29	215.7802466		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1.607529622	0.194200875	8.277664	5.23E-09
pairs	0.010859722	0.00063859	17.00579	2.72E-16

[44] REA Bulletin 345-150, "Specifications and Drawings for Construction of Direct Buried Plant," (1989) p.5.

[45] Unlike with the prior data set, there were no observations for trenching. All installations were plow installations.

The BCM2 data can also be compared with the standard construction costs found in Means' Heavy Construction. Means explains that its trenching costs include excavation, backfill and removal of soil, and compaction (p.314). Assuming a zero to one foot slope for the trench, and depths of two and three feet, respectively, Means reports that the cost per linear foot for trenching with a backhoe is $2.08 and $2.91, values in line with the BCM2 data, with the exception of rocky trench in hard rock. Means does not identify how the trenching costs vary by soil type.

In 1965, the Air Force printed a manual, "Broad Gauge Unit Costs for Outside Plant Telephone Installation and Remove," that provides some useful data on this issue. The manual identifies the additional hours of work required for trenching relative to normal conditions. The Air Force identifies the additional labor hours required for each 1,000 feet of trenching for buried cable under adverse conditions.[46] I have converted the hourly time to a per-foot cost based on a loaded hourly wage of $41.10 for an equipment operator (Means, p. 333). The additional trenching cost is in the range of one to three cents per foot when the construction is done in sand, gravel, coral rock, or rock fragmentation. While, at first, this value strikes me as low, it is consistent with the BCM2 data for soft rock relative to normal conditions. The BCM2 data show no difference in installation costs until the installer confronts hard rock.

Based on the trenching data summarized above, I find the BCM2 trenching numbers to be reasonable on average, with the exception of trenching in hard rock. The sponsors of the model should consider using the REA data for rural areas. I have been unable to locate data that allow me to benchmark the BCM2 data for the cost of trenching in hard rock.

Continuing down the BCM2 list, the bore cable cost is hard to verify. Means provides data on borrowing (pp. 46-47), but the unit of measurement, the cubic yard is different than the unit of measurement used in a telephone cost study, a linear foot. Therefore, I am unable to judge the reasonableness of the bore cable value. Neither am I able to comment on the merit of the value for pushed pipe. Means has lots of data

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[46] The Air Force no longer publishes this guidebook.