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 Rock S Normal	1.42 1.09 1.02
Urban	5	Rock H Rock S Normal	1.19 0.92 0.86
Rural	4	Rock H Rock S Normal	0.71 0.42 0.29
Rural	3	Rock H Rock S Normal	0.70 0.41 0.28
Rural	2	Rock H Rock S Normal	0.69 0.39 0.26
Rural	1	Rock H Rock S Normal	0.67 0.37 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

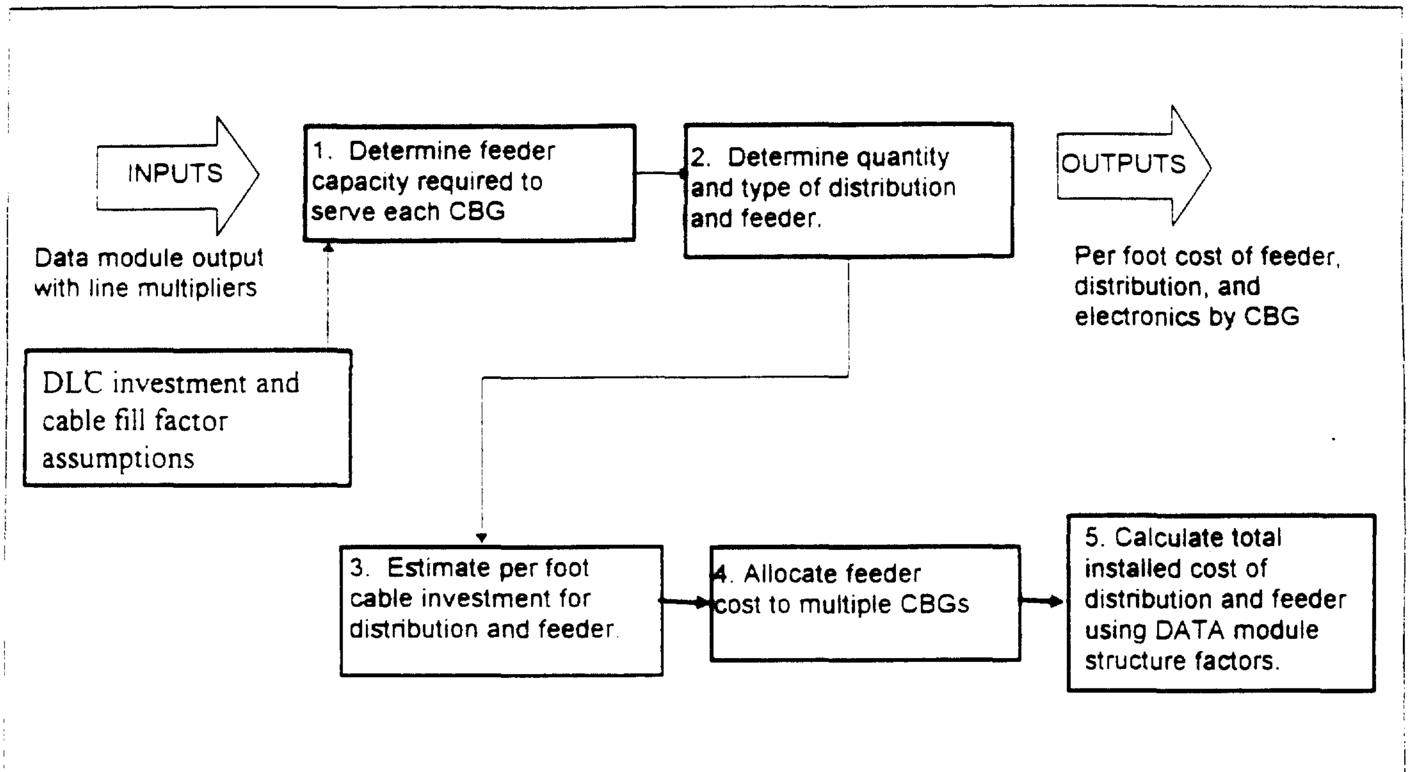
1. Overview

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.

Applying unit investment costs and structure factors to calculate total loop plant investment costs -- After the Loop Module has determined the number and size of all loop components in the network, it calculates the total loop investment costs. The Loop Module costs out the network sheet by matching the calculated copper and fiber cable sizes with per foot plant costs for copper feeder, copper distribution and fiber. The investment costs for other plant types are calculated using the same basic method. Because main feeder segments typically serve multiple CBGs along the feeder route, formulas assign the feeder segment costs to each associated CBG and then to each household using the "Segment Type" and "Household Count" variable described above.

After these investments have been determined, structure cost factors (i.e., the Distribution Cable Multiplier, Feeder Cable Multiplier and Fiber Multiplier) are applied. As explained earlier, different structure factors apply to each combination of plant type (Aerial or Underground), Density Zone and terrain type.

For example, the cable structure percentage for a CBG that was served by cable feeder but which had a Segment Type 2 of SLC and a Segment Type 3 of AFC — meaning that other CBGs further out along the main feeder route are served by SLC and AFC feeder — would be 80%, while the SLC Structure percentage and AFC Structure percentage would be 10% each. The copper factor for that CBG would then be weighted by 80% and the fiber factor would be weighted by 20%. These weighted factors are multiplied by the corresponding copper and fiber feeder investments and the results are summed. The structure factors for distribution cable are similarly weighted and applied to develop the total investment costs for distribution including structure.

4. Description of Model Outputs and Connection to Next Module

The Loop Module produces total investment costs by CBG for distribution cable, associated structure, feeder cable and electronics and a total of all these loop investment costs. The Loop Module then feeds this Total Loop Cost, plus Loop Cost per Household, Household Density Range and average Total Loop Length for each CBG to the Convergence Module, which combines them with switching, signaling and transmission investments.

F. WIRE CENTER INVESTMENT MODULE

1. Overview

This Module produces network investments at the wire center, interoffice transport, signaling and operator systems levels in the following categories:

Switching and wire center investment -- This category includes investment in local and tandem switches, along with associated investments in wire center facilities, including buildings, land and power systems and distributing frames.

Signaling network investment -- This includes investment in Signal Transfer Points, Service Control Points ("SCPs") and signaling links.

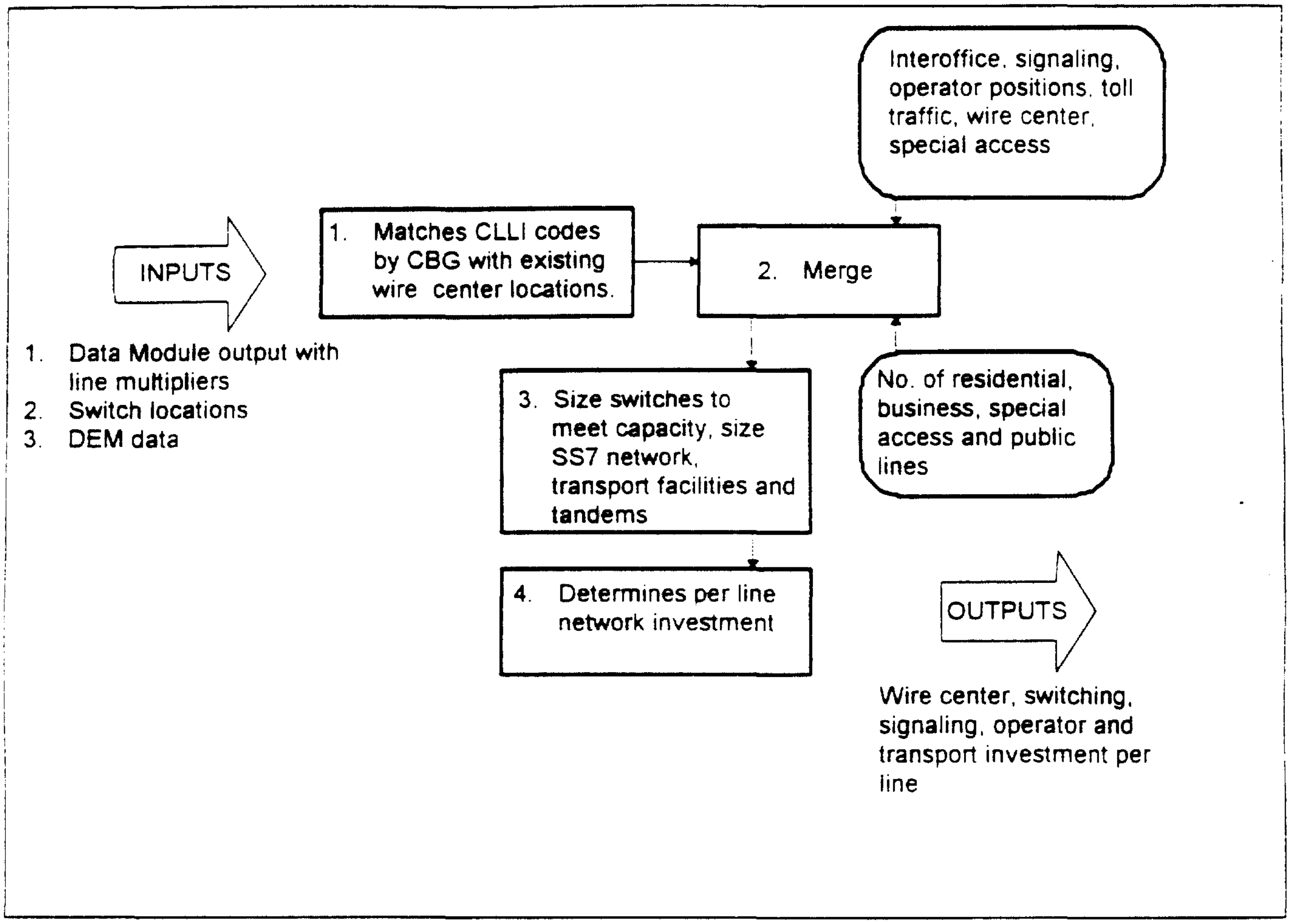
Transport investment -- This category consists of investment in transmission systems supporting local interoffice (tandem and direct) trunking, intraLATA toll facilities (tandem and direct) and access facilities (tandem and direct). The model also separately calculates investment in operator trunks.

Operator Systems Investment -- This includes investments in operator systems positions.

The Wire Center Investment Module, as shown in Figure 1, contributes wire center-related investments to the Convergence Module, which in turn combines these with loop-related investments for application to the Expense Module.

The Wire Center Investment Module adds several network components to the modeling process that are omitted from the BCM. The BCM estimates only end office switching investment and does not address complete wire center investments that would include tandem switching, transport, signaling and operator services investments. Furthermore, the BCM estimates monthly costs by multiplying loop and switching investment per line by a single constant and does not allow the user to vary capital or expense factors to reflect the values pertaining to a specific company or study area.

Figure 5 Wire Center Module



2. Description of Inputs and Assumptions.

For the wire center module to compute switching and transmission investments, it must be given total line counts for each wire center and wire center geographical locations must be known for distance computations. It also requires subscriber traffic assumptions, as well as inputs describing the distribution of total traffic among local intraoffice, local interoffice, intraLATA toll, interexchange access and operator services. This module uses as inputs overall line counts obtained from the BCM Data Module and line counts per wire center obtained from the Line Multiplier Module.

Many of the calculations in the wire center module rely on traffic assumptions obtained from Bellcore documents.[27] These inputs, which the user may alter, assume 1.3

[27] Bell Communications Research, *LATA Switching Systems Generic Requirements, Section 17: Traffic Capacity and Environment*, TR-TSY-000517, Issue 3, March 1980.

busy hour call attempts ("BHCA") per residential subscriber and 3.5 BHCA per business line, each with an average holding time of 150 seconds. Other inputs, which also may be changed by the user, specify the fraction of interoffice traffic, the fraction of traffic that flows to operator services, the local fraction of overall traffic, as well as the breakdowns of direct-routed and tandem-routed local, intraLATA toll and access traffic. The default values for these parameters are as follows:

Interoffice fraction of total traffic	0.65
Local fraction of total traffic	0.75[28]
Operator services fraction of total traffic	0.02
Tandem-routed fraction of local interoffice traffic	0.40
Tandem routed fraction of intraLATA toll traffic	0.20
Tandem-routed fraction of access traffic	0.20

These values were determined from conversations with AT&T and MCI representatives, as well as from publicly-available studies of usage produced by LECs.

3. Explanation of Key Algorithms

The following sections describe the key algorithms used to generate investments associated with switching, wire centers, interoffice transport, signaling and operator systems functions.

a) Switching investment calculations

The Wire Center Module computes investment per line for end office and operator tandem switching, by separately developing the wire center investments required for each switch in the modeled network.

The Module assigns at least one end office switch to each wire center. It sizes switches in the wire center by adding up all the lines in the CBG's served by the wire center and then compares this line total to the maximum allowable switch line size. This parameter is user-adjustable, but set at 100,000 lines with a fill factor of 0.80, yielding a maximum effective switch line size of 80,000. The model will equip the wire center with a single switch if the number of switched access lines served by the wire center is no greater than 80,000, using the default assumptions. In general, a switch may serve any line count between zero and 80,000. Thus, if a wire center serves 90,000 lines, the model will compute the investment required for two 45,000 line switches[29]. The wire center module also compares the BHCA produced by the mix of lines served by each switch with a user-

28 The fraction of local traffic is determined by Dial Equipment Minutes ("DEM") statistics reported by each carrier to the FCC; the typical value of this fraction is approximately 0.75.

29 If multiple switches are required in the wire center, they are sized equally to allow growth on both switches.

adjustable processor capacity (set at 1,000,000 BHCA) to determine whether the switch is line-limited or processor limited.

End office switches may exhaust their capacity by running out of processor capacity, exceeding port limits, or by exceeding traffic (switching matrix) capacity. Typically, they are limited by processor capacity or by line port capacity. While processor capacity requirements are typically stated in terms of the effective number of BHCA that a processor configuration may handle, the processor is also affected by use of rates custom calling features, the need for processing SS7 messages and other processing tasks. Including both a processor limit and a port limit allows the model to consider the overall switch capacity in practical terms. The model's specific default values were set according to the engineering judgment of the Hatfield Model developers and are based on practical values for current end office switches.

Once the model determines the end-office switch line size, it obtains the investment per line from an investment function that relates per-line switching investment to switch line size. The data to define this function were obtained from a publicly-available study of the central office equipment market published annually by McGraw-Hill.[30] This study shows the average investment per new line of digital switching paid by BOCs to be $104 and by independents to be $241 in 1994. The model combined these figures with average BOC (11,200) and independent (2,761) switch line sizes derived from data published in the FCC's Statistics of Communications Common Carriers, along with information on much larger switches obtained from switch manufacturers to develop the complete investment function.[31] Figure 6 shows the resulting investment curve.

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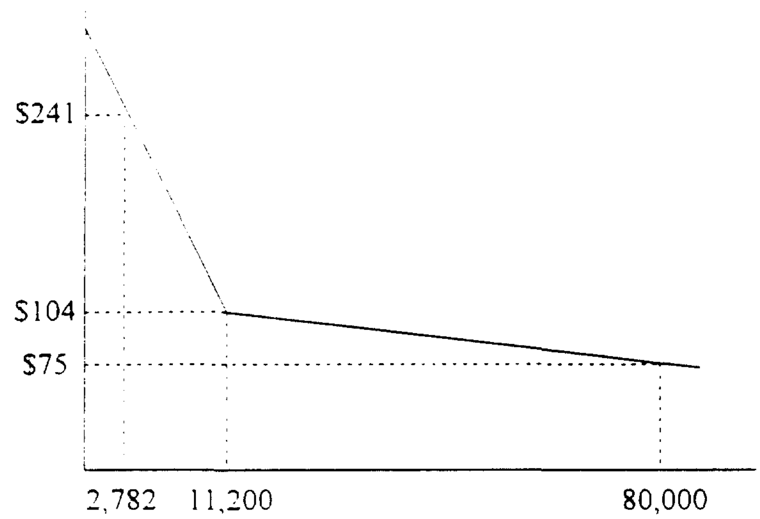
30 Northern Business Information study: *U.S. Central Office Equipment Market -- 1994*, McGraw-Hill.

31 Federal Communications Commission, *Statistics of Communications Common Carriers*, Tables 2.3 and 2.4 1994 edition.

Figure 6 Switching Investment Function



The wire center module uses existing tandem locations for computing interoffice transmission distances. These tandem locations are obtained from the LERG data. Tandem and operator tandem switching investment are computed according to assumptions contained in an AT&T report on interexchange capacity expansion costs filed at the FCC.[32] The investment calculation assigns a price to switch "common equipment," switching matrix and control structure and adds to these amounts the investment in trunk interfaces. The numbers of trunks and their related investments, are derived from the transport calculations described below.

Wire center investments required to support end office and tandem switches are based on HAI assumptions about the size of room required to house a switch (for end offices, this size varies according to the line sizes of the switch), construction costs, lot sizes, land acquisition costs and investment in power systems and distributing frames.

The model computes required wire center investments separately for each switch. For wire centers housing multiple end office switches, the wire center investment calculation adds switch rooms to house each additional switch. Tandem wire center

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32 AT&T, "An updated study of AT&T's Competitors' Capacity to Absorb Rapid Demand Growth", filed with the FCC in CC Docket No. 79-252, April 24,1995 ("AT&T Capacity Cost Study")

calculations assume the maximum switch room size, power and distributing frame investments. Tandem switches also include a separate land investment.

b) Transport calculations

Transport calculations are driven primarily by the traffic and routing assumptions listed above, along with the total mix of access lines served by each switch. The model determines the overall breakdown of traffic per subscriber according to the traffic assumptions and computes the numbers of trunks required to carry the traffic. These calculations are based on the fractions of total traffic assumed for interoffice, local direct routing, local tandem routing, intraLATA direct and tandem routing and access direct and tandem routing. These traffic fractions are applied to the total traffic generated in each wire center according to the mix of business and residential lines and appropriate per-line offer load assumptions. These trunk loading assumptions include a maximum trunk utilization of 27.5 CCS, which is user-adjustable.[33]

Tandem transport distances are computed from existing wire center and tandem locations. The model conservatively assumes rectilinear routing. It does this by adding the north-south and east-west distances between end offices and their homed tandem locations to produce the overall facilities distance. This is superior to calculating the airline distance between the endpoints because facilities routes usually follow streets and highways that typically are oriented in north-south and east-west directions. The resulting distances are somewhat greater than they would be if calculated as airline mileage.

Direct-route distances for local, intraLATA and access traffic are set as user-definable inputs. It is not possible to compute these values from wire center locations, because actual exchange area definitions determine which routes will carry local versus intraLATA toll traffic. Because interexchange carrier points of presence ("POPs") are not available for entry into the model to compute access route distances, the default distances for direct transport are 10 miles for local direct routes, 25 miles for intraLATA direct routes and 25 miles for access facilities. These route distance assumptions are developed from conversations with AT&T and MCI representatives who have studied publicly-available LEC documentation.

Transport investment is based on a user-defined per-channel-mile figure. The default value is $30 per DS0 channel mile. This is computed based on a 15-mile transmission facility consisting of a 144-fiber cable installed in conduit at a total cost per foot of $14. Terminal equipment is assumed to have a 4 DS-3 capacity with an installed investment of $52,000 per end. This fiber and installation investment is based on BCM fiber assumptions. The terminal equipment investment derives from pricing and installation assumptions for a fully-equipped AT&T (now Lucent Technologies) DDM-

[33] The 27.5 CCS value is based on an AT&T estimate of maximum per trunk usage one can expect on typical size trunk group. See, AT&T Capacity Cost Study.

1000 180 Mbps optical multiplexer The specific assumptions are that the multiplexer investment is $42,000 and installation is $10,000

c) Signaling network calculations

The Wire Center Module uses existing switch and STP locations for computing signaling link distances. The model uses the STP pair locations in each LATA, as reported in the LERG and computes the total link distance to each switch as the sum of the distances from each wire center to each STP location. Routing is again rectilinear as described for transport calculations. The investment per link-mile is assumed to be the same $30 per DS0 channel-mile figure discussed earlier. The latter value is appropriate because signaling links typically share transmission routes carrying common and dedicated transport trunks.

The model always equips at least two signaling links per switch. It also computes SS7 message traffic according to the call traffic assumptions described earlier. User inputs define the number of ISUP ("ISDN User Part") messages, along with the message length, required for interoffice call control. Default values are six messages per interoffice call attempt with twenty-five octets per message. These values are those assumed in the AT&T capacity cost study.[34]

Other inputs define the number and length of TCAP ("Transaction Capabilities Applications Part") messages required for database lookups, along with the percentage of calls requiring TCAP message generation. Default values, also obtained from the AT&T capacity cost study, are two messages per transaction, at 100 octets per message and 10% of all traffic requiring TCAP generation. If the message traffic from a given switch exceeds the link capacity (also user-adjustable and set at 56 kbps and 40% occupancy as default values), the model will add links to carry the computed message load. The total link distance calculation includes all the links required by a given switch.

Signal transfer point capacity is expressed as the total number of signaling links each STP in a pair can terminate (default value is 720 with an 80% fill factor). The investment per pair is set at $5 million and may also be changed by the user. These default values derive from the AT&T capacity cost study.

Service control point ("SCP") investment is expressed in terms of dollars of investment per transaction per second. The transaction calculation is based on the fraction of calls requiring TCAP message generation and the total TCAP message rate in each LATA considered by the model is used to determine the total SCP investment. The

[34] See, AT&T Capacity Cost Study.

default SCP investment is $20,000 per transaction per second and is based on a number reported in the AT&T capacity cost study [35]

d) Operator systems calculations

Operator tandem and trunk requirements are based on the operator traffic fraction inserted by the user into the model and on the overall maximum trunk value of 27.5 CCS discussed above. Operator tandem investment assumptions are the same as for local tandems. The Model assumes that subscriber databases required for operator services are included in overall operator tandem common equipment investment of $1 million. This is the same value assumed for local tandem common equipment that was derived from the AT&T capital cost study

Operator positions are assumed to be based on current personal computer terminal technology. The default operator position investment is $3500 to purchase a high quality personal computer terminal with a suitable interface to the operator tandem. The total investment is based on the engineering judgment of the Hatfield Model developers. The Model includes assumptions for maximum operator "occupancy" expressed in CCS. The default assumption is that each position can be in service 27.5/36 of each hour. This value is related to the maximum trunk occupancy assumption described above. Also because many operator services traditionally handled by human operators may now be served by announcement sets and voice response systems, the model includes a "human intervention" factor that reflects the fraction of calls that require human operator assistance. The default factor is 10, which is believed to be a conservative estimate. (A factor of ten implies that one out of ten calls will require human intervention).

G. CONVERGENCE MODULE

The Convergence Module combines the loop investment produced by the BCM with the wire center, switching, transport, signaling and operator systems investments calculated by the wire center investment module. The output of the Convergence Module is the complete collection of network investments for use by the expense module.

There are, as noted elsewhere in this document, several loop components missing from the BCM, most notably serving area interfaces (SAIs), the interface between feeder and distribution cables, terminals or pedestals and associated distribution cable splices, the interfaces between distribution cables and subscriber drops, along with associated splices required to tap into the distribution cables, the drops extending to each customer's premises and the network interface device ("NID") that marks the boundary between the customer's inside wiring and the network.

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[35] See, AT&T Capacity Cost Study.

The convergence module adds these components to the loop investment produced by the BCM. The NID, drop and terminal/splice values are added for each line directly. The values used, which are user-adjustable, are: $30 for the NID, obtained from discussions with subject-matter experts; $40 for the drop, taken from the NET Incremental Cost Study;[36] and $35 for the terminal and splice, based on the engineering judgment of the model developers.

The SAI investments depend on whether copper or fiber feeder cable is used the particular CBG. If the feeder cable is copper, the SAI is a simple cross-connect arrangement, whose investment is obtained from a table listing SAI installed prices by total lines served. For optical feeder cable, the SAI consists of an optical multiplexer with an associated cross-connect, cabinet, powering arrangement and prepared site.

The BCM "structure" investment for distribution and feeder facilities are of particular interest. The BCM developers use the term "structure" to refer to investment in poles, conduit and the necessary installation labor to place aerial and underground cable.

Structure investment may be shared among utilities, typically local exchange carriers, cable television operators and electric companies. To the extent that more than one utility may place cables in common trenches, conduits, or on common poles, it is appropriate to share the costs of these structural items among them. The Convergence Module thus separately reports the structure investment to the Expense Module, where the user may select the fraction of distribution and feeder structure investment to be assigned to telephone service.

H. EXPENSE MODULE

1. Overview

The Expense Module provides per-line and per-month cost summaries for each Basic Network Function ("BNF") by calculating capital carrying cost, operating expenses, network operation expense and attributable support expenses for each of eleven unbundled network functions, plus public telephone terminal equipment.

The Expense Module uses the output of the Convergence Module to capitalize the investments needed for each BNF, reflecting TSLRIC principles as presented in Appendix 1. The module requires investment, revenue and expense data reported by individual LECs in their annual ARMIS reports. The Module's other required inputs are data on individual carrier (debt-equity ratio, cost of debt and cost of equity) capital structure parameters.

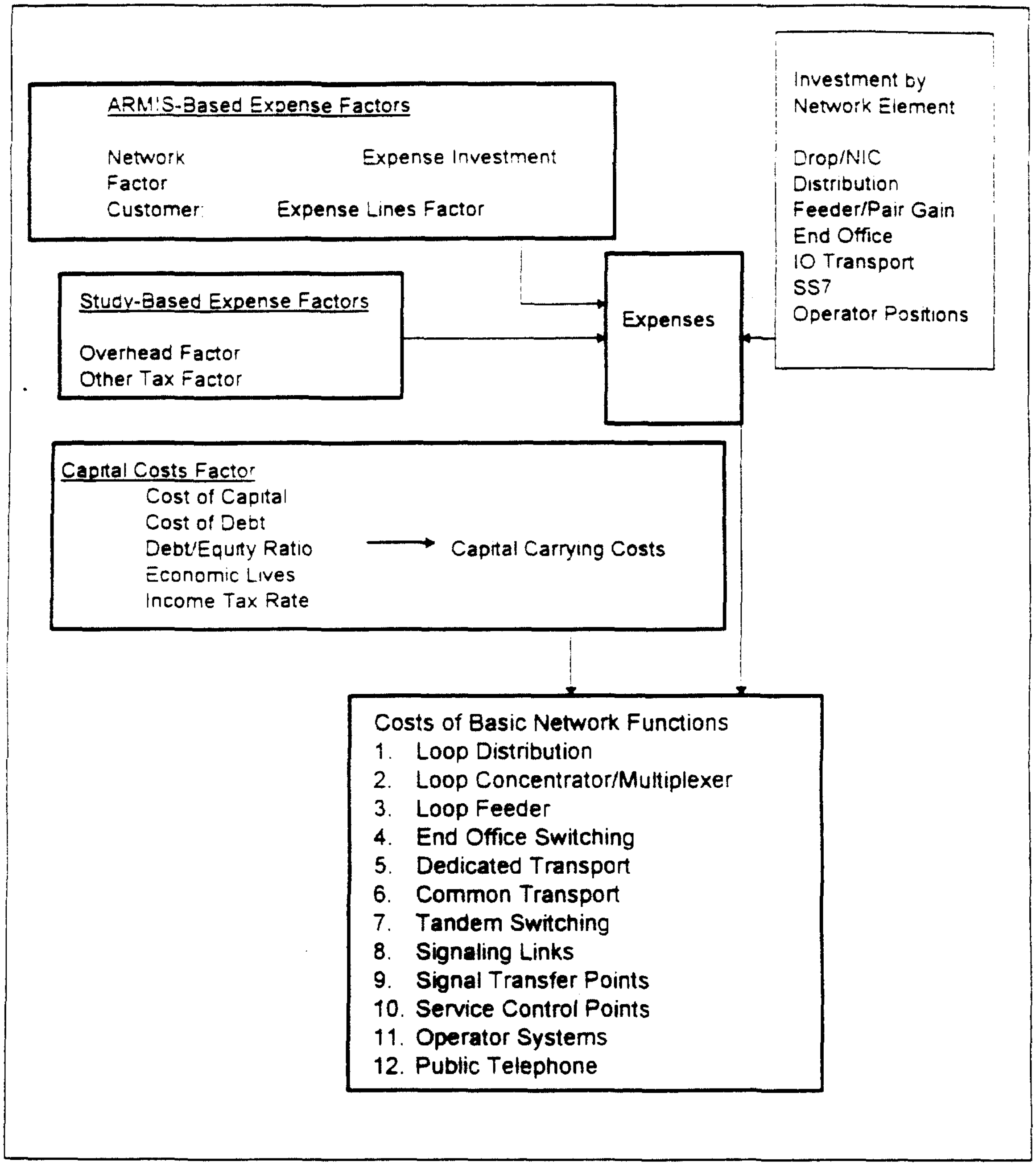
[36] 1993 New Hampshire Incremental Cost Study

The Expense Module uses these data to calculate operational expense ratios using the comparable plant specific and network operations expenses and investments, along with the LEC's leverage, revenues, tax rate, cost of debt and equity and economic service lives for various types of network equipment[37]

This section will describe the inputs and assumptions of the Expense Module, including Convergence Module inputs, ARMIS data, capital structure parameters and expense factors built into the module It will also explain the key algorithms used to determine capital costs and operating expenses

[37] Note that the Expense Module does not use these historical data on embedded expenses as direct elements of LEC TSLRIC. Rather, it develops efficient, forward-looking values for these expenses that are extrapolated from relationships that may have existed historically.

Figure 7 Expense Module



2. Description of Inputs and Assumptions

a) Convergence Module Outputs

The primary input to the Expense Module is the Convergence Module output which outlines the investments required to "build up" a virtual telephone network for the area or carrier under study. These investments include the hardware, software, engineering and installation of the network elements. They are sorted by household