Default Values:

Distribution Cable Structure Fractions			
Density Zone	Aerial/Block Cable	Buried Cable	Underground Cable (calculated)
0-5	.25	.75	*0*
5-100	.25	.75	*0*
100-200	.25	.75	*0*
200-650	.30	.70	*0*
650-850	.30	.70	*0*
850-2,550	.30	.70	*0*
2,550-5,000	.30	.65	*.05*
5,000-10,000	.60	.35	*.05*
10,000+	.85	.05	*.10*

Support: It is the opinion of outside plant engineering experts that density, measured in Access Lines per Square Mile, is a good determinant of structure type. That judgment is based on the fact that increasing density drives more placement in developed areas, and that as developed areas become more dense, placements will more likely occur under pavement conditions.

Aerial/Block Cable:

"The most common cable structure is still the pole line. Buried cable is now used wherever feasible, but pole lines remain an important structure in today's environment."[10]

Where an existing pole line is available, cable is normally placed on the existing poles. Abandoning an existing pole line in favor of buried plant is not usually done unless such buried plant provides a much less costly alternative.

HM 4.0 accounts for drop wire separately. Cable attached to the [out]sides of buildings, normally found in higher density areas, are also appropriately classified to the aerial cable account. To facilitate modeling, HM 4.0 reasonably includes Intrabuilding Network Cable under its treatment of aerial cable.

Therefore, the default percentages above 2,550 lines per square mile indicate a growing amount of block and intrabuilding cable, rather than cable placed on pole lines (although existing joint use pole lines are also more prevalent in older, more dense neighborhoods built prior to 1980).

Buried Cable:

Default values in HM 4.0 reflect an increasing trend toward use of buried cable in new subdivisions. Since 1980, new subdivisions have usually been served with buried cable for several reasons. First, before 1980, cables filled with water blocking compounds had not been perfected. Thus, prior to that time, buried cable was relatively expensive and unreliable. Second, reliable splice closures of the type required for buried facilities were not the norm. And third, the public now clearly desires more out-of-sight plant for both aesthetic and safety-related reasons. Contacts with telephone outside plant engineers, architects and property developers in several states confirm that in new subdivisions, builders typically not only prefer buried plant that is capable of accommodating multiple uses, but they usually dig the trenches at their own expense and place power, telephone, and CATV cables in the trenches, if the utilities are willing to supply the materials. Thus, many buried structures are available to the LEC at no charge, although the Model does not reflect such savings, since it is uncertain.

[10] *BOC Notes on the LEC Networks - 1994*, Bellcore, p. 12-41.

Underground Cable:

Underground cable, conduit, and manholes are primarily used for feeder and interoffice transport cables, not for distribution cable. Distribution plant in congested, extensively paved, high density areas usually runs only a short distance underground from the SAI to the block terminal, thus it requires no intermediate splicing chambers. In high density residential, distribution cables are frequently run from pole lines, under a street and back up onto a pole line, or from buried plant, under a street and back to a buried cable run. Such conduit runs are short enough to not require a splicing chamber or manhole and are therefore classified to the aerial or buried cable account, respectively.

There may be rare exceptions where distribution cable from a SAI is so long that it requires an underground splicing chamber (manhole). Sometimes feeder cable will be extended, via a lateral, into a SAI, and distribution pairs in the same feeder stub will run back into the same manhole for further routing to aerial or buried structures down a street. In those cases, manholes and conduit were placed for feeder cable and have already been accounted for in the cost of feeder plant structure. Therefore it is unnecessary to double count such manholes and conduit when used occasionally for the routing of a distribution backbone cable.

In a "campus environment," where underground structure is used, it is owned and operated by the owner of the campus and not the ILEC. The cable is treated as Intrabuilding Network Cable between buildings on one customer's premises, and the cost of such cable is not included in the model.

2.6. CABLE FILL AND POLE SPACING

2.6.1. Distribution Cable Fill Factors

Definition: The Hatfield Model uses the distribution cable fill factor input to calculate the size of cable needed to serve a given quantity of demand. HM 4.0 divides the number of pairs required in a distribution cable by this factor to determine the minimum number of pairs required, then uses the next larger available size cable.

Default Values:

Distribution Cable Fill Factors	
Density Zone	Fill Factors
0-5	.50
5-100	.55
100-200	.55
200-650	.60
650-850	.65
850-2,550	.70
2,550-5,000	.75
5,000-10,000	.75
10,000+	.75

Support: In determining appropriate cable size, an outside plant engineer is more interested in a sufficient number of administrative spares than in the percent fill ratio. The appropriate "target" distribution cable fill factor, therefore, will vary depending upon the size of cable. For example, 75% fill in a 2400 pair cable provides 600 spares. However, 50% spare in a 6 pair cable provides only 3 spares. Since smaller cables are used in lower density zones, Distribution Cable Fill Factors in HM 4.0 are lower in the lowest density zones to account for this effect.

In general, the level of spare capacity provided by default values in HM 4.0 is sufficient to meet current demand plus some amount of growth. Because the model calculates the unit loop investment cost as the total loop investment (including spare capacity), divided by the current loop demand, the resulting unit costs are a conservatively high estimate of the economic cost of meeting current loop demand. This occurs because, in reality, some of the spare distribution plant can and will be used to satisfy additional loop demand in the future, without causing any additional investment cost, thus a larger number of customers will pay for the cable over time. In this sense, the HM 4.0 default values for the distribution cable fill factors are conservatively low from an economic costing standpoint.

2.6.2. Distribution Pole Spacing

Definition: Spacing between poles supporting aerial distribution cable.

Default Values:

Distribution Pole Spacing	
Density Zone	Spacing
0-5	250
5-100	250
100-200	200
200-650	200
650-850	175
850-2,550	175
2,550-5,000	150
5,000-10,000	150
10,000+	150

Support: Distances between poles are longer in more rural areas for a several reasons. Poles are usually placed on property boundaries, and at each side of road intersections (unless cable is run below the road surface in conduit). Property boundaries tend to be farther apart in less dense areas, and road intersections are also farther apart.

Depending on the weight of the cable, and the generally accepted guideline that sag should not exceed 10 feet at mid-span, while still maintaining appropriate clearances as designated by the National Electric Safety Code, very long spans between poles may be achieved. This length may be as great as 1,500 feet using heavy gauge strand and very light cable, or may be shorter for heavier cables.[11] In practice, much shorter span distances are employed, usually 400 feet or less.

"...where conditions permit, open wire spans can approach 400 feet in length with practical assurance that the lines will withstand any combination of weather condition. Longer spans mean savings in construction costs and a net reduction in over-all plant investment, including fewer poles to buy, smaller quantity of pole hardware required, and less construction time. The use of long spans also means a reduction in maintenance expense."[12]

[11] Bellcore, *Clearance for Aerial Cable and Guys in Light, Medium and Heavy Loading Areas, (BR 627-070-015), Issue 1*, 1987.
see also, Bellcore, *Clearances for Aerial Plant, (BR 918-117-090), Issue 5*, 1987.
see also, Bellcore, *Long Span Construction (BR 627-370-XXX)*, date unk.

[12] Lee, Frank E., *Outside Plant, abc of the Telephone Series, Volume 4*, abc TeleTraining, Inc., Geneva, IL, 1987, p. 41.

2.7. GEOLOGY AND POPULATION CLUSTERS

2.7.1. Distribution Distance Multiplier, Difficult Terrain

Definition: The amount of extra distance required to route distribution and feeder cable around difficult soil conditions, expressed as a multiplier of the distance calculated for normal situations.

Default Value:

Distribution Distance Multiplier, Difficult Terrain
1.0

Support: HM 4.0 treats difficult buried cable placement in rock conditions using five parameters: 1) Distribution Distance Multiplier, Difficult Terrain; 2) Surface Texture Multiplier; 3) Rock Depth Threshold, inches; 4) Hard Rock Placement Multiplier; and 5) Soft Rock Placement Multiplier. The last three of these pertain to the effect of bedrock close to the surface – see Section 2.7.2 through 2.7.5. The first pertains to difficult soil conditions such as the presence of boulders.

While the typical response to difficult soil conditions is often to simply route cable around those conditions, which could be reflected in this parameter, HM 4.0 instead treats the effect of difficult soil conditions as a multiplier of placement cost - see Parameter 6.5, Surface Texture Multiplier. Therefore, the distribution distance multiplier is set to 1.0.

2.7.2. Rock Depth Threshold, Inches

Definition: The depth of bedrock, less than which (that is, closer to the surface) additional costs are incurred for placing distribution or feeder cable. The depth of bedrock is provided by USGS data for each CBG.

Default Value:

Rock Depth Threshold, Inches
24 inches

Support: Cable is normally placed at a minimum depth of 24 inches. Where USGS data indicates the presence of rock closer to the surface, HM 4.0 imposes additional costs.

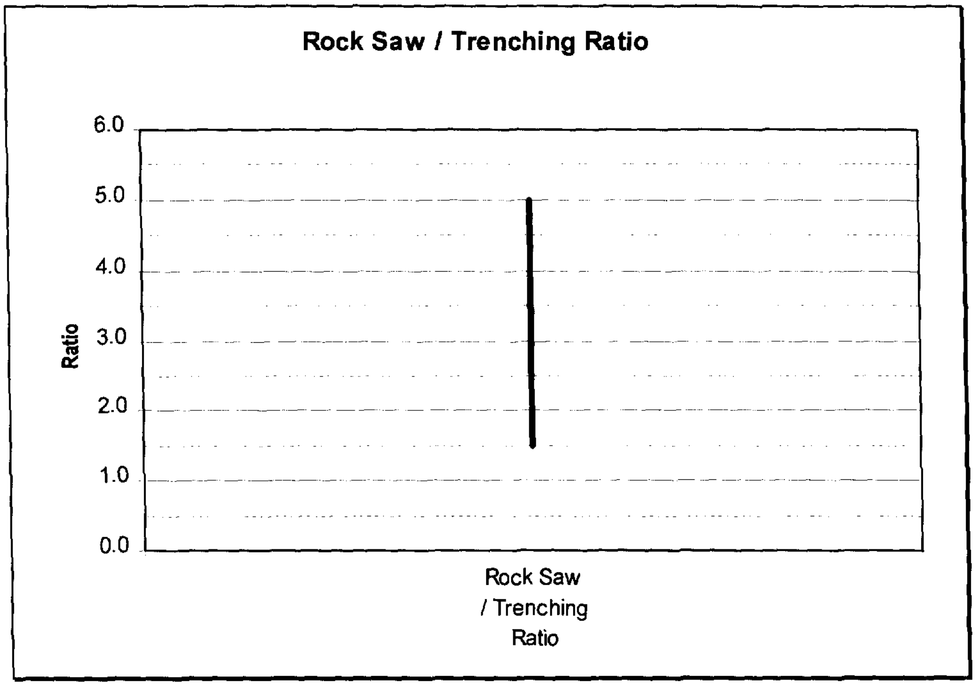
2.7.3. Hard Rock Placement Multiplier

Definition: The increased cost required to place distribution or feeder cable in bedrock classified as hard, when it is within the rock depth threshold of the surface, expressed as a multiplier of normal installation cost per foot.

Default Value:

Hard Rock Placement Multiplier
3.5

Support: A rock saw is used whenever hard rock must be excavated. Information received from independent contractors who perform this type of work is reflected below. Hard rock costs are reflected at the top of the scale.



2.7.4. Soft Rock Placement Multiplier

Definition: The increased cost required to place distribution or feeder cable in bedrock classified as soft, when it is within the rock depth threshold of the surface, expressed as a multiplier of normal installation cost per foot.

Default Value:

Soft Rock Placement Multiplier
2.0

Support: A rock saw or tractor-mounted ripper is used whenever soft rock must be excavated. Information received from independent contractors who perform this type of work is reflected in the figure in section 2.7.3. Soft rock costs are reflected at the lower end of the scale.

2.7.5. Sidewalk / Street Fraction

Definition: The fraction of small, urban CBGs that are streets and sidewalks, used in the comparison of occupied CBG area with number of lines to identify cases where high rise buildings are present. To qualify as a small urban CBG, the total land area must be less than .03 square miles and the line density must exceed 30,000 lines per square mile.

Default Value:

Sidewalk / Street Fraction
.20

Support: The sidewalk/street fraction is computed using a .03 square mile (836,352 square feet) CBG, the largest CBG to which it applies. This densely urban CBG is assumed to be square, which means each side of the CBG is approximately 915 feet long. As a result, the roads and sidewalks running around the outside of such a CBG would cover a total land area of approximately 165,000 square feet (915 feet per side times 4 sides times (15 foot wide sidewalk + .5 times 60 foot wide street), or 20 percent of the CBG's total area. The remaining 80 percent, or non-sidewalk/street land area, is occupied by buildings.

2.7.6. Local RT (per Cluster) Thresholds – Maximum Total Distance

Definition: The maximum potential distribution length, in feet, above which Remote Terminals are located at the center of each cluster, rather than at the center of the CBG, in order to reduce the remaining distribution length.

Default Value:

Local RT (per cluster) Thresholds Maximum Total Distance
18,000 ft.

Support: The default value was chosen to be consistent with the minimum distance at which long loop treatment is usually required.[13]

2.7.7. Town Factor

Definition: The fraction of business and residential customers that are assumed to be located in clusters, as opposed to surrounding areas, for those rural population cases in which the model determines that such clustering is likely. The rural clustering assumption is made for all CBGs falling in the lowest three line density zones, and all other CBGs whose fraction of empty area is greater than 50 percent. The default value is equal to one minus the fraction of rural population that is located on farms, averaged across the U.S.

Default Value:

Town Factor
.85

Support: Derived from data in the *Statistical Abstract of the United States, 1995*. Using rural population (table 44), farm data (table 1105), and 4 pops per farm, town factors are computed as one minus the fraction of rural population that is located on farms (i.e., town factor (state) = 1 – (number of farms * 4 pops per farm) / rural pops). A table containing the computed town factor for each state is provided below.

State	Rural Pop (1,000)[14]	Farms[15] (1,000)	Farm Pop	Town Factor

[13] *BOC Notes on the LEC Networks - 1994*, Bellcore, p. 12-4.

State	Rural Pop (1,000)[14]	Farms[15] (1,000)	Farm Pop	Town Factor
Alabama	1,601	47	188,000	0.8826
Alaska	179	1	4,000	0.9776
Arizona	458	8	32,000	0.9302
Arkansas	1,093	47	188,000	0.8279
California	2,189	85	340,000	0.8447
Colorado	579	27	108,000	0.8134
Connecticut	686	4	16,000	0.9767
Delaware	180	3	12,000	0.9332
Florida	1,971	41	164,000	0.9168
Georgia	2,381	48	192,000	0.9194
Hawaii	122	5	20,000	0.8361
Idaho	429	22	88,000	0.7946
Illinois	1,762	83	332,000	0.8116
Indiana	1,946	68	272,000	0.8602
Iowa	1,094	104	416,000	0.6196
Kansas	765	69	276,000	0.6392
Kentucky	1,775	93	372,000	0.7904
Louisiana	1,348	32	128,000	0.9051
Maine	680	7	28,000	0.9588
Maryland	893	15	60,000	0.9328
Massachusetts	947	7	28,000	0.9704
Michigan	2,739	54	216,000	0.9212
Minnesota	1,319	89	356,000	0.7300
Mississippi	1,362	40	160,000	0.8826
Missouri	1,601	108	432,000	0.7302
Montana	379	25	100,000	0.7363
Nebraska	534	57	228,000	0.5734
Nevada	140	3	12,000	0.9145
New Hampshire	544	3	12,000	0.9779
New Jersey	820	8	32,000	0.9610
New Mexico	409	14	56,000	0.8632
New York	2,826	39	156,000	0.9448
North Carolina	3,291	62	248,000	0.9246
North Dakota	298	34	136,000	0.5443
Ohio	2,808	84	336,000	0.8803
Oklahoma	1,015	70	280,000	0.7243
Oregon	839	37	148,000	0.8236
Pennsylvania	3,693	53	212,000	0.9426
Rhode Island	140	1	4,000	0.9714
South Carolina	1,581	25	100,000	0.9368
South Dakota	348	35	140,000	0.5978
Tennessee	1,907	89	356,000	0.8133
Texas	3,352	186	744,000	0.7780
Utah	224	13	52,000	0.7676

[14] Rural population counts are from the Statistical Abstract, 1995, table 44. For the definition of rural population, see the Statistical Abstract, p.4.

[15] Farm counts from Statistical Abstract, 1995, table 1105 (4 pops/farm). Farms are defined as any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the census year.

State	Rural Pop (1,000)[14]	Farms[15] (1,000)	Farm Pop	Town Factor
Vermont	382	7	28,000	0.9266
Virginia	1,894	46	184,000	0.9028
Washington	1,149	37	148,000	0.8712
West Virginia	1,145	21	84,000	0.9267
Wisconsin	1,680	80	320,000	0.8095
Wyoming	159	9	36,000	0.7735

2.7.8. Maximum Lot Size, Acres

Definition: The maximum effective lot size allowed in a non-rural CBG, above which it is assumed that the population is clustered into areas whose effective lot size is the default value (that is, there is a cap on the amount of land each subscriber occupies).

Default Value:

Maximum Lot Size
3.0 acres

Support: Based on observations that subdivisions, towns, or other areas where a grid distribution structure is used rarely consist of plots greater than 3 acres.

2.7.9. Town Lot Size, Acres

Definition: The assumed lot size– including common areas such as streets and parks -- of subscribers residing in rural population clusters.

Default Value:

Town Lot Size
3.0 acres

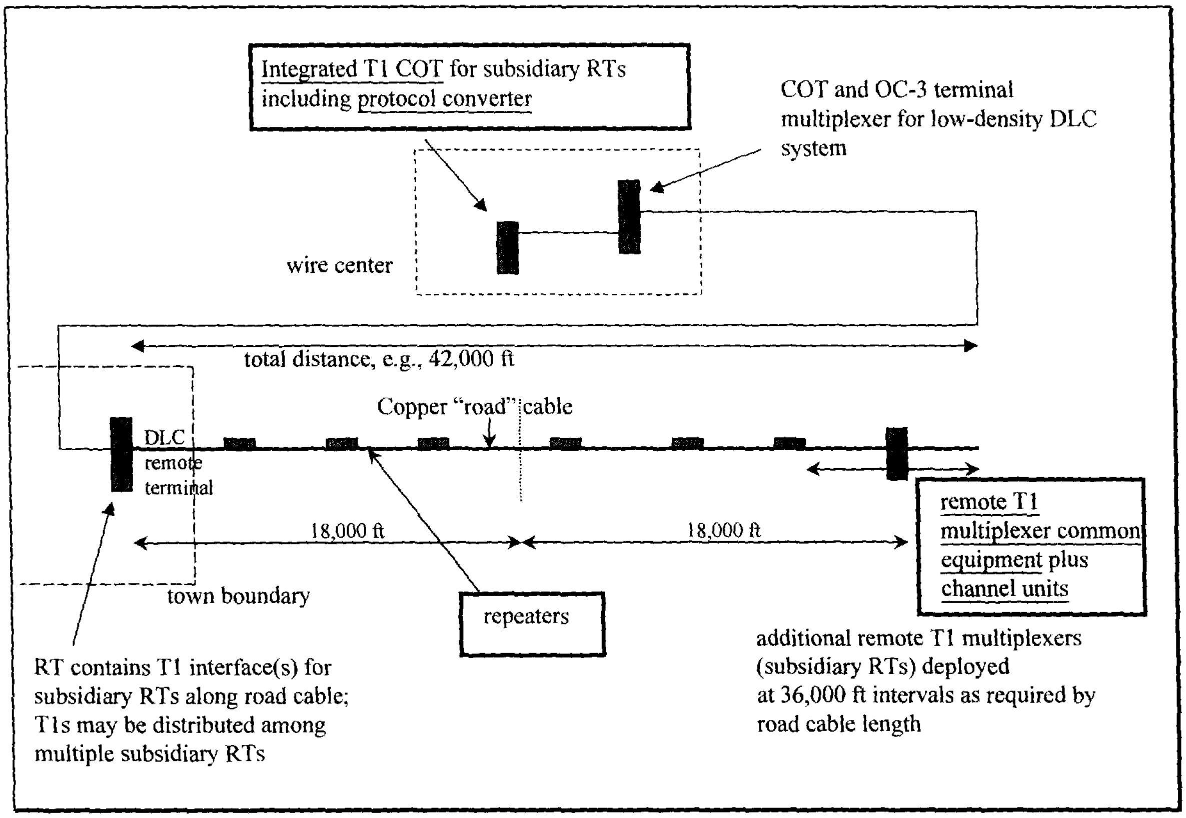
Support: For clustering in rural areas the model calculates total cluster area as the sum of individual lot sizes. Larger lot sizes thus produce more distribution cable in this case. Assuming three acre lot sizes within a cluster yields a conservatively high cost estimate.

2.8. LONG LOOP INVESTMENTS

General:

HM 4.0 extends fiber fed Integrated Digital Loop Carrier (IDLC) deep into the loop. Even if feeder cable is shorter than the Copper Feeder Maximum Distance, if the total length of copper is greater than 18,000 feet, HM 4.0 places fiber and IDLC into the quadrants of the CBG using either GR-303 or Low Density DLC. An additional test is performed to determine if the copper distribution cable is still longer than 18,000 feet. If it is, HM 4.0 calls for use of T1 on copper to feed small Digital Loop Carrier sites (maximum of 24 lines per T1) with repeaters as necessary.

The T1 system has a number of components described in parameters 2.8.1. through 2.8.5. The relationship among these components is shown in the following figure.



2.8.1. T1 Repeater Investments, Installed

Definition: The investment per T1 repeater, including electronics, housing, and installation, for T1 extension of loops longer than 18,000 ft.

Default Value:

Repeater Investment, Installed
$300

Support: The cost of a line powered T1 repeater was estimated by a team of experienced outside plant experts with extensive experience in purchasing such units, and arranging for their installation. The equipment portion of this investment is based on supplier information less discount.

2.8.2. Integrated T1 COT, Installed

Definition: The installed Central Office Terminal (COT) investment per road cable required to terminate the copper fed T1 DLC connection serving subscribers along roads longer than 18,000 ft.

Default Value:

Integrated COT, Installed
$4,400

Support: The cost of an initial increment of this type of Integrated Digital Loop Electronics was estimated by a team of experienced outside plant experts who were in contact with vendors of appropriate small size IDLC equipment suitable for extending bandwidth on conditioned copper pairs. The equipment portion of this investment is based on supplier information less discount.

2.8.3. Remote T1 Multiplexer Common Equipment Investment, Installed

Definition: The installed investment per T1 fed Subsidiary Remote Terminal, including the T1 interface in the DLC RT, used to serve subscribers along road cables longer than 18,000 ft.

Default Value:

Remote Mux Common Equip, Installed
$5,510

Support: The cost of an initial increment of this type of Integrated Digital Loop Electronics was estimated by a team of experienced outside plant experts who were in contact with vendors of appropriate small size IDLC equipment suitable for extending bandwidth on conditioned copper pairs. The equipment portion of this investment is based on supplier information less discount.

2.8.4. T1 Channel Unit Investment per Subscriber

Definition: The investment per line in POTS channel units installed in T1 fed Subsidiary RTs serving subscribers located along roads longer than 18,000 ft.

Default Value:

Channel Unit Investment per Subscriber
$125

Support: The cost of appropriate line cards used for this type of Integrated Digital Loop Electronics was estimated by a team of experienced outside plant experts who were in contact with vendors of appropriate small size IDLC equipment suitable for extending bandwidth on conditioned copper pairs. The equipment portion of this investment is based on supplier information less discount.

2.8.5. COT Investment per T1 RT, Installed

Definition: The installed investment per T1 fed Subsidiary RT in protocol conversion equipment for interfacing with the integrated COT.

Default Value:

COT Investment per RT, Installed
$1,265

Support: The cost of an initial increment of this type of Integrated Digital Loop Electronics was estimated by a team of experienced outside plant experts who were in contact with vendors of appropriate small size IDLC equipment suitable for extending bandwidth on conditioned copper pairs. The equipment portion of this investment is based on supplier information less discount.

2.9. SAI INVESTMENT

Definition: The installed investment in the Serving Area interface (SAI) that acts as the physical interface point between distribution and feeder cable.

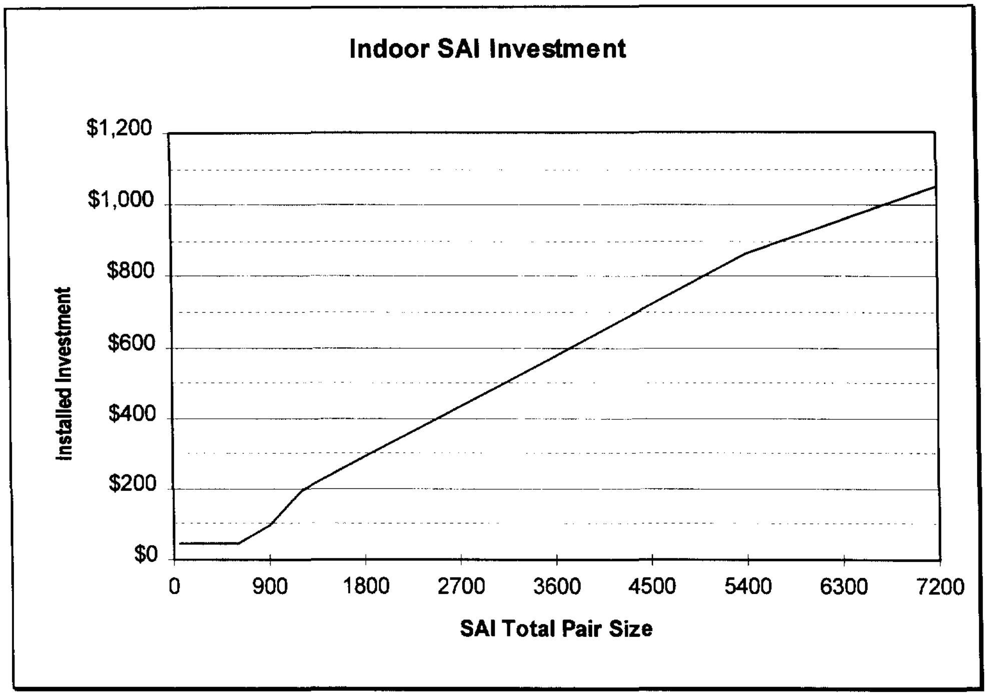
Default Values:

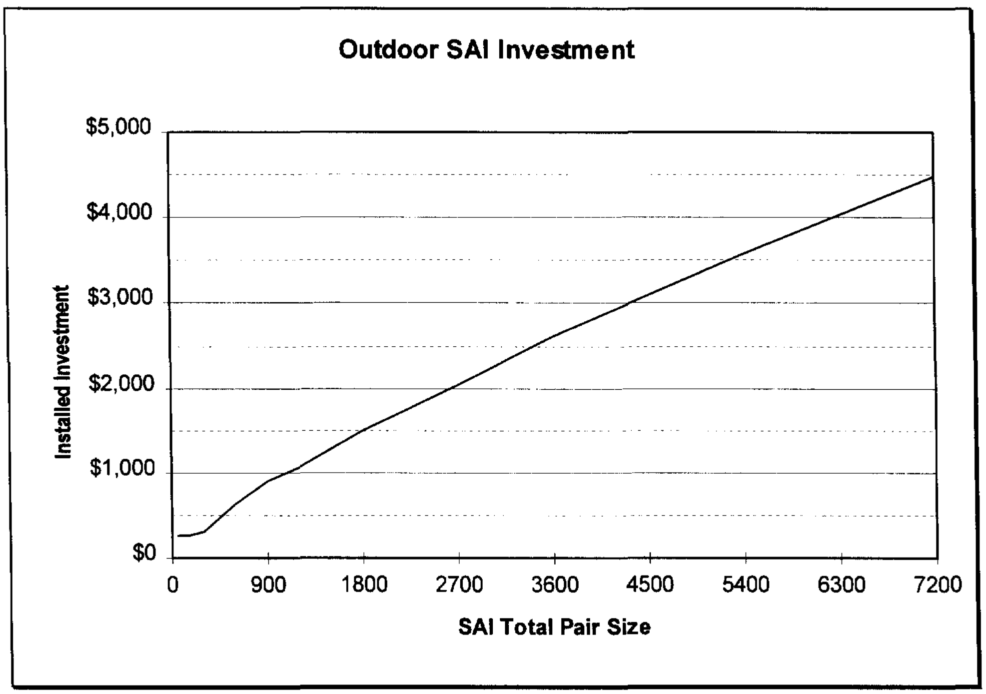
SAI Investment		
SAI Size	Indoor SAI	Outdoor SAI
7200	$3,456	$10,000
5400	$2,592	$8,200
3600	$1,728	$6,000
2400	$1,152	$4,300
1800	$864	$3,400
1200	$576	$2,400
900	$432	$1,900
600	$288	$1,400
400	$192	$1,000
200	$96	$600
100	$48	$350
50	$48	$250

Support: Indoor Serving Area Interfaces are used in buildings, and consist of simple terminations, or punch down blocks, and lightning protection where required. Equipment is normally mounted on a plywood backboard in common space. Outdoor Serving Area Interfaces are more expensive, requiring steel cabinets that protect the cross connection terminations from the direct effects of water. Both indoor and outdoor SAI investments are a function of the total number of pairs, both Feeder and Distribution, that the SAI terminates.

The total number of pairs terminated in the SAI is computed as follows. a) The number of Feeder Pair terminations provided is equal to 1.5 times the number of households plus the number of business, special access, and public lines required. b) The number of Distribution Pair terminations provided is equal to 2.0 time the number of households plus the number of business, special access, and public lines required.

Prices are the opinion of a group of Engineering Experts.


Indoor SAI Investment
Installed Investment
$1,200
$1,000
$800
$600
$400
$200
$0
0
900
1800
2700
3600
4500
5400
6300
7200
SAI Total Pair Size


Outdoor SAI Investment
Installed Investment
$5,000
$4,000
$3,000
$2,000
$1,000
$0
0
900
1800
2700
3600
4500
5400
6300
7200
SAI Total Pair Size

2.10. DEDICATED CIRCUIT INPUTS

2.10.1. Percentage of Dedicated Circuits

Definition: The fractions of total circuits included in the count of total private line and special access circuits that are DS-0 and DS-1 circuits, respectively. The fraction of DS-3 and higher capacity circuits is calculated by the model as (1 minus fraction DS-0 minus fraction DS-1). The equivalence between the three circuit types -- that is, DS-0, DS-1, and DS-3 -- and wire pairs is expressed in Section 2.10.2.

Default Values:

[illegible]	
[illegible]	[illegible]
100%	0%

Support: These parameters provide the breakdown of reported dedicated circuits into voice-grade equivalents and DS-0s, DS-1s, and DS-3s. The default database values for dedicated circuits represent special access voice-grade and DS-0 equivalents as reported in ARMIS 43-08. Thus, the default input values are 100 percent for DS-0/voice grade, and 0 percent for DS-1 and DS-3.

2.10.2. Pairs per Dedicated Circuit

Definition: Factor expressing the number of wire pairs required per dedicated circuit classification.

Default Values:

[illegible]		
[illegible]	[illegible]	[illegible]
1	2	56

Support: A DS-1 bit stream on copper requires one transmit pair and one receive pair. Although a DS-3 signal can only be transmitted on fiber or coax, the bit stream carries the equivalent of 28 DS-1's. Since a DS-1 requires 2 pairs, a DS-3 is represented in HM 4.0 as requiring 28 times 2 pairs, or a total of 56 pairs. While many DS-0s are provided on 4-wire circuits, the model conservatively assumes only one pair per DS-0.

3. FEEDER INPUT PARAMETERS

3.1. COPPER PLACEMENT

3.1.1. Copper Feeder Structure Fractions

Definition: The relative amounts of different structure types supporting copper feeder cable in each density zone. Aerial feeder cable is attached to telephone poles, buried cable is laid directly in the earth, and underground cable runs through underground conduit.

Default Values:

[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]
0-5	.50	.45	*.05*
5-100	.50	.45	*.05*
100-200	.50	.45	*.05*
200-650	.40	.40	*.20*
650-850	.30	.30	*.40*
850-2,550	.20	.20	*.60*
2,550-5,000	.15	.10	*.75*
5,000-10,000	.10	.05	*.85*
10,000+	.05	.05	*.90*

Support: ***{NOTE: Excerpts from the discussion in Section 2.5. [Distribution] are reproduced here for ease of use.}***

It is the opinion of outside plant engineering experts that density, measured in Access Lines per Square Mile, is a good determinant of structure type. That judgment is based on the fact that increasing density drives more placement in developed areas, and that as developed areas become more dense, placements will more likely occur under pavement conditions.

Aerial/Block Cable:

"The most common cable structure is still the pole line. Buried cable is now used wherever feasible, but pole lines remain an important structure in today's environment."[16]

Where an existing pole line is available, cable is normally placed on the existing poles. Abandoning an existing pole line in favor of buried plant is not usually done unless such buried plant provides a much less costly alternative.

Buried Cable:

Default values in HM 4.0 reflect an increasing trend toward use of buried cable. Since 1980, there has been an increase in the use of buried cable for several reasons. First, before 1980, cables filled with water blocking compounds had not been perfected. Thus, prior to that time, buried cable was relatively expensive and unreliable. Second, reliable splice closures of the type required for buried facilities were not the norm. And third, the public now clearly desires more out-of-sight plant for both aesthetic and safety-related reasons.

[16] *BOC Notes on the LEC Networks - 1994*, Bellcore, p. 12-41.

Underground Cable:

Underground cable, conduit, and manholes are primarily used for feeder and interoffice transport cables, not for distribution cable. Any conduit runs short enough to not require a splicing chamber or manhole are classified to the aerial or buried cable account, respectively.

3.1.2. Copper Feeder Manhole Spacing, Feet

Definition: The distance, in feet, between manholes for copper feeder cable.

Default Values:

[illegible]	[illegible]
0-5	800
5-100	800
100-200	800
200-650	800
650-850	600
850-2,550	600
2,550-5,000	600
5,000-10,000	400
10,000+	400

Support: "The length of a conduit section is based on several factors, including the location of intersecting conduits and ancillary equipment such as repeaters or loading coils, the length of cable reels, pulling tension, and physical obstructions. Pulling tension is determined by the weight of the cable, the coefficient of friction, and the geometry of the duct run. Plastic conduit has a lower coefficient of friction than does concrete or fiberglass conduit and thus allows longer cable pulls. Conduit sections typically range from 350 to 700 ft in length."[17]

The higher density zones reflect reduced distances between manholes to provide transition points for changing types of sheaths and the increased number of branch points.

Maximum distances between manholes is also a function of the longest amount of cable that can be placed on a normal cable reel. Although larger reels are available, the common type 420 reel supports over 800 feet of 4200 pair cable[18], the largest used by the Hatfield Model. Therefore the longest distance between manholes used for copper cable is 800 feet.

3.1.3. Copper Feeder Pole Spacing, Feet

Definition: Spacing between poles supporting aerial copper feeder cable.

[17] Bellcore, *BOC Notes on the LEC Networks - 1994*, p. 12-42

[18] AT&T, *Outside Plant Systems*, pp. 1-7.

Default Values:

[illegible]	[illegible]
0-5	250
5-100	250
100-200	200
200-650	200
650-850	175
850-2,550	175
2,550-5,000	150
5,000-10,000	150
10,000+	150

Support: ***{NOTE: The discussion in Section 2.6.2. [Distribution] is reproduced here for ease of use.}***

Distances between poles are longer in more rural areas for a several reasons. Poles are usually placed on property boundaries, and at each side of road intersections (unless cable is run below the road surface in conduit). Property boundaries tend to be farther apart in less dense areas, and road intersections are also farther apart.

Depending on the weight of the cable, and the generally accepted guideline that sag should not exceed 10 feet at mid-span, while still maintaining appropriate clearances as designated by the National Electric Safety Code, very long spans between poles may be achieved. This length may be as great as 1,500 feet using heavy gauge strand and very light cable, or may be shorter for heavier cables.[19] In practice, much shorter span distances are employed, usually 400 feet or less.

"...where conditions permit, open wire spans can approach 400 feet in length with practical assurance that the lines will withstand any combination of weather condition. Longer spans mean savings in construction costs and a net reduction in over-all plant investment, including fewer poles to buy, smaller quantity of pole hardware required, and less construction time. The use of long spans also means a reduction in maintenance expense."[20]

3.1.4. Copper Feeder Pole Investment

Definition: The installed cost of a 40' Class 4 treated southern pine pole.

[19] Bellcore, *Clearance for Aerial Cable and Guys in Light, Medium and Heavy Loading Areas, (BR 627-070-015), Issue 1*, 1987.
see also, Bellcore, *Clearances for Aerial Plant, (BR 918-117-090), Issue 5*, 1987.
see also, Bellcore, *Long Span Construction (BR 627-370-XXX)*, date unk.

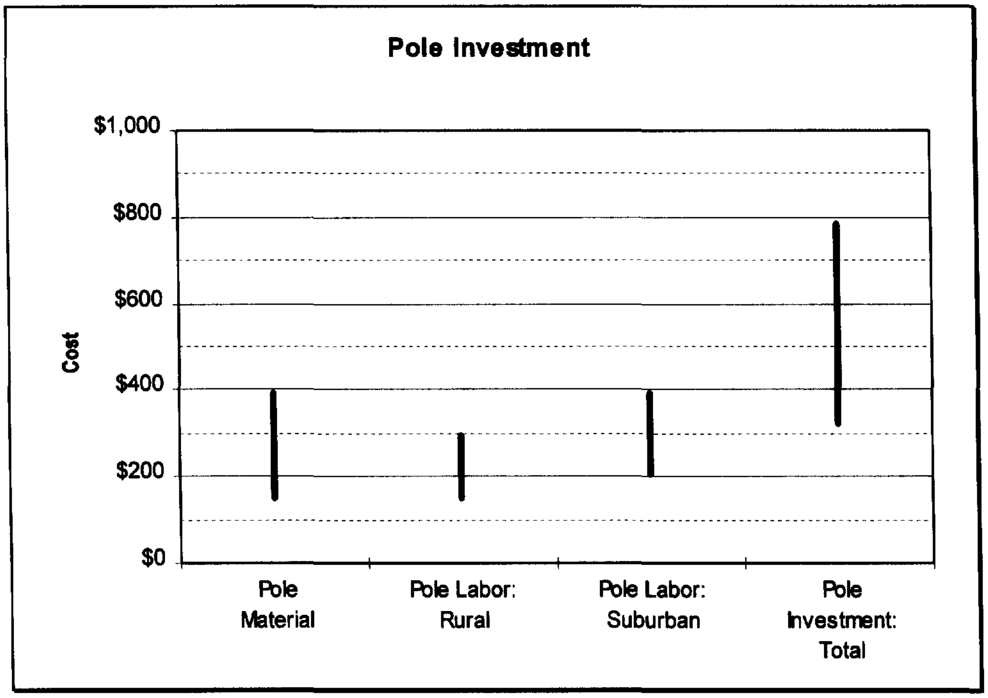
[20] Lee, Frank E., *Outside Plant, abc of the Telephone Series, Volume 4*, abc TeleTraining, Inc., Geneva, IL, 1987, p. 41.

Default Values:

[illegible]	
Materials	$201
Labor	$216
Total	*$417*

Support: ***{NOTE: The discussion in Section 2.4.1. [Distribution] is reproduced here for ease of use.}***

Pole investment is a function of the material and labor costs of placing a pole. Costs include periodic down-guys and anchors. Utility poles can be purchased and installed by employees of ILECs, but are frequently placed by contractors. Several sources revealed the following information on prices.



The exempt material load on direct labor includes ancillary material not considered by FCC Part 32 as a unit of plant. That includes items such as downguys and anchors that are already included in the pole placement labor cost. The steel strand run between poles is likewise an exempt material item, charged to the aerial cable account. The cost of steel strands is not included in the cost of poles; it is included in the installed cost of aerial cable.

3.1.5. Innerduct Material Investment per Foot

Definition: Material cost per foot of innerduct.

Default Value:

[illegible]
$0.30

Support: Innerduct might permit more than one fiber cable per 4" PVC conduit. The model adds investment whenever fiber overflow cables are required.

3.2. FIBER PLACEMENT

3.2.1. Fiber Feeder Structure Fractions

Definition: The relative amounts of different structure types supporting fiber feeder cable in each density zone. Aerial feeder cable is attached to telephone poles, buried cable is laid directly in the earth, and underground cable runs through underground conduit.

Default Values:

[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]
0-5	.35	.60	*.05*
5-100	.35	.60	*.05*
100-200	.35	.60	*.05*
200-650	.30	.60	*.10*
650-850	.30	.30	*.40*
850-2,550	.20	.20	*.60*
2,550-5,000	.15	.10	*.75*
5,000-10,000	.10	.05	*.85*
10,000+	.05	.05	*.90*

Support: ***{NOTE: Excerpts from the discussion in Section 2.5. [Distribution] are reproduced here for ease of use.}***

It is the opinion of outside plant engineering experts that density, measured in Access Lines per Square Mile, is a good determinant of structure type. That judgment is based on the fact that increasing density drives more placement in developed areas, and that as developed areas become more dense, placements will more likely occur under pavement conditions.

Aerial/Block Cable:

"The most common cable structure is still the pole line. Buried cable is now used wherever feasible, but pole lines remain an important structure in today's environment."[21]

Where an existing pole line is available, cable is normally placed on the existing poles. Abandoning an existing pole line in favor of buried plant is not usually done unless such buried plant provides a much less costly alternative.

Buried Cable:

Default values in HM 4.0 reflect an increasing trend toward use of buried cable. Since 1980, there has been an increase in the use of buried cable for several reasons. First, before 1980, cables filled with water blocking compounds had not been perfected. Thus, prior to that time, buried cable was relatively expensive and unreliable. Second, reliable splice closures of the type required for buried facilities were not the norm. And third, the public now clearly desires more out-of-sight plant for both aesthetic and safety-related reasons.

[21] *BOC Notes on the LEC Networks - 1994*, Bellcore, p. 12-41.

Underground Cable:

Underground cable, conduit, and manholes are primarily used for feeder and interoffice transport cables, not for distribution cable. Any conduit runs short enough to not require a splicing chamber or manhole are classified to the aerial or buried cable account, respectively.

3.2.2. Fiber Feeder Pullbox Spacing, Feet

Definition: The distance, in feet, between pullboxes for underground fiber feeder cable.

Default Values:

[illegible]	[illegible]
0-5	2,000
5-100	2,000
100-200	2,000
200-650	2,000
650-850	2,000
850-2,550	2,000
2,550-5,000	2,000
5,000-10,000	2,000
10,000+	2,000

Support: Unlike copper manhole spacing, the spacing for fiber pullboxes is based on the practice of coiling spare fiber (slack) within pullboxes to facilitate repair in the event the cable is cut or otherwise impacted. Fiber feeder pullbox spacing is not a function of the cable reel lengths, but rather a function of length of cable placed. The standard practice during the cable placement process is to provide for 5 percent excess cable to facilitate subsurface relocation, lessen potential damage from impact on cable, or provide for ease of cable splicing when cable is cut or damaged.[22] It is common practice for outside plant engineers to require approximately 2 slack boxes per mile.

3.2.3. Buried Fiber Sheath Addition, per Foot

Definition: The cost of dual sheathing for additional mechanical protection of buried fiber feeder cable.

Default Value:

[illegible]
$0.20 / ft.

Support: Incremental cost for mechanical sheath protection on fiber optic cable is a constant per foot, rather than the ratio factor used for copper cable, because fiber sheath is approximately ½ inch in diameter, regardless of the number of fiber strands contained in the sheath. The incremental per foot cost was estimated by a team of experienced outside plant experts who have purchased millions of feet of fiber optic cable.

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[22] *Cable Construction Manual, 4th Edition*, CommScope, p. 75.

3.3. FILL FACTORS

3.3.1. Copper Feeder Cable Fill Factors

Definition: The spare capacity in a feeder cable, calculated as the ratio of the number of assigned pairs to the total number of available pairs in the cable.

Default Values:

[illegible]	[illegible]
0-5	.65
5-100	.75
100-200	.80
200-650	.80
650-850	.80
850-2,550	.80
2,550-5,000	.80
5,000-10,000	.80
10,000+	.80

Support: ***{NOTE: The discussion in Section 2.6.1. [Distribution] is reproduced here for ease of use.}***

In determining appropriate cable size, an outside plant engineer is more interested in a sufficient number of administrative spares than in the percent fill ratio. The appropriate "target" distribution cable fill factor, therefore, will vary depending upon the size of cable. For example, 75% fill in a 2400 pair cable provides 600 spares. However, 50% spare in a 6 pair cable provides only 3 spares. Since smaller cables are used in lower density zones, Distribution Cable Fill Factors in HM 4.0 are lower in the lowest density zones to account for this effect.

In general, the level of spare capacity provided by default values in HM 4.0 is sufficient to meet current demand plus some amount of growth. Because the model calculates the unit loop investment cost as the total loop investment (including spare capacity), divided by the current loop demand, the resulting unit costs are a conservatively high estimate of the economic cost of meeting current loop demand. This occurs because, in reality, some of the spare distribution plant can and will be used to satisfy additional loop demand in the future, without causing any additional investment cost, thus a larger number of customers will pay for the cable over time. In this sense, the HM 4.0 default values for the distribution cable fill factors are conservatively low from an economic costing standpoint.

3.3.2. Fiber Feeder Cable Fill Factor

Definition: Maximum fraction of fiber strands in a cable that are available to be used.

Default Values:

[illegible]	[illegible]
0-5	1.00
5-100	1.00
100-200	1.00
200-650	1.00
650-850	1.00
850-2,550	1.00
2,550-5,000	1.00
5,000-10,000	1.00
10,000+	1.00

Support: Standard fiber optic multiplexers operate on 4 fibers. One fiber each is assigned to primary optical transmit, primary optical receive, redundant optical transmit, and redundant optical receive. Since the fiber optic multiplexers used by HM 4.0 have 100 percent redundancy, and do not reuse fibers in the loop, there is no reason to divide the number of fibers needed by a fill factor, prior to sizing the fiber cable to the next larger available size.

3.4. CABLE COSTS

3.4.1. Copper Feeder Cable, Cost per Foot

Definition: The investment per foot in copper feeder cable, engineering, installation, and delivery.

Default Values:

4200	$29.00
3600	$26.00
3000	$23.00
2400	$20.00
1800	$16.00
1200	$12.00
900	$10.00
600	$7.75
400	$6.00
200	$4.25
100	$2.50

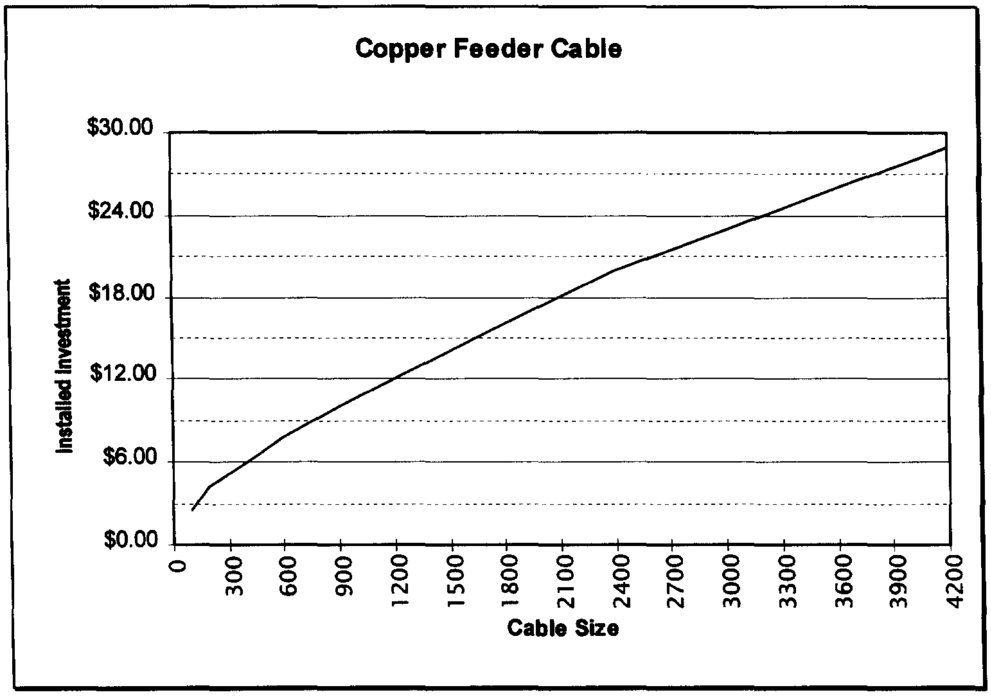
Support: These costs reflect the use of 24-gauge copper feeder cable for cable sizes below 400 pairs, and 26-gauge copper feeder cable for cable sizes of 400 pairs and larger. Although 24-gauge copper is not required for transmission requirements within 18,000 feet of a digital central office with a 1,500 ohm limit, a heavier gauge of copper is used in smaller cable sizes to prevent damage from craft handling wires in pedestals where wires may be exposed, rather than sealed in splice cases. For cables of 400 pairs and larger, splices are normally enclosed in splice cases, and are not subject to wire handling problems.

<u>Cable below 400 Pairs</u>: Outside plant planning engineers commonly assume that the cost of cable material can be represented as an a + bx straight line graph. In fact, Bellcore Planning tools, EFRAP I, EFRAP II, and LEIS:PLAN have the engineer develop such an a + bx equation to represent the cost of cable. As technology, manufacturing methods, and competition have advanced, the price of cable has been reduced. While in the past, the cost of copper cable was typically ($.50 + $.01 per pair) per foot, current costs are typically ($.30 + $.007 per pair) per foot.

In the opinion of expert outside plant engineers, material represents approximately 40% of the total installed cost. This is a widely used rule of thumb among outside plant engineers. Experience of outside plant experts used for developing the HM 3.1 includes writing and administering hundreds of outside plant "estimate cases" (large undertakings). Outside plant engineering experts have agreed that 40% material to total installed cost is a good approximation. Such expert opinions were also used to determine that the average engineering content for installed copper cable is 15% of the installed cost. The remaining 45% represents direct labor for placing and splicing cable, exclusive of the cost of splicing block terminals into the cable.

<u>Cable of 400 Pairs and Larger</u>: As copper cable sizes become larger, engineering cost is based more and more on sheath feet, rather than cable size. The same is true for cable placing and splice set-up. Therefore the linear relationship between the number of copper pairs and installed cost is somewhat reduced. A review of many installed cable costs around the country were used by the engineering team to estimate the installed cost of copper cable for sizes of 400 pairs and larger.

The following chart represents the default values used in the model.



3.4.2. Fiber Feeder Cable, Cost per Foot

Definition: The investment per foot in fiber feeder cable, engineering, installation, and delivery.

Default Values:

[illegible]	[illegible]
216	$13.10
144	$9.50
96	$7.10
72	$5.90
60	$5.30
48	$4.70
36	$4.10
24	$3.50
18	$3.20
12	$2.90

Support: Outside plant planning engineers commonly assume that the cost of cable material can be represented as an a + bx straight line graph. In fact, Bellcore Planning tools, EFRAP I, EFRAP II, and LEIS:PLAN have the engineer develop such an a + bx equation to represent the cost of cable. As technology, manufacturing methods, and competition have advanced, the price of cable has been reduced. While in the past, the cost of fiber cable was typically ($.50 + $.10 per fiber) per foot, current costs are typically ($.30 + $.05 per fiber) per foot.