2. Description of Inputs and Assumptions

The Line Multiplier module uses access line demand data from the Operating Data Reports, ARMIS 43-08, submitted to the FCC's Common Carrier Bureau on an annual basis by all Tier 1 LECs.[11] The HM developers obtained these data from Table III ("Access Lines in Service") of those carriers' 1994 ARMIS 43-08 reports and entered it into the model without any adjustments. The HM includes the following company-wide data for each of the LECs.[12]

- Residential access lines, including analog and digital. These totals include all residential switched access lines, including flat rate (1FR) and measured rate (1MR) service.[13]
- Business access lines, including analog single line, analog multiline and digital. These totals include flat rate business (1MB) and measured rate business (1MR) single lines, PBX trunks, Centrex lines, hotel/motel LD trunks and multi-line semi-public lines.[14]
- Special access lines, including analog and remote digital. These totals include dedicated lines connecting end users' premises to an interexchange carrier point of presence, but do not include intraLATA private lines.[15]
- Public access lines, that is, lines associated with coin (public and semi-public) payphones, excluding customer owned pay telephones ("COPT").[16]

As explained below, the module's algorithms map the data to individual CBGs. This requires certain inputs from the Data Module, namely a listing of each CBG (identified by CLLI code of the wire center, company name and CBG code) and its associated household count. This module draws these parameters from the Input Data file.

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11 See Reporting Requirements for Certain Class A and Tier 1 Telephone Companies (Parts 31, 43, 67 and 69 of the FCC's Rules), CC Docket No. 86-182, 2 FCC Rcd 5770 (1987) (ARMIS Order), modified on recon., 3 FCC Rcd, 6375 (1988). Tier 1 LECs are those with more than $100 million in annual revenues from regulated services and includes over 50 carriers.

12 These LECs include the seven RBOCs, GTE California and GTE Texas.

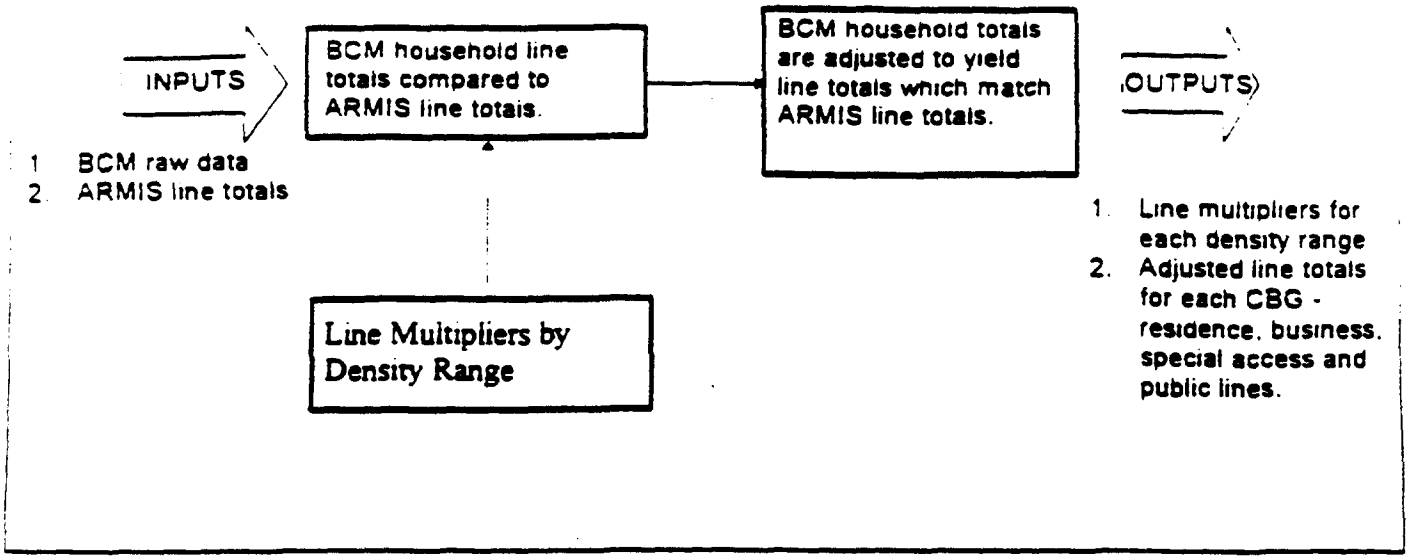
13 Revision of ARMIS USOA Report (FCC Report 43-02) for Tier 1 Telephone Companies and Annual Report Form M, AAD 92-46, DA 92-1405, released October 16, 1992, Appendix C, at FCC Report 43-08 - Report Definition for Table S-3, page 2.

14 *Id.* at FCC Report 43-08 - Report Definition for Table S-3, pages 1-2.

15 *Id.* at FCC Report 43-08 - Report Definition for Table S-3, pages 2-3.

16 *Id.* at FCC Report 43-08 - Report Definition for Table S-3, page 2.

Figure 2 Line Multiplier



3. Explanation of Key Algorithms

The Hatfield Model, like the BCM, uses the CBG as a basic unit of analysis. Therefore, to take into account sources of access line demand other than residence service, the Model must estimate the demand for such services; e.g., business, special access and public access lines, within each CBG. This data is not provided publicly by the LECs, although they do possess service-specific demand data at a wire center level. Rather, the LECs allege that these data are proprietary (e.g., for competitive Centrex services). Thus they are not currently available for incorporation into the HM.[17]

As an alternative, the Line Multiplier Module uses a consistent method to translate the ARMIS access line data that LECs report on a territory-wide basis into service-specific access line counts on a CBG basis. The module performs this translation separately for each service category (residence, business, special access and public access line). In each case, the total number of lines reported for the service category are assigned to specific CBG based upon explicit, user-modifiable assumptions regarding how demand for the service varies by Density Zone.

[17] Curiously, some RBOCs, notably the Southwestern Bell companies, formerly published this information for use by their interexchange carrier customers, but the practice has apparently been discontinued. See SWB, *Interexchange Customer Information Handbook*, Volume IV (End Office Profile), 1987.

The first step of the Line Multiplier Module's algorithms is to assign a primary residence access line to each household identified in the CBG data provided by the Data Module.[18] The remaining residence access lines (i.e., the total ARMIS residence line count for the given LEC minus the household count), as well as the lines associated with each of the other service categories, are then assigned to individual CBGs based on a set of "line multiplier" factors (see Figure 2). Table 3 below illustrates representative line multiplier values.

Table 3 Illustrative Line Multipliers

Density Zone	Total Multiplier	Two-Line Households	Business Line	Special Access	Public Access
1	1.045	0.00	0.02	0.025	0.000
2	1.118	0.02	0.05	0.038	0.010
3	1.296	0.04	0.20	0.045	0.011
4	1.479	0.06	0.35	0.055	0.014
5	1.622	0.10	0.44	0.063	0.019
6	2.106	0.30	0.70	0.080	0.026

Specifically, the Line Multiplier Module uses an iterative process to estimate the demand within each CBG for lines associated with each of the four service categories. In the initial calculation, the HM assigns each CBG a line count for each service category (e.g., business access lines) by multiplying the household totals in each CBG by the initial user-specified line multipliers. For example, if the household count for a particular CBG in Density Zone 3 is 100 and the Additional Lines multiplier is 0.04 (see Table 3), then the HM assigns 4 = 100 x 0.04 additional lines to that CBG. The module then compares total line count for all CBGs to the service category's line count reported in ARMIS. If the totals within a service category fail to reconcile within ± 0.5%, then the module adjusts the multiplier factors upward or downward and the totals are recalculated. This process continues until the totals for each service category are within a ± 0.5% tolerance range.

The module contains an Iteration Macro to automatically adjust the line multipliers; alternatively, the module also allows for a manual adjustment. In either case, the module applies the same basic constraints, namely that the multipliers must be non-negative and increase monotonically with increasing population density. These rules reflect a presumption that sparsely populated areas will tend to have fewer business and second residential lines in proportion to household count than will more densely populated areas. Although specific CBGs may exhibit exceptions from this trend, at higher levels of aggregation (e.g., the wire center or LATA level), the mix of services will progressively approach the total company mix reported in the ARMIS data.

[18] Some additional lines are added to reflect growth in primary residence access line demand due to net gains in households that occurred between the 1990 time frame of CBG household data collected by the U.S. Census and the 1994 time frame of the FCC ARMIS data.

The line multipliers are user-specified inputs Therefore, users can adjust them to reflect LEC-supplied data on service penetration levels by density zone (if such data becomes available), tested for sensitivity effects, or otherwise modified at the discretion of the model user

4. The Modeling of Business Loop Lengths

LECs have asserted that business lines typically have shorter loop lengths than residence lines and therefore should have lower average loop investment costs. Although the BCM algorithms used to determine loop distance make no explicit distinction between residence and business (and other non-residence) loops, the Line Multiplier Module allows for such distinctions. By using business line multipliers that increase the proportion of business lines assigned to the higher density zones, the average loop investment for business lines will reflect both the shorter feeder distances required to serve CBGs in more densely populated areas and the shorter distribution distances that characterize the more compact CBGs found in denser areas.

In the rural zones where CBGs encompass larger geographic areas, the BCM's assumption of uniformly distributed customer locations may overstate somewhat the distribution lengths and associated investment costs for business lines, especially because business locations are likely concentrated nearer the center of the CBG. However, the BCM independently calculates feeder and sub-feeder distances; hence, any possible overstatement of distribution lengths for business lines will not affect these calculations. Accordingly, the sizing of feeder cables and associated support structure will also be unaffected by any overstatement of business lines' distribution distances, so the Model will capture accurately any scale or scope economies engendered by carriers' provision of multiple access line services.

5. Description of Module Outputs and Connection to Next Module

The primary output from the Line Multiplier Module is the Input Data File modified with additional residential, business, special access and public lines. Both the Data Module and the Wire Center Module use these data.

D. DATA MODULE

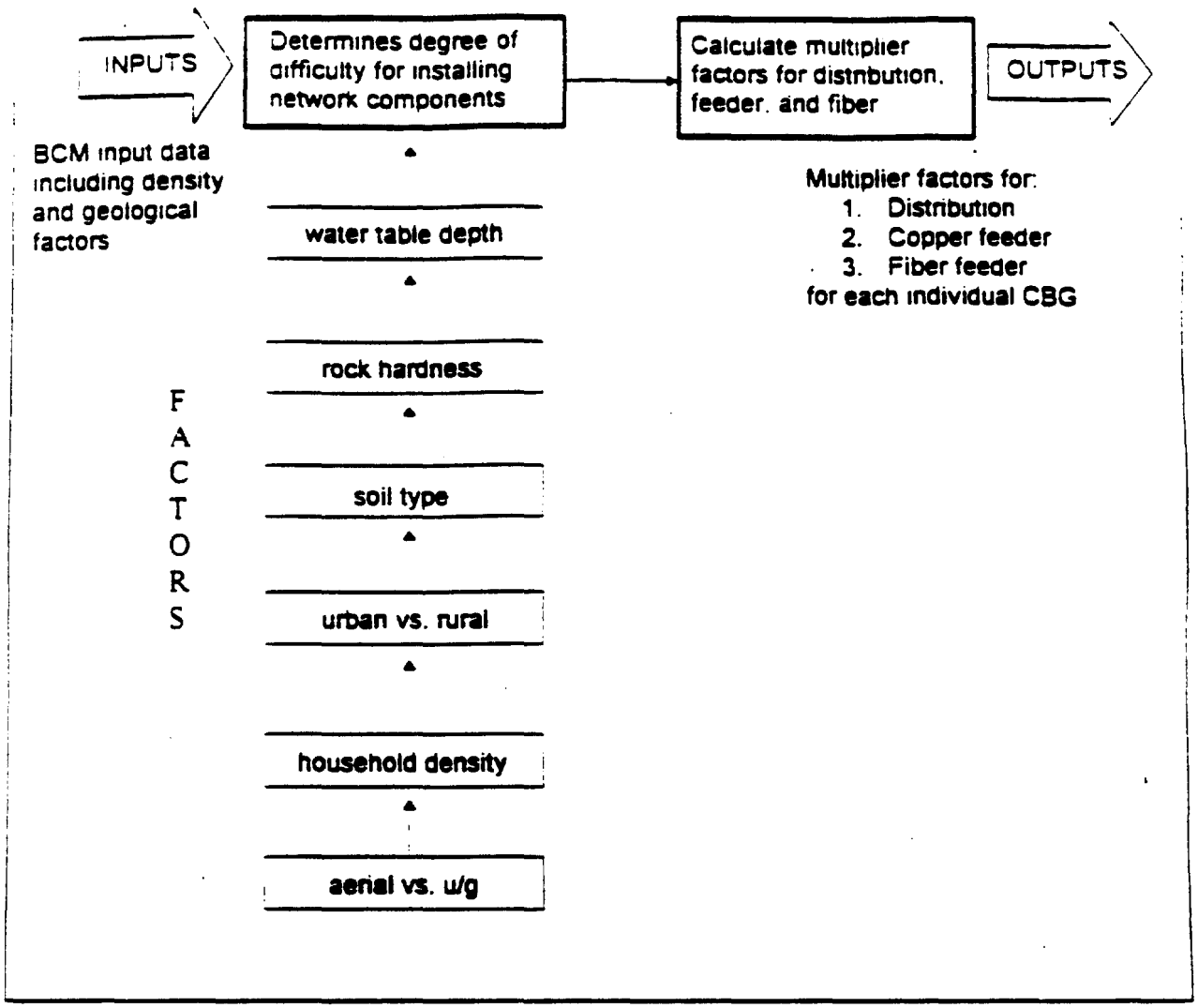
1. Overview

The Data Module is the first module of the BCM. The input for the Data Module is the BCM Input Data File. The results from the Data Module, in turn, are the input to the Loop Module. The Hatfield Model inserts the Line Multiplier Module before the two, but its output does not affect the operation of the Data Module. The BCM developers have designed the Data Module to accomplish two functions:

- Calculate lengths for the feeder, sub-feeder (if required) and distribution portions of the loop
- Determine the appropriate cost structure multipliers to each of the loop segments (feeder, sub-feeder and distribution) to reflect the costs of conduits, innerduct, poles, etc., as well as the capitalized costs of cable placement.

The HM generally uses the structure cost values which the Data Module produces, with one exception. Because the BCM appears to understate the distribution structure costs in sparsely populated areas the HM selectively increases this value in certain low density CBGs.

Figure 3 Data Module



2. Description of Inputs and Assumptions

The Data Module bases its loop length calculations on a number of important assumptions adopted by the BCM's developers. They include the following:

- Feeder cable extends from the wire center to the edge of the CBG.
- There are four main feeder routes that leave each wire center with sub-feeder routes placed at 90 degree angles from the main feeder routes.
- Households are distributed evenly throughout a CBG.
- Distribution cables must extend from the edge of the CBG to each customer premises.

- Four equal-length distribution legs are used to serve each CBG The size of the CBG determines the length of each leg

3. Explanation of Key Algorithms

The Data Module calculates loop distances and structure costs The following describes these key loop calculations

a) Calculating Segment Lengths

To calculate the lengths of feeder segments in the network, the BCM employs trigonometric functions to create a right triangle -- one side being the airline distance from wire center to the center of the CBG, a second side being the feeder route and the final side the sub-feeder. The Joint Sponsors describe this in their December 1, 1995, filing.[19]

Main Feeder Distance -- The BCM Input Data File gives the CBG centroid distance and the appropriate angle. The Data Module calculates the main feeder distance.

Sub-feeder Distance -- The BCM assumes that all CBGs are square and calculates the length of one side of the CBG as the square root of the CBG area. The BCM then determines if sub-feeder is necessary. If the sub-feeder length is less than half of the CBG side, a portion of the CBG overlaps the main feeder and the model sets the sub-feeder length at zero.[20]

Distribution Distance -- The BCM uses other geometric relationships to calculate distribution distances. The distribution distance is the average distance between a household and the center of the CBG. Implicit in this calculation are assumptions that: 1) households are uniformly distributed in the CBG, 2) the CBGs are square, 3) the feeder plant ends at the edge of the CBG and 4) the average distribution plant length equals to the sum of the average horizontal distance of distribution plant and the average vertical distance of distribution plant. The module calculates the average distribution distance within one CBG as 0.75 of the length of one side of the CBG.[21] Because populations tend to cluster in towns and subdivisions, the BCM assumption of uniform population distribution tends to overstate distribution distance and thus the required loop investment.

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19 FCC 80-286, Joint Sponsors, December 1, 1995 filing, Attachment 4 at IV-10-12.

20 The main feeder distance will be overstated whenever the CBG boundary crosses the Main Feeder route, since the algorithm does not subtract the portion of the calculated Main Feeder that extends beyond the intersection of the CBG, whereas the Distribution calculation assumes that the Main Feeder ends at the edge of the CBG. Because the larger CBGs found in low density areas are more likely to cross the Main Feeder route, loop costs will tend to be somewhat overstated in low density zones.

21 FCC 80-286, Joint Sponsors, December 1, 1995 filing, Attachment 4 at IV-14.

b) Structure Multipliers

A variety of demographic and geological factors affect the choice of loop plant, as well as the costs of initial placement. These include the population density, the nature of the soil and the prevailing water table depth. The Data Module calculates the effects of these terrain variables as "structure multipliers." These multipliers also incorporate the material costs of poles, conduit, inner ducts and other structure. The Data Module calculates separate structure factors for placing copper distribution cable, copper feeder, and fiber feeder.

The formulas associated with these cost multipliers use a set of look-up tables. There are a total of 54 of these weighted cost factors which range from a magnitude of 0.233 (the multiplier for distribution plant in rural areas with the lowest household density and with "normal" surface texture) to 11.5456 (the multiplier for fiber plant in urban areas with the greatest household density and the hardest surface texture). To derive the weighted cost factor table, the Data Module matches all the terrain variables to a cost for using different types of cable and multiplies them together (see Figure 3 for a presentation of the logic used to generate these cost structure factors). The module derives these weighted cost factors from 24 "unweighted" cost multipliers. Four tables are generated: Urban Copper Cable, Rural Copper Cable, Urban Fiber and Rural Fiber.

Table 4 shows the cost multipliers for copper feeder and copper distribution in density zones 5 and 6. The BCM developers define these as "urban" density zones.

Table 4 Urban Copper Cable Cost Multiplier

Structure	Underground Cost Factor	Aerial Cost Factor
Rock "Hard"	1.53	0.69
Rock "Soft	1.22	0.48
Rock Normal	1.11	0.48

Table 5 shows the corresponding multipliers in the four lowest density zones.

Table 5 Rural Copper Cable Cost Multiplier

Structure	Underground Cost Factor	Aerial Cost Factor
Rock "Hard"	0.66	0.80
Rock "Soft	0.35	0.54
Rock Normal	0.21	0.44

Table 6 contains the multipliers for fiber feeder in density zones 5 and 6 and Table 7 shows the fiber multipliers for the rural zones 1 through 4.

- Four equal-length distribution legs are used to serve each CBG The size of the CBG determines the length of each leg

3. Explanation of Key Algorithms

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Sub-feeder Distance -- The BCM assumes that all CBGs are square and calculates the length of one side of the CBG as the square root of the CBG area. The BCM then determines if sub-feeder is necessary. If the sub-feeder length is less than half of the CBG side, a portion of the CBG overlaps the main feeder and the model sets the sub-feeder length at zero.[20]

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19 FCC 80-286, Joint Sponsors, December 1, 1995 filing, Attachment 4 at IV-10-12.

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21 FCC 80-286, Joint Sponsors, December 1, 1995 filing, Attachment 4 at IV-14.

b) Structure Multipliers

A variety of demographic and geological factors affect the choice of loop plant, as well as the costs of initial placement. These include the population density, the nature of the soil and the prevailing water table depth. The Data Module calculates the effects of these terrain variables as "structure multipliers." These multipliers also incorporate the material costs of poles, conduit, inner ducts and other structure. The Data Module calculates separate structure factors for placing copper distribution cable, copper feeder, and fiber feeder

The formulas associated with these cost multipliers use a set of look-up tables. There are a total of 54 of these weighted cost factors which range from a magnitude of 0.233 (the multiplier for distribution plant in rural areas with the lowest household density and with "normal" surface texture) to 11.5456 (the multiplier for fiber plant in urban areas with the greatest household density and the hardest surface texture). To derive the weighted cost factor table, the Data Module matches all the terrain variables to a cost for using different types of cable and multiplies them together (see Figure 3 for a presentation of the logic used to generate these cost structure factors). The module derives these weighted cost factors from 24 "unweighted" cost multipliers. Four tables are generated: Urban Copper Cable, Rural Copper Cable, Urban Fiber and Rural Fiber.

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Table 6 Urban Fiber Cable Cost Multiplier

Structure	Underground Cost Factor	Aerial Cost Factor
Rock "Hard"	9.02	3.50
Rock "Soft	7.22	2.50
Rock Normal	6.56	2.50

Table 7 Rural Fiber Cable Cost Multiplier

Structure	Underground Cost Factor	Aerial Cost Factor
Rock "Hard"	3.00	4.25
Rock "Soft	1.45	2.90
Rock Normal	1.02	2.30

The module then weights the values in these tables by the underground/aerial ratios for distribution cable (always copper), copper feeder and fiber feeder. The "mix" of these architectures varies by density zone (see below).

Table 8 Distribution (Copper) UG/Aerial Mix

Density	UG %	Aerial %
1	90	10
2	80	20
3	70	30
4	65	35
5	60	40
6	50	50

Table 9 Copper Feeder UG/Aerial Mix

Density	UG %	Aerial %
1	60	40
2	65	35
3	70	30
4	80	20
5	90	10
6	100	0

Table 10 Fiber Feeder UG/Aerial Mix

Density	UG %	Aerial %
1	60	40
2	65	35
3	70	30
4	80	20
5	90	10
6	100	0

The formulas in the Data Module are relatively simple references to the look-up tables. However, the module does make several preliminary calculations.

A general description of several of the more important of these preliminary calculations follows.

Density – In order to determine cost factors, the Data Module places CBGs into one of six density zones. The HM designates the top two density zones as "urban" within which the model applies a 1.28 cost multiplier to account for the higher costs associated with placing plant in urban areas. In addition, density zones determine the aerial/underground mix of copper and fiber cable.

Surface Texture Indicators – The original data from the USGS Satellite Survey data is qualitative in nature (e.g., clay loam). The surface texture definitions lead to a binary indicator in the Data Module: a "1" indicates an additional cost and a "0" indicates no additional cost.

Copper Depth Condition – The Data Module assumes a value of 24 inches for the normal placement depth for buried/underground copper cable. The Data Module matches this assumption with the original input variables of rock depth, rock hardness and surface texture for all CBGs. The BCM calculates values from 1 to 3 based on the expense of placing copper cable in that specific CBG. A value of "1" is the most expensive.

Fiber Depth Condition – Similar to copper depth, fiber depth determines the costs associated with placing fiber given the specific terrain characteristics of each CBG. The BCM uses a value of 36 inches for the normal placement depth of buried/underground fiber. This function also produces a value from 1 to 3. A value of "1" is the most expensive.

Ultimately, the "Cost Factor Table" (which incorporates all geographic factors, except for the water table depth) drives Data Module outputs. If the water table depth is less than 3 feet, the value that the model derives from the cost factor table is multiplied by 1.3

Tables 11 and 12 are the final lookup tables for loop distribution and feeder structure factors

Table 11 Cost Factor Table for Distribution

Urban/Rural	Density Zone	Surface Category	Weighted Cost Factor
Urban	6	Rock H	1.42
		Rock S	1.09
		Normal	1.02
Urban	5	Rock H	1.19
		Rock S	0.92
		Normal	0.86
Rural	4	Rock H	0.71
		Rock S	0.42
		Normal	0.29
Rural	3	Rock H	0.70
		Rock S	0.41
		Normal	0.28
Rural	2	Rock H	0.69
		Rock S	0.39
		Normal	0.26
Rural	1	Rock H	0.67
		Rock S	0.37
		Normal	0.23

Table 12 Cost Factor Table For Feeder

Cable	Area	Density Zone	Terrain	Factor
Copper	Urban	6	Rock H	1.96
			Rock S	1.56
			Normal	1.42
Copper	Urban	5	Rock H	1.45
			Rock S	1.15
			Normal	1.05
Cooper	Rural	4	Rock H	0.69
			Rock S	0.39
			Normal	0.26
Copper	Rural	3	Rock H	0.70
			Rock S	0.41
			Normal	0.28
Copper	Rural	2	Rock H	0.71
			Rock S	0.42
			Normal	0.29
Copper	Rural	1	Rock H	0.72
			Rock S	0.43
			Normal	0.30
Fiber	Urban	6	Rock H	11.55
			Rock S	9.24
			Normal	8.40
Fiber	Urban	5	Rock H	8.47
			Rock S	6.75
			Normal	6.15
Fiber	Rural	4	Rock H	3.25
			Rock S	1.74
			Normal	1.28
Fiber	Rural	3	Rock H	3.38
			Rock S	1.89
			Normal	1.40
Fiber	Rural	2	Rock H	3.44
			Rock S	1.96
			Normal	1.47
Fiber	Rural	1	Rock H	3.50
			Rock S	2.03
			Normal	1.53

4. Outputs

The Data Module creates outputs that are used by the Loop Module The following describes these outputs and indicates whether it is used in calculating the network cable lengths (for feeder, sub-feeder and distribution lengths) or terrain effects (cost multipliers) Other data transferred from the Data Module to the Loop Module are company name, wire center identification (CLLI code), block group number, quadrant, total households and density

Table 13 New Data for Loop Module

Category	Column	Function
B	E	Cable lengths
A Feeder Portion	F	Cable lengths
Distribution Distance	G	Cable lengths
Distribution Cable Multiplier	J	Terrain effects
Copper Feeder Cable Multiplier	K	Terrain effects
Fiber Multiplier	L	Terrain effects
B Segment distance	M	Cable lengths

E. LOOP MODULE

1. Overview

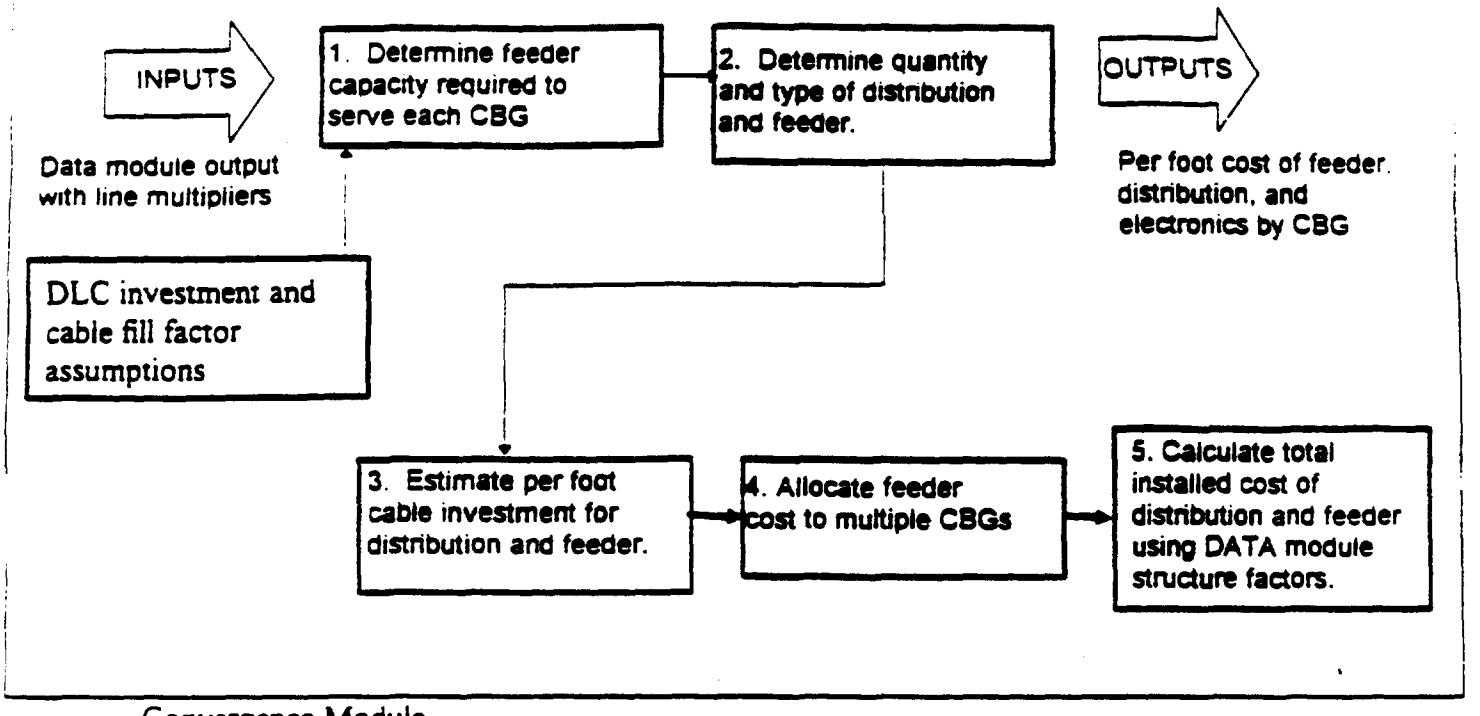
The Loop Module is the third of the four BCM modules. It produces the total loop facilities' investment estimate for the HM. The Loop Module employs a "bottoms-up" network design process that uses forward-looking loop plant engineering and planning practices, the best publicly available information on component prices and installation costs and least-cost cable sizing algorithms to estimate outside plant investment costs appropriate to a TSLRIC analysis. There have been no changes to the BCM algorithms in either the Data Module or the Loop Module.

However, as explained in more detail below, the Model does adjust structure multipliers to achieve more realistic costs for structure investment in low density areas than those generated by the BCM. In addition, recognizing all significant sources of access line demand in the Loop Multiplier Module results in a more realistic modeling of the overall scale of the local exchange network used by a multi-service provider than does the BCM (which sizes the network to accommodate only demand for primary residence lines).

As illustrated in Figure 1, this Module is positioned between the Data Module and the Convergence Module. The Data Module supplies the Loop Module with the calculated lengths for feeder, sub-feeder and distribution for each CBG, plus the structure

factors that represent the costs of conduit, poles and other supporting investment. After the Loop Module sizes the required outside plant facilities and estimates the loop investment costs associated with each CBG, this information is forwarded to the

Figure 4 Loop Module



Convergence Module.

2. Description of Inputs and Assumptions

There are two broad categories of inputs and assumptions in the Loop Module. In the first category are the loop length and structure cost inputs derived from calculations performed in the Data Module. The second category includes parameters that are used in the Loop Module, but may be adjusted by the model user. These include the cable and digital loop carrier ("DLC") equipment fill factors, DLC investments per access line and vendor discounts for copper cable, fiber cable and DLC electronics.

a) Inputs derived from the Data Module

The following outputs from the Data Module are used as inputs by the Loop Module:

"B," "A," and Distribution Distance – These are the feeder, sub-feeder and distribution lengths calculated for each CBG.

Distribution Cable Multiplier, Feeder Cable Multiplier and Fiber Multiplier – These are the cable multipliers reflecting aerial/underground plant mixes and CBG-specific demographic and terrain cost factors.

B Segment Distance – These data express the main feeder distance ("B") for each CBG in terms of its incremental distance from the CBG served by that feeder that is the next closest to the wire center (the "segment" length). The formula used to develop B segment length first matches the CBG with all others served by the same wire center and are within the same quadrant (i.e., on the same main feeder route). It then calculates the B segment length for each CBG by subtracting from its total B length the next highest total B length, which is associated with the next CBG moving inward toward the wire center. Segmentation of the main feeder in this way is necessary for the Loop Module to simulate the tapering requirements for cable facilities along the feeder route (i.e., to size the feeder segments closest to the central office switch to carry the capacity of CBGs locates further out along the feeder route).

b) User Specified Inputs

Because the Loop Module simulates the "bottoms up" development of a network, it requires numerous inputs specifying the type and purchase price for local network components (e.g., copper and fiber cable or electronics), plus certain network parameters (e.g., plant utilization or "fill" levels). While the actual prices paid for these components and their network characteristics may vary from carrier to carrier, HAI has developed a set of standard input values, based on public data sources and the informed judgments of its engineers and other industry experts. In those cases where reliable public data were not available or a range of possible values was indicated, we have chosen values that are likely to be conservative, in the sense that they will produce cost estimates that are likely to be higher than those from a strict least-cost, forward-looking view of outside plant costs. The standard input values applied to the Loop Module are detailed below.

c) Distribution Plant

Network Interface Device ("NID") – The BCM does not include a NID in its calculations. The Hatfield Model adds this investment in the Convergence Module as discussed below.

Drop Wire – The BCM also does not compute a subscriber drop investment. This is added in the Hatfield Model's Convergence Module and is discussed in the corresponding section below.

Terminal/splice – The terminal and associated splice connect the subscriber drop to the distribution cable. The BCM does not include this investment. The Hatfield Model adds these values in the Convergence Module, as described later in this document.

Serving Area Interface ("SAI") – This is the interface between the feeder cable and each distribution cable. It consists of a cabinet, including suitable physical mounting and a

simple passive cross connect in the case of copper feeder, or an optical multiplexer and cross connects in the case of optical feeder. BCM does not include this investment, but it is added by the Hatfield Model, as is discussed in the Convergence Module section below.

Mix of aerial and underground plant for distribution -- Distribution cables typically fan out from the feeder network at one or more cross-connect points and run down individual streets within a defined area. Distribution plant may be aerial (carried on telephone poles) or placed underground (either simply buried in a trench or placed in conduit). We have used the same mix of aerial and underground distribution plant as is used in the BCM (see Table 14 below). These values presumably reflect the engineering expertise of the participating LECs: NYNEX, US West and Sprint.

Table 14 Distribution Plant, UG/Aerial Mix

Density Zone	UG %	Aerial %
1	90	10
2	80	20
3	70	30
4	65	35
5	60	40
6	50	50

Unit Costs for Distribution Cable-- HAI has not altered the unit cost values provided by the Joint Sponsors for the BCM. As shown in Table 15, the Loop Model selects from unit (per foot) costs for 11 discrete sizes of copper distribution cable, ranging from 50 to 3600 wire pairs. These costs are based upon information provided by cable vendors. All copper cable is 24 gauge. Aerial cable costs represent non-armored cable, with both aluminum and plastic jacketing. Buried cable costs are for armored, single jacket filled cable.[22]

[22] CC Docket 80-286, Joint Sponsors, December 1, 1995 filing, at IV-5.

Table 15 **Distribution Cable Unit Costs**

Cost ($ per foot)		
Cable Size	Underground	Aerial
3600	22.20	21.90
3000	18.80	18.50
2400	14.30	14.10
1800	12.44	12.24
1200	10.68	10.00
900	7.82	7.51
600	7.13	7.05
400	4.56	4.62
200	2.36	2.33
100	1.26	1.27
50	0.68	0.57

Fill Factors for Distribution Cable – The Loop Module also accepts user inputs regarding the level of plant utilization or "fill" for distribution and feeder cable facilities. A cable fill factor represents the ratio of working lines (measured in terms of voice grade equivalent channels or copper wire pairs) to installed line capacity. Cable fills are always less than 1.0 in practice, with some spare cable facilities required to accommodate line administration, defective pairs and cable "breakage" effects. [23] It is also appropriate for cable fill factors to allow for some additional spare capacity for future growth, to the extent that the service provider's overall costs are reduced by installing this "extra" plant in advance of demand, due to economies in installation (e.g., trenching) and the discrete sizing of cables.

However, the cable fills in current LEC networks are likely to understate plant utilization relative to efficient, forward-looking provisioning practices for narrowband telephony. This is because embedded fills may reflect loop plant installed to pursue existing competitive and/or non-regulated services (e.g., Centrex) and/or new market opportunities (e.g., broadband services or enhanced services). The distribution cable fill factors selected by the BCM's Joint Sponsors, which range from 0.25 to 0.45 in the three lowest density zones, appear to reflect precisely these types of strategic plant deployments and therefore have been revised upward by HAI (see Table 16 below).

[23] "Breakage" refers to wire pairs that become unusable in cable segments due to the splicing of different cable sizes along a tapered cable route.

Table 16 **Cable Fill Factors**

Density Zone	Feeder	Distribution
1	0.65	0.50
2	0.75	0.55
3	0.80	0.60
4	0.80	0.65
5	0.80	0.70
6	0.80	0.75

d) Feeder Plant

Feeder cables extend from the wire center to one or more points where they are cross-connected to the distribution network.[24] Depending on required feeder capacity, distance or economics may dictate that feeder be provisioned using various sizes of copper cabling, or "DLC" systems. The Loop Module assumes that a CBG will be served with fiber-fed DLC equipment whenever the total loop length (including distribution) exceeds 12,000 feet. For shorter loop lengths, baseband copper feeder is assumed.

Use of a 12,000 foot loop distance threshold for copper vs. fiber feeder deployment – The Joint Sponsors of the BCM implemented the 12,000 foot copper/fiber breakpoint so that it is effectively "locked" and unalterable by users. This 12,000 foot breakpoint assumption appears to be supported by other input cost assumptions of the BCM.

Fill Factors for Feeder Cable – Similar to the fill factors for distribution cable (see above), these factors represent the ratio of working lines to installed lines. HAI has used the values that were developed by the BCM Joint Sponsors without adjustment (see Table 16, above).

Unit Costs for Feeder Cable – HAI has not altered the unit cost values provided by the Joint Sponsors for the BCM. As shown in Table 17, the Loop Model selects from unit (per foot) costs for 11 discrete sizes of copper feeder cable, ranging from 100 to 4200 wire pairs. These costs rely upon information provided by cable vendors. All copper cable is 24 gauge. Aerial cable costs represent non-armored cable, with both aluminum and plastic jacketing. Buried cable costs are for armored, single jacket filled cable.

[24] Under the Bellcore Standard Serving Area Concept ("SAC") planning guidelines used by many LECs, the points of connection between feeder and distribution are referred to as Serving Area Interfaces ("SAIs").

Table 17 **Copper Feeder Cable Unit Costs**

	Cost ($ per foot)	
Cable Size	Underground	Aerial
4200	25.70	25.40
3600	22.20	21.90
3000	18.80	18.50
2400	14.30	14.10
1800	12.44	12.24
1200	10.68	10.00
900	7.82	7.51
600	7.13	7.05
400	4.56	4.62
200	2.36	2.33
100	1.26	1.27

Nine sizes of fiber feeder cable may be used, ranging from 12 to 144 strand cable. The unit costs for each size are shown in Table 18, which assume the same armoring and jacketing as for copper feeder cable.[25]

Table 18 Fiber Feeder Cable Unit Costs

	Cost ($ per foot)	
Cable Size	Underground	Aerial
144	5.56	5.24
96	3.80	3.53
72	2.84	2.65
60	2.41	2.23
48	1.98	1.84
36	1.60	1.46
24	1.18	1.05
18	0.98	0.85
12	0.79	0.66

DLC Equipment Costs per Access Line – The Loop Module employs two types of DLC equipment for loop runs over 12,000 feet. The first is designated "SLC" (after the AT&T trademark) and the second is designated "AFC" (for the name of its manufacturer, Advanced Fiber Communications). The Loop Module selects AFC technology for use in the lowest density zone, where the feeder runs are the longest, and SLC systems for use in all other density zones.

[25] CC Docket 80-286, Joint Sponsors, December 1, 1995 filing, at IV-5.

The investments associated with DLC equipment are developed using several inputs (see Table 19), for which HAI has developed standard values. The Loop Module specifies a per-line investment cost for each of the two DLC equipment types and requires a separate discount factor for each type. The default values used in the BCM for the list price per-line investments for SLC and AFC are $500 and $550, respectively, with assumed discounts off of list of 10%. These values overstate significantly the investments for DLC equipment because of the much higher discounts that are typically available to LECs for such network equipment. The corresponding HAI assumptions are list price of $250 and $500 per line, with discounts of 40% and 25%. We have carried forward the Joint Sponsors' use of 0.80 fill factors for both types of DLC equipment. The rationale for the selection of these values follows:

Table 19 DLC Inputs

User Input	HAI Values
Fill Factor for AFC Electronics	.80
Fill Factor for SLC Electronics	.80
SLC Cost per Access Line	$250
AFC Cost per Access Line	$500
SLC Electronics Discount %	40%
AFC Electronics Discount %	25%

For point comparisons with known prices indicate that the list price and discount factor for SLC equipment have been set at levels that produce a realistic estimate of the per-line SLC prices actually paid by LECs. An RBOC engineer responsible for the procurement and acceptance testing of TR-303-compatible DLC equipment has for example, informed HAI that his company pays approximately $135 per line for this equipment from AT&T. Using HAI's list price and discount assumptions for SLC produce a $150 investment per line. Dividing by the 0.8 fill factor yields a total investment per working line of $187.50. This total per-line cost includes both material investment and engineering and installation costs. No attempt is made here to separate these costs because they are capitalized along with the equipment investment.

The AFC input assumptions have also been revised to produce a realistic estimate of the prices actually confronting LECs. The AFC input assumptions of $500 per line at a 25% discount and 0.8 fill factor yield a net effective investment per line of $468.75. Calculations based on published equipment configurations and prices show that these estimates are reasonable.[26] HAI estimates a typical undiscounted price per line of about $400. If one assumes a conservative typical discount of 15%, the per-line investment is

[26] Advanced Fiber Communications.

$320. The net effective investment of $468.75 thus allows for $148.75 (38% of the equipment investment) per line for engineering and installation. This assumption is consistent with that for the higher density DLC equipment described above. As before, no attempt is made to separate installation and engineering costs because both are capitalized along with the equipment investment.

The Loop Module's sizing of DLC equipment is consistent with TSLRIC principles (see Appendix 1), because it results in sufficient capacity in the network to serve the specified total demand level. Because DLC investments can be increased incrementally, the module does not need to allow for equipped but unused DLC subscriber interfaces. Consequently, the standard DLC equipment fill values of 0.80 for both SLC and AFC technology are reasonable and the total investments per working line of $187.50 for SLC and $468.75 for AFC accommodate properly the equipment investment as well the associated engineering and installation.

Mix of aerial and underground plant for feeder — Like distribution facilities, feeder may be installed as aerial or underground plant. We have used the mix of aerial and underground feeder plant developed by the Joint Sponsors of the BCM (see Table 20 below). The same mix applies to both copper and fiber feeder.

Table 20 Copper and Fiber Feeder Plant, UG/Aerial Mix

Density Zone	UG %	Aerial %
1	60	40
2	65	35
3	70	30
4	80	20
5	90	10
6	100	0

3. Explanation of Key Algorithms

The Loop Module's algorithms perform several main tasks:

- Selecting copper vs. fiber-fed DLC feeder technology to serve each CBG, based on the 12,000 foot copper/fiber loop feeder breakpoint.
- Sizing main feeder segments to accommodate the cumulative capacity requirements along the route.
- Determining the type and quantity of feeder facilities and distribution cables to meet each CBG's capacity requirements.
- Applying unit investment costs and structure factors to the appropriately-sized cables and DLC equipment to cost out the total loop plant.

Each of these steps is explained below:

Feeder Technology Section Based on 12,000 Foot Decision Rule -- If the total loop distance to the CBG (including feeder, sub-feeder and the averaged distribution length) exceeds 12,000 feet, fiber-fed DLC systems are selected, otherwise copper feeder cables are used. In those cases where DLC systems are chosen, the SLC equipment is selected unless the CBG is classified as Density Zone 1, in which case the AFC equipment is used.

Sizing Main Feeder Segments to Reflect Cumulative Capacity Requirements Along the Route ("Tapering") -- After the choice of copper or fiber feeder technology has been determined for each CBG, the Loop Module must size each main feeder segment to have sufficient capacity to meet the traffic demand of CBGs farther out along the main feeder segment. A key feature of the Loop Module is its ability to reflect the provision of a hybrid combination of fiber and copper facilities along a feeder route, as may occur when multiple CBGs are served by a common route. The module does this by assigning a "Segment Type 2" and "Segment Type 3" to CBGs whose main feeder segments contain multiple technologies. A CBG will have a "Segment Type 2" if another CBG further out along the main feeder route employs a single main feeder technology different from its own. It will have "Segment Type 3" if CBGs further out along the feeder route employed two feeder technologies different from its own.

For example, as illustrated below in Table 21, if the first CBG in a sequence of 3 CBGs. CBG 1 is served by a copper main feeder segment and if CBGs 2 and 3 are served by SLC, then the Segment Type 2 for CBG 1 would be SLC. In this case, CBGs 2 and 3 would not have a Segment Type 2. If in the above example, CBG 3 was served by AFC, then CBG 1 would have a third Segment Type -- AFC. Furthermore, CBG 2 would have a Segment Type 2 of AFC and CBG 3 would have only a Segment Type 1 -- AFC.

Table 21 Main Feeder Segment Types for CBGs in the Same Quadrant

Office	Quadrant	Block Group Seqnc. #	Segment Type 1	Segment Type 2	Segment Type 3
ABCDSTMA	1	1	Copper	SLC	--
ABCDSTMA	1	2	SLC	--	--
ABCDSTMA	1	3	SLC	--	--
ABCDSTMA	2	1	Copper	SLC	AFC
ABCDSTMA	2	2	SLC	AFC	--
ABCDSTMA	2	3	AFC	--	--

The BCM then assigns to each CBG an aggregate number of households for each main feeder technology, again for the purpose of calculating the capacity requirements of each main feeder segment. For example, as illustrated below in Table 22, the number of households "on copper" for the first CBG in a sequence of three CBGs that are all served by copper would be the total number of households in the three CBGs. The number of

households on copper for the second CBG would be equal to its households plus those in the third CBG

Returning to our first example where CBG 1, CBG 2 and CBG 3 were served by copper, SLC and AFC respectively, the households on copper for the first CBG would equal the number of households in CBG 1, the households on SLC for CBG 1 would equal the number of households in CBG 2 and the households on AFC for CBG 1 would equal the number of households in CBG 3

Table 22 Main Feeder Segment Types and Household Count for CBGs in the Same Quadrant

Segment Type 1	Households in the CBG	Segment Type 2	Segment Type 3	HH on Copper	HH on SLC	HH on AFC
Copper	250	--	--	400	--	--
Copper	100	--	--	150	--	--
Copper	50	--	--	50	--	--
Copper	300	SLC	AFC	300	150	100
SLC	150	AFC	--	--	150	100
AFC	100	--	--	--	--	100

Determining the type and quantity of feeder facilities and distribution cables to meet each CBG's capacity requirements -- Once the household totals for each main feeder technology have been calculated, the Loop Module uses this information to calculate the number and size of copper feeder pairs required by each CBG and the number and size of SLC and AFC fibers as well. In the case of CBGs served by copper main feeder, it divides the number of households on copper by the feeder fill factor appropriate to the CBG's household density.

For example, a CBG with 6,000 households on copper and a household density of 1,000 households per square mile would, applying the Loop Module's default fill factors, have a feeder fill factor of 0.8 and thus require 7,500 copper feeder pairs. In the case of copper plant, the Loop Module then translates the capacity requirements for each CBG into the number of maximum size cables that would be employed (4200 pair for copper feeder) and the minimum cable size necessary to carry any remaining fraction of total capacity.

Sub-feeder and distribution cables are selected using the same method, placing the minimum quantity and size of cables out of the available discrete cable types to accommodate demand. However, sub-feeder and distribution facilities are required to carry only the traffic of their associated CBGs. Therefore, their capacity requirements are calculated on the basis of the number of households in each particular CBG as opposed to the total households served by that CBG's main feeder segment.