HAI Model

Release 5.0a

Model Description

HAI Consulting, Inc.

737 29th Street, Suite 200
Boulder, Colorado 80303

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TABLE OF CONTENTS

LIST OF APPENDICES

1. Introduction

1.1. Overview

The HAI Model, Release 5.0a ("HM 5.0a") has been developed by HAI Consulting, Inc. ("HAI"), of Boulder, Colorado,[1] at the request of AT&T and MCI for the purpose of estimating the forward-looking economic costs of:

a) Basic local telephone service;

b) Unbundled network elements ("UNEs"); and

c) Carrier access to, and interconnection with, the local exchange network.

All three sets of costs are calculated based on Total Service Long Run Incremental Cost ("TSLRIC") principles, and use a consistent set of assumptions, procedures and input data.[2]

The HAI Model uses the definition of basic local telephone service adopted by the Federal-State Joint Board on Universal Service ("Joint Board") for universal service funding purposes. The Joint Board states that the following functional elements are to be considered as required components of universal service:[3]

- single-line, single-party access to the first point of switching in a local exchange network;
- usage within a local exchange area, including access to interexchange service;
- touch tone capability;
- access to 911 services, operator services, directory assistance, and telecommunications relay service for the hearing-impaired.

Excluded from this definition of universal service are many other local exchange company ("LEC") services, such as toll calling, custom calling and CLASS[SM] features,

[1] With its Release 5.0a, the model formerly known as the Hatfield Model is now named the HAI Model. Hatfield Associates, Inc., the firm that developed prior versions of the Hatfield/HAI Model no longer performs telecommunications consulting. All of the staff of Hatfield Associates who have played an active role in developing the Hatfield/HAI Model have formed a successor firm, called HAI Consulting, Inc.

[2] When applied to the costing of unbundled network elements, TSLRIC equates to Total Element Long Run Incremental Costs, or TELRIC as the term is used by the Federal Communications Commission.

[3] Federal-State Joint Board on Universal Service, CC Docket No. 96-45, Recommended Decision, November 8, 1996, ("Recommended Decision") Paragraph 45-53, 65-70.

private line services and white pages directory listings.[4] The existence of such services is taken into account in developing the cost estimates for UNEs -- to the extent that the joint provision of UNEs and other services impacts the costs of UNEs. Model users also may adjust the degree to which several specific UNEs are included in calculating universal service support requirements.

The HAI Model calculates the costs of the following UNEs:

- Network Interface Device ("NID")
- Loop Distribution
- Loop Concentrator/Multiplexer
- Loop Feeder
- End Office Switching
- Common Transport
- Dedicated Transport
- Direct Transport
- Tandem Switching
- Signaling Links
- Signal Transfer Point ("STP")
- Service Control Point ("SCP")
- Operator Systems
- Public Telephones

Finally, the model estimates the per-minute economic cost of providing local network interconnection and access. These are estimated for connection points at end office and tandem switches.

The model constructs a "bottom up" estimate of the pertinent costs based upon detailed data describing demand quantities, network component prices, operational costs, network operations costs, and other factors affecting the costs of providing local service. The model's demand data, particularly data describing customer locations, line demand, and traffic volumes, serve as the key initial drivers. From these data, the model engineers and costs a local exchange network with sufficient capacity to meet total demand, and to maintain a high level of service quality.[5] The model's inputs also include the prices of various network components, with their associated installation and placement costs, along with various capital cost parameters. These data are used to populate detailed input tables describing, for example, the cost per foot of various sizes of copper and fiber cable, cost per line of switching, cost of debt, and depreciation lives for each specific network component.

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[4] Although previous versions of the Hatfield/HAI Model included the monthly cost of maintaining a white pages telephone listing for each subscriber, the Joint Board and FCC have explicitly excluded this item from the definition of supported universal service. Thus, in HM 5.0a its inclusion in cost calculations for basic service is only at the user's express direction.

[5] In general, the level of service quality engineered into the HAI Model exceeds, by a substantial margin, the customary level of basic service quality offered by the LECs over their embedded networks.

Using these data, the model calculates required network investments by detailed plant category. Next, the capital carrying cost of these investments is calculated. Operations expenses are then added to compute the total monthly cost of universal service, various unbundled network elements, stated on both a total cost and an appropriate per-unit basis, and carrier access to and interconnection with the local exchange network. Costs can then be displayed on a study area, density zone,[6] wire center, Census Block Group ("CBG"), or customer cluster basis.[7]

This document describes the structure and operation of the HM 5.0a, including a discussion of various inputs to the model. Section 1.2 describes the recent evolution of the Hatfield/HAI Model. Section 2 summarizes changes made to the model between HM 4.0 and this version. Section 3 provides a general overview of the local network being modeled. Section 4 reviews briefly the structure of the model and its data. Section 5 focuses on the method by which customer locations are determined and clustered. Section 6 describes in detail each module and its operation. Section 7 summarizes the document.

Appendix A provides a brief history of the Hatfield/HAI Model. Appendix B identifies the user inputs to the model and their default values. Appendix C provides flow charts describing the data input development process used to obtain demographic and geological information, residence and business line counts, wire center mappings and loop distances. Appendix D describes the HM 5.0a's calculation of interoffice network distances. Finally, Appendix E provides equation listings of the HM 5.0a's network engineering logic modules.

1.2. Evolution of the Hatfield/HAI Model

On May 7, 1997, the FCC released its Order implementing the mandate for universal service contained in the Telecommunications Act of 1996. In the Order, it declined, on the basis of its current record, including the Report of the State Members of the Joint Board, to endorse a model, and indicated it would issue a Further Notice of Proposed Rulemaking (FNPRM) detailing what it believed to be the appropriate requirements and guidelines that such a cost methodology should incorporate. This FNPRM was released on July 18, 1997. In this FNPRM the FCC provided a wealth of information about what the Commission believes are the appropriate properties to be incorporated into a proxy cost methodology. These include:

- A more sophisticated and precise method of locating customers;

[6] The HM 5.0a differentiates among density zones based on the number of subscriber access lines per square mile of service area.

[7] A CBG is a unit defined by the U.S. Bureau of the Census, and nominally comprises between 400 and 600 households. Customer clusters are dynamically formed aggregations ranging from singleton isolated customer locations, up to 1800 customer locations. See, Section 5.5 below, for a description of the spatial and size criteria used by the HM 5.0a in forming customer clusters.

- A choice of outside plant technologies and structures that reflects more closely local cost conditions;

- Explicit modeling of host/remote relationships between end office switches; and

- More flexible assignments of expenses based either on lines or relative investments.

The Commission set up a series of weekly meetings, and Comment and Reply cycles to address each of these and other related issues in greater depth. The Commission also indicated its intention to select a model for determining universal service support for nonrural carriers by the end of 1997.

HM 5.0a, as here submitted, is responsive to each the Commission's requirements as presented in the Order, the requirements outlined in the FNPRM on cost modeling, and the public notice guidance provided by the Commission subsequent to its release of the FNPRM. Indeed, HM 5.0a represents a revolutionary advance in the modeling of local telephone network costs by its incorporation of:

- Actual gecoded customer locations;

- An algorithm that identifies clusters of customers that may be served efficiently together – without recourse to arbitrary geographic limitations;

- Numerous optimization routines that ensure the use of outside plant that is most technically and economically suited to particular local conditions;

- Explicit specification of host, remote and stand-alone switches;

- An optimizing algorithm for the creation of efficient interoffice SONET transport rings; and

- Opportunities to allocate flexibly expenses based on lines or relative investments.

As a result of these many changes, HM 5.0a has refined greatly the task of identifying actual customer locations, and clustering them into units logically served by telecommunications outside plant. The model has thus moved well ahead of other models that employ more geographically limited, rule-of-thumb calculation techniques.

HM 5.0 was originally submitted to the FCC on December 11, 1997. A number of small but significant changes have been made to the Model's data, logic and documentation since that time. These are incorporated into a revision referred to as HM 5.0a, released January 28, 1998. Section 2.8 summarizes the changes between HM 5.0 and HM 5.0a. To the extent those changes impact the model description, they are reflected in this document.

2. Summary of Changes Between HM 4.0 and HM 5.0

The changes between HM 5.0 and the previous release of the model, HM 4.0, are summarized in the first portions of this section. Section 2.8 summarizes the changes between HM 5.0 and HM 5.0a. All of these changes are reflected in the discussion of how HM 5.0a operates, presented in Sections 4 and 6.

2.1. User Interface

- The new features of the user interface provide the user with many additional inputs and options. Among the new inputs included are the ability to designate specific end office switches as hosts, remotes, or standalones – as well as to assign remotes to a particular host; ability to specify variable T1 repeater spacing; ability to enable the steering of feeder toward population clusters within a quadrant; the ability to invoke a wireless distribution option if its cost is less than wireline, and many more.

- The interface also now allows the user to select multiple companies from one or more states (limited only by hard drive space) to be run in automatic sequence by the model. Expense Modules and workfiles are then produced for each individual company, and their universal service calculations rolled up.

2.2. Input Data

- The HM 5.0a input data locate customers much more precisely. These data determine the actual precise locations of as many customers as possible through latitude and longitude geocoding of their addresses. The remainder are located to at least the Census Block ("CB") level of precision and are assumed to be placed along the CB's periphery.[8]

- A clustering algorithm is used to determine groupings of customers that have extremely realistic correlation to efficient distribution areas.

- The August 1997 Local Exchange Routing Guide ("LERG") is used to identify and locate LEC wire centers.

- Business Location Research ("BLR") wire center boundaries are used to associate customer locations with LEC wire centers. This ensures that all identified clusters

[8] Previous versions of the HM only located customers precisely to their Census Block Group (CBG). Within high density CBGs, customers were assumed either to be spread uniformly across the CBG. In low density CBGs, a portion of customers was assumed to be clustered in quadrants, while another portion was assumed to spread along outlying roads.

are restricted to include only customer locations that fall within the boundaries of a single wire center.

- Company line count totals are determined from the most recent available data, including that provided in the 1996 ARMIS data and NECA USF Loops filing for 1996.

- The method of estimating line counts by LEC wire center is refined, and line counts can be determined by CB.

- 1996 ARMIS data (rather than 1995 ARMIS data) are used to estimate traffic volumes and expense inputs.

2.3. Outside Plant Selection

- HM 5.0a automatically adjusts buried and aerial structure fractions to account for varying maintenance costs and placement costs occasioned by local soil conditions and bedrock. The amount of one type of structure substituted for another depends both on differences in placement costs and on a life-cycle analysis of maintenance and capital carrying costs of the two types of structure.

2.4. Distribution Module

- HM 5.0a lays its distribution plant directly over the actual identified locations of customer clusters.

- Rather than assuming that the distribution area is square, HM 5.0a engineers its distribution grid as a rectangle. The aspect ratio (height-to-width) of this rectangle is determined by the data input development process for each cluster, and distribution cable is laid out in a fashion that reflects this aspect ratio.

- HM 5.0a serves "outlier" clusters from "main clusters" on which they home, using digital T1 technology whenever the road cable length exceeds a user-adjustable maximum analog copper distance.[9] The cables carrying T1 signals to the outlier clusters are separate from the analog copper cables that extend from the T1 terminal in each outlier cluster to the customer locations within the outlier cluster.

- Assuming that the distance of a cable run is sufficiently short so that use of copper feeder is a technically acceptable option, the HM 5.0a performs an analysis of the relative life-cycle costs of copper versus fiber feeder to determine which feeder technology should be used to serve the given main cluster.

[9] Outlier clusters are clusters that contain fewer than five lines. Main clusters are cluster containing five or more lines. These clusters are served by feeder linking them to their serving wire center. See Section 6.3.2 for more detail.

- The HM 5.0a also incorporates an optional, user-adjustable "cap" on distribution investment. This cap is structured to reflect the potential cost structure of wireless distribution technologies.

2.5. Feeder Module

- HM 5.0a engineers feeder to serve actual population main clusters (and uses distribution cable to serve main clusters' subtending outlier clusters), rather than simply engineering to each CBG.

- At the user's option, the HM 5.0a "steers" feeder routes toward the preponderant location of main clusters within a given wire center quadrant.[10] When this steering is invoked, the user may also apply an adjustable route-to-airline distance multiplier to the amounts of cable placed along these "steered" feeder routes.

- Manhole placement costs are increased by a user-specified amount whenever the local water table depth is less than the user-specified threshold.

2.6. Switching and Interoffice Module

- At the user's discretion, HM 5.0a will both engineer and cost explicit combinations of host, remote and stand-alone end office switches. If the user does not make such a specification, the HM 5.0a defaults to computing end office switching investments using input values that provide average per-line investments for an efficient portfolio of host, remote, and stand-alone switches.[11] If the host/remote/standalone designation option is invoked, the user is required to specify whether a wire center houses switches that are hosts or remotes, as well as to assign the correspondence between host and remote switches.

- Further, when the user chooses the model to distinguish explicitly between switch types, the HM 5.0a assumes that each host and its remotes are on a Synchronous Optical Network ("SONET") fiber optics ring separate from the interoffice rings used to interconnect host, standalone and tandem switches with each other.

- The HM 5.0a calculates explicitly a set of interoffice SONET rings that interconnect host, standalone, and tandem switches with each other. Based on this explicit specification of what wire centers are on each interoffice ring, the HM 5.0a determines associated ring distances using the actual locations of the wire centers along the ring. In addition, the rings are appropriately interconnected

[10] The default treatment, if steering is not invoked, is for the Feeder Module to calculate feeder distances using "right angle routing" in the four cardinal compass point directions, as employed in HM 4.0.

[11] The Model defaults to an average per-line mix because accurate data on the purchase prices of a portfolio of host, remote and standalone switches of varying capacities, and on the identification of hosts, remotes, and stand-alone switches, may not be available to the user.

with each other, and tandem switches are also interconnected if they fall within the same LATA.[12].

- The HM 5.0a engineers redundant paths and associated transmission terminal equipment for the point-to-point (folded) rings that may be specified to connect small offices to the larger wire centers on which they home.[13]

2.7. Expense Modules

- A Uniform System of Accounts ("USOA") detail worksheet is included that breaks out HM 5.0a investments and expenses by Part 32 account for comparison purposes.

- The proportion of total expenses that are assigned to loop network elements (i.e., NID, distribution, concentration and feeder) can be varied based either on relative number of lines, or on the relative amount of direct expenses (direct expenses include both maintenance expenses and capital carrying costs for the specific network elements).

- Both federal and state universal service fund requirements can be calculated in the density zone USF worksheet. This separate calculation permits differing state and federal cost benchmarks to be specified, as well as different collections of local services (e.g., primary and secondary residential lines, single business lines, etc.) to receive universal service support.

- In addition to displays of costs at the lines density zone and wire centers levels of aggregation, costs can also be displayed at the CBG and individual population cluster level.

2.8. Changes Incorporated in HM 5.0a

2.8.1. Distribution Module

- HM 5.0a modifies its method of dividing clusters to more efficiently ensure that the length of cables carrying analog signals never exceeds the user-set maximum (default = 18,000 ft).

- HM 5.0a corrects minor typographical errors in equations used to calculate the portions of structure that "swing" between buried and aerial based on abnormal local life-cycle costs, and in the wireless cap equations.

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[12] InterLATA links are excluded from the model because such links are not part of the local exchange network.

[13] The user may specify a minimum number of lines that a wire center must serve (default of just one) before that wire center is placed on an interoffice ring with other end office switches – rather than being interconnected directly only to its "home" wire center.

- Adds columns that calculate average loop lengths.

2.8.2. Switching and Interoffice Module

- The time required to execute this module for large companies is reduced by sourcing from other portions of the workbook, rather than calculating, certain distance and DS3 count information.

- For wire centers owned by small LECs without local tandems, connectivity to a tandem is established in two pieces. First, a spur is engineered to the closest large LEC wire center that is on an interoffice ring. Second, the equivalent investments in facilities and terminal equipment associated with the required number of leased circuits on this ring that are used to connect this large LEC wire center to its tandem are calculated on a per-DS0 facilities basis. This is in contrast to the previous method of determining the cost of interoffice route between the Large LEC wire center and its tandem based on multiplying the distance between these nodes by an assumed dedicated circuit-mile charge.

- Rings now must have a minimum of four nodes, assuming there are that many wire centers, versus a prior minimum of two nodes.

- HM 5.0a provides several new “traps” to prevent certain execution problems. These include: 1) the ring-generating code is modified to expect the user-specified “host/remote enable” option as boolean type rather than a string; 2) stand-alone tandems now have an associated interoffice distance; 3) the number of allowed wire center records has been increased from 1,500 to 2,000; 4) the ring-generating code contains logic to determine whether host/remote calculations are enabled before eliminating remotes as first order ring candidates; 5) the ring-generating code uses wire center records generated from the HM5.0a database as the source of the locations associated with a particular state and operating company; 6) the ring-generating code now updates the progress bar in closer proportion to the module’s degree of completion; 7) the ring-generating code writes all results into a list in the “ring io” worksheet; 8) the array dimension in the routine computing interoffice mesh distances has been increased from 25 to 100 elements; and 9) several additional “divide checks” are provided and syntax errors corrected.

2.8.3. Expense Modules

2.8.3.1. Density Zone and Wire Center Versions

- Corrects the calculation of weighted average depreciation life for non-metallic cable to include interoffice fiber facilities.

- The “Cost detail” sheet of the DZ version allows for the substitution of ICO-equivalent DS0 transport values.

- Corrects cell references for residential and business usage in the wire center USF sheet from absolute to relative.

2.8.3.2. Expense Modules – CBG and Cluster Versions

- Improves on the previous CBG expense module by associating cluster costs to the several CBGs that may overlay the cluster in proportion to the relative number of lines that each CBG displaces of the cluster's total quantity of lines.

- Adds a Cluster expense module that displays cost results on a customer cluster-by-cluster basis.

2.8.4. Interface Items

- Corrects several non-functioning items in the interface, including: 1) permitting Puerto Rico to be run through the interface; 2) fixing the OLE error that previously has occurred the initial time the newly installed HM 5.0 is run; and 3) speeding the run time of the Feeder module

2.8.5. Input Data Items

- Corrects several data discrepancies, including: 1) correcting the several "problem clusters" that previously were incorrectly sized; 2) adding the clusters that were missing from the California data; and 3) assigning correctly the lines density classification of Puerto Rico clusters; and 4) correcting the state assignment of several small LECs that operate across state borders.

- Adds CBGMulti data table that relates clusters to the several CBGs that overlay them based on relative counts of lines associated with each CBG.

- Adds data that permit easy calculation of average loop lengths by cluster and wire center.

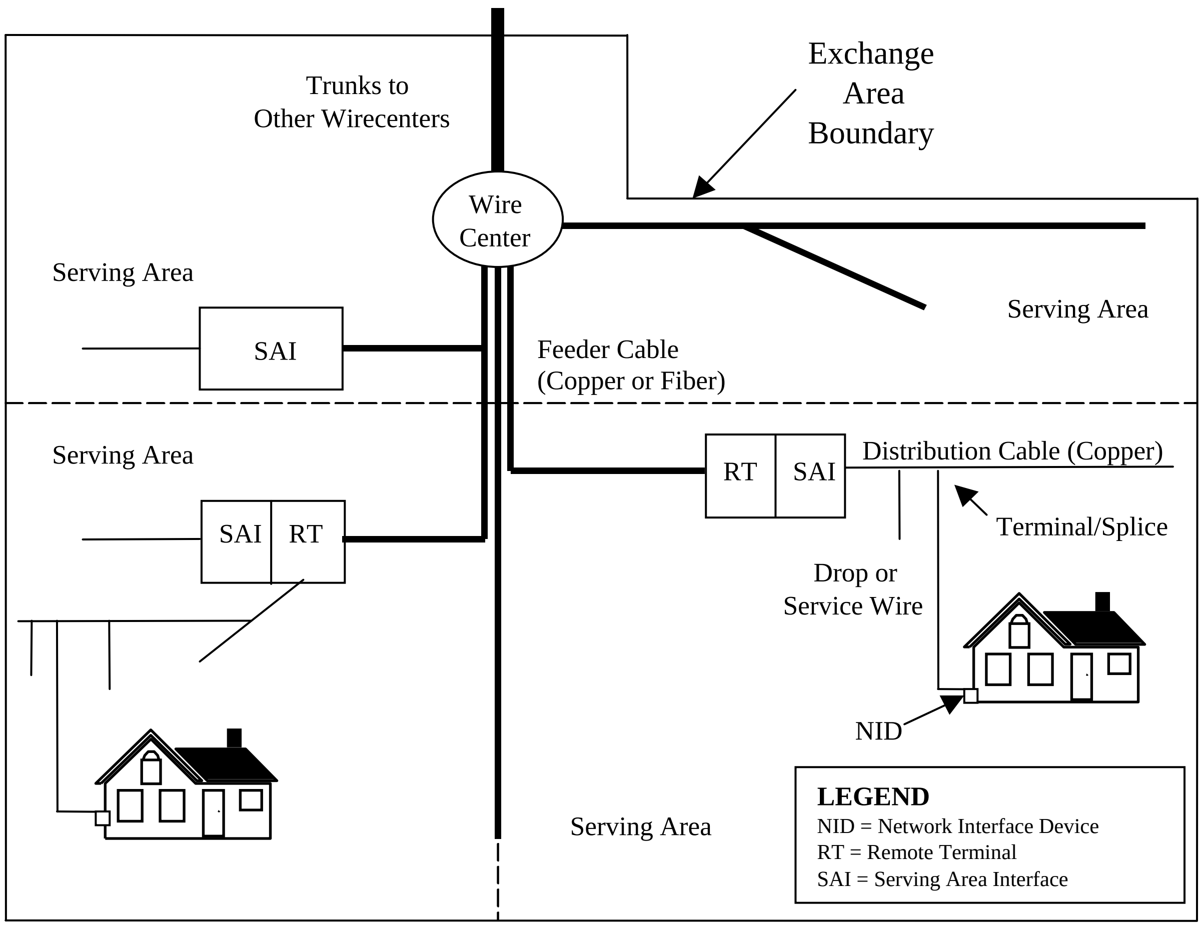
3. Fundamental Structure of Local Network

3.1. Components of the Local Exchange Network

This section describes the network configuration and components modeled in HM 5.0a. Figures 1, 2 and 3 depict the relationships among the loop, switching, interoffice, and signaling network components.

3.1.1. Loop Description

Figure 1 depicts the loop model utilized in HM 5.0a. Section 3.1.1.1 defines the serving area. Section 3.1.1.2 provides a general description of the loop, depicted in Figure 1. Section 3.1.1.3 describes the loop components in more detail.



Adapted from Engineering and Operations in the Bell System, 2nd Edition, 1983

Figure 1 Loop Components

3.1.1.1. Serving Area

The total area served by a wire center is organized into one or more serving areas, each of which contains a portion of the area and lines served by the wire center. The serving areas are delineated by dotted lines in the above figure. In HM 5.0a the serving areas equate to main customer clusters and their subtending outlier clusters, as discussed in Section 6.2.

3.1.1.2. General Loop Description

One end of the feeder portion of the loop terminates within the central office building, or "wire center." Copper cable feeder facilities terminate on the "vertical side" of the main distributing frame ("MDF") in the wire center, and fiber optic feeder cable serving integrated digital loop carrier ("IDLC") systems terminates on a fiber distribution frame in the wire center.

The other end of the feeder extends to an appropriate termination point in the serving area. Copper feeder cables terminate on one or more serving area interfaces ("SAIs") in each serving area, where they are cross-connected to copper distribution cables. Fiber feeder cables extend to a digital loop carrier ("DLC") remote terminal ("RT") in the serving area, where optical digital signals are demultiplexed and converted to analog signals. Individual circuits from the DLC are cross-connected to copper distribution cables at an adjacent SAI.

Copper distribution cable extends from the SAI along routes passing individual customer premises. At appropriate points, these cables pass through block terminals typically serving several housing units. In the terminal, individual copper pairs in the distribution cable are spliced to "drops" that extend from the terminal to the customers premises. The drop terminates at a network interface device, or NID, at the customer's premises.

Feeder, distribution, and drop cables are supported by "structures." These structures may be underground conduit, poles, or trenches for buried cable and underground conduit. Underground cable is distinguished from buried cable in that underground cable is placed in conduit, while buried cable comes into direct contact with soil.[14] In more urban areas, aerial distribution cable may be attached directly to the outside of buildings, in what is called a "block cable" arrangement, or, for high-rise buildings, may consist of riser cable inside the building.

3.1.1.3. Local Loop Components

1) *Network Interface Device*

    The NID is the demarcation point between the local carrier's network and the customer's inside wiring. This device terminates the drop wire and is an access point that may be used to isolate trouble between the carrier's network and the customer's premises wiring. The NID also contains protection against externally-

[14] Although the conduit supporting underground cable is always placed in a trench, buried cable may either be placed in a trench or be directly plowed into the earth.

induced hazardous voltages, such as those associated with lightning strikes and contact between telephone and electric lines. In a multi-tenant building, the protection is located at the point at which the distribution cable enters the building.

2) *Drop*

A copper drop cable, typically containing several wire pairs, extends from the NID at the customer's premises to the block terminal at the distribution cable that runs along the street or the lot line. The drop can be aerial or buried; generally it is aerial if the distribution cable is aerial, and buried if the distribution cable is buried or underground.

3) *Block Terminal*

The "block terminal" is the interface between the drop and the distribution cable. When aerial distribution cable is used, the block terminal is attached to a pole in the subscriber's front yard at the edge of a road. A pedestal contains the block terminal when distribution cable is buried.

4) *Distribution Cable*

Distribution cable runs between the block terminals and an SAI located in the serving area. Limitations on the capacity of an SAI and/or the distribution design used in a particular serving area may lead to multiple SAIs. Distribution structure components may consist of poles, trenches and conduit.[15]

5) *Conduit and Feeder Facilities*

Feeder facilities constitute the transmission system between the SAI and the wire center. These facilities may consist of either pairs of copper wire or a DLC system that uses optical fiber cables as the transmission medium. In a DLC system, the analog signals for multiple individual lines are converted to a digital format and multiplexed into a composite digital bit stream for transmission over the feeder facilities

Feeder structure components include poles, trenches and conduit. Manholes for copper feeder or pullboxes for fiber feeder are also normally installed in conjunction with underground feeder cable. Manhole spacing is a function of population density and the type of feeder cable used. Pullboxes that are installed for underground fiber cable are normally farther apart than manholes used with copper cables, because the lightness and flexibility of fiber cable permits it to be pulled over longer distances than copper cable.

[15] Because underground distribution exists only in the highest density zones where runs are relatively short, and because in such zones underground structure is commonly shared with feeder, distribution facilities typically do not include manholes.

Several utilities, e.g., electric utilities, LECs, IXCs and cable television ("CATV") operators, typically share structure because it is economical to do so. Manholes may be shared with low-voltage facilities. The amount of sharing of structure and manholes may differ in different density zones and between feeder and distribution cables.

3.1.2. Switching and Interoffice Network Description

This section provides a general description of the network components comprising the wire center and interoffice facilities. Figures 2 and 3 illustrate the relationships among the components described below.

3.1.2.1. Wire Centers

The wire center is a location from which feeder routes extend towards customer premises and from which interoffice circuits or "trunks" emanate toward other wire centers. A wire center normally contains at least one end office ("EO") switch and may also contain a tandem switch, an STP, an operator tandem, or some combination of these facilities. Wire center physical facilities include a building, power and air conditioning systems, rooms housing different switches, transmission equipment, distributing frames and entrance vaults for interoffice and loop feeder cables.

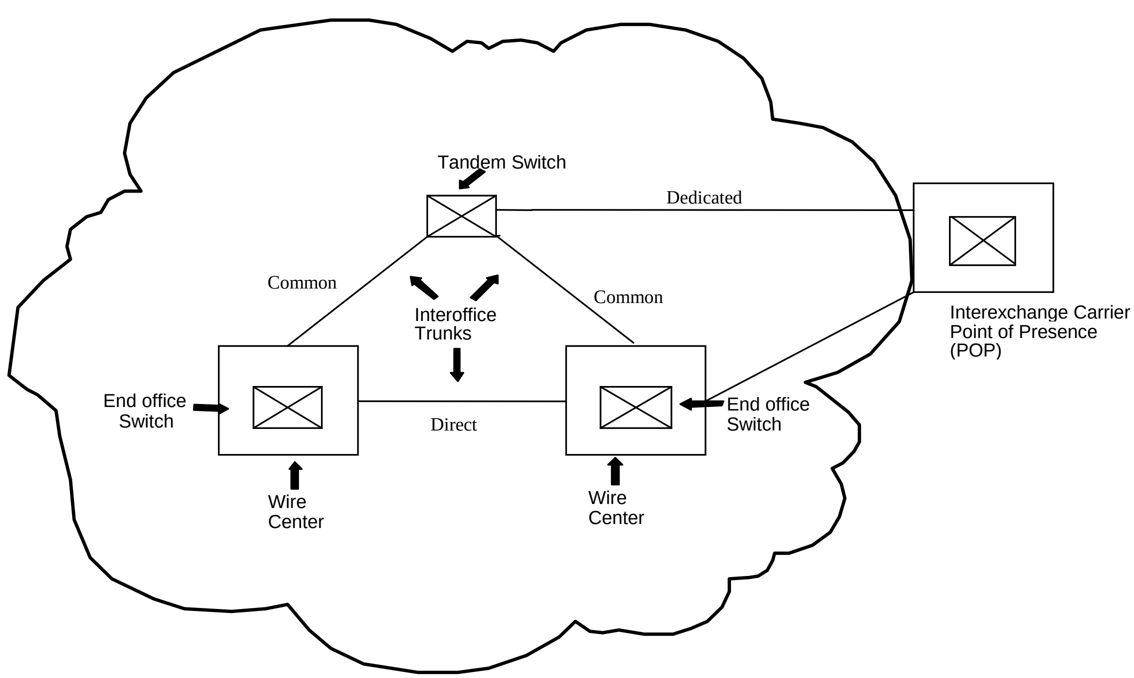


Figure 2 Interoffice Network

3.1.2.2. End Office Switches

The end office switch provides dial tone to the switched access lines it serves. It also provides on-demand connections to other end offices via direct trunks, to tandem switches via common trunks, to interexchange carrier ("IXC") points of presence ("POPs") via dedicated trunks, and to operator tandems via operator trunks.

3.1.2.3. Tandem Switches

Tandem switches interconnect end office switches via common trunks, and may also provide connections to IXC POPs via dedicated trunks. Common trunks also provide alternatives to direct routes for traffic between end offices. Tandem switching functions often are performed by switches that also perform end office functions. Tandems normally are located in wire centers that also house end office switches

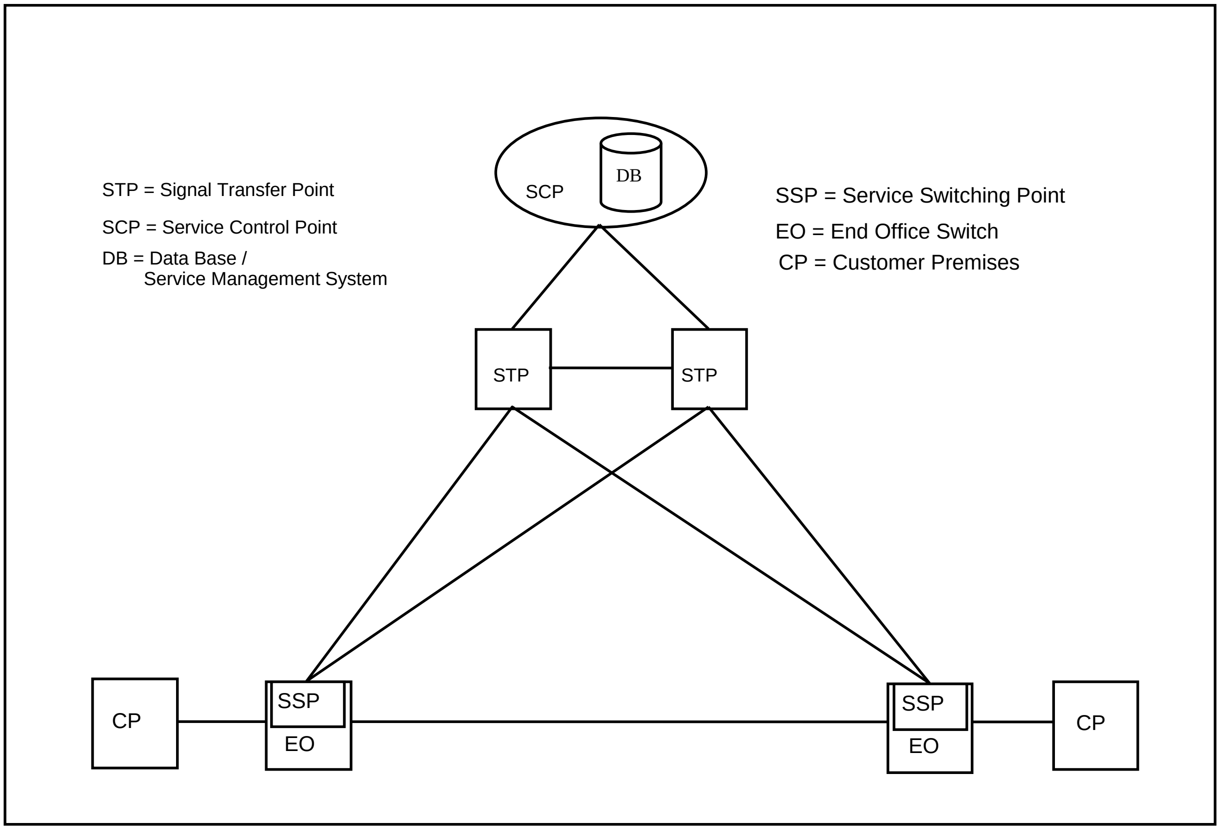


Figure 3 Interoffice Signaling Network Components

3.1.2.4. Interoffice Transmission Facilities

Interoffice transmission facilities carry the trunks that connect end offices to each other and to tandem switches. The signaling links in a Signaling System 7 ("SS7") signaling network are also normally carried over these interoffice facilities.

Interoffice transmission facilities are predominantly optical fiber systems that carry signals in SONET format. Both economic and service quality considerations increasingly prescribe the use of a fiber optic ring configuration to link switches, except for switches that serve few lines or that are too remote from other switches, where ring costs might be prohibitive. In this case, the small switches are typically connected to a nearby wire center housing another end office switch that is on a ring, or the tandem on which the small switch homes, via point-to-point links that are increasingly provided on a route-diverse (that is, redundant) basis for the sake of increasing reliability. Use of rings and redundant point-to-point links in this fashion provides an extremely secure path between any two switches, and the potential for substantial cost savings relative to the ubiquitous deployment of traditional point-to-point facilities interconnecting all switches.

3.1.2.5. Signal Transfer Points

STPs route signaling messages between switching and control entities in a SS7 network. Signaling links connect STPs and Service Switching Points ("SSPs"). STPs are equipped in mated pairs, with at least one pair in each Local Access Transport Area ("LATA").

3.1.2.6. Service Switching Points and Signaling Links

SSPs are SS7-compatible end office or tandem switches. They communicate with each other and with Service Control Points ("SCPs") through signaling links, which are 56 kbps dedicated circuits connecting SSPs with the mated STP pair serving the LATA.

3.1.2.7. Service Control Points

SCPs are databases residing in an SS7 network that contain various types of information, such as IXC identification or routing instructions for 800 numbers in regional 800 databases, or customer line information in Line Information Databases ("LIDB").

4. HM 5.0a Model Organization, Structure and Logic

4.1. Overview of HM 5.0a Organization

Figure 4 shows the relationships among the various modules contained within HM 5.0a. An overview of each component of the Model follows.

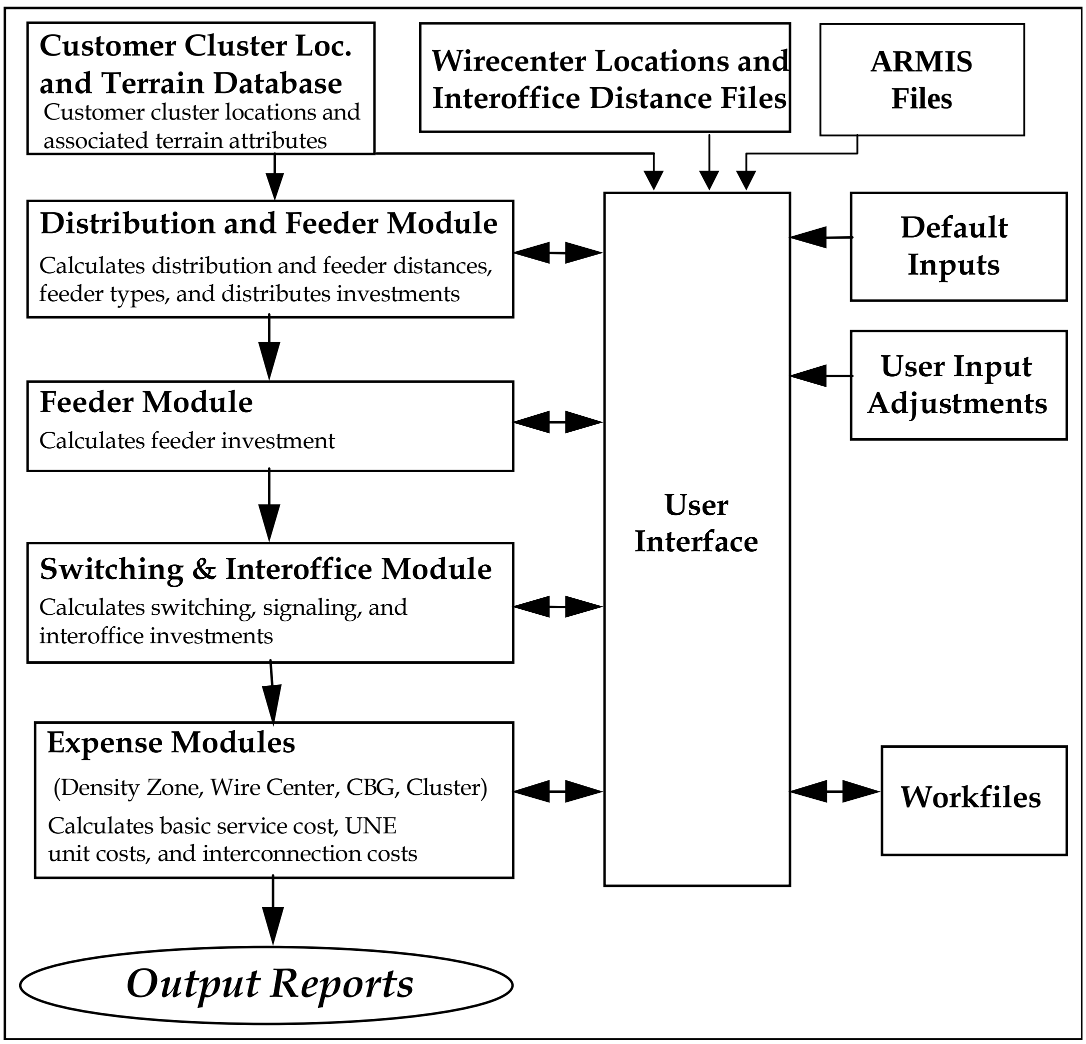


Figure 4 HM 5.0a Organization Flow Chart

4.2. Input Data

Inputs to HM 5.0a include detailed data describing the following items.

- Demographic, geographic and geological characteristics of the areas served by each telephone company. These data records are specific to individual “clusters” of customer locations (i.e., “main” clusters and their subtending “outlier” clusters). They include information on the number of customer locations and lines receiving telephone service in a cluster, the geometric configuration of the cluster’s boundaries, the wire center that serves the cluster and the cluster’s location relative to this wire center and to other nearby clusters, and the type of terrain that characterizes the cluster. The character and development of these data are described in greater detail in Section 5.

- Wire center locations, and interoffice distances between end offices, tandems, and STPs used to determine the route miles required for interoffice transmission and signaling facilities. These data are largely developed from Bellcore’s LERG and NECA Tariff 4.

- 1996 ARMIS data reported by the Tier 1 LECs. These data provide information about current demand levels that the LEC must serve, and relationships between the LEC’s embedded expenses and investments.

- Numerous user-adjustable inputs that allow users to set carrier- or locale-specific parameters, and perform sensitivity analyses. These inputs have preset default values based on the engineering experience and judgment of HAI personnel, as well as the judgements of independent subject matter expert consultants to HAI.

4.3. Workfiles

A run “workfile” is created from the input data files when a particular state/company (i.e., study area) combination is run for the first time. As a complete run of the HM 5.0a progresses, intermediate outputs from the HM 5.0a’s constituent modules are stored in the run’s workfile. Once the run is complete, its workfile may be examined. A great deal of information above and beyond that presented in the Expense Module spreadsheets (that contain the principal final results of the model’s analysis) may be obtained from the run’s workfile. One example is average loop length, by cluster and by wire center. Additionally, the user may perform separate analyses on the LEC study area by directing the model to create a new workfile for a subsequent run.

4.4. User Interface

The HAI Model includes a user interface program that facilitates model operation, including extraction of data from the input files, providing dialog boxes for users to manipulate model inputs, executing the Excel workbooks that constitute the model, saving intermediate results, and managing the flow of intermediate results between different modules.

The user interface program also performs certain simple aggregation and summarization calculations in Visual Basic for Applications ("VBA"). This shortens greatly execution times and allows users examining the model's Excel workbooks to focus on the model's fundamental engineering logic.[16]

4.5. Distribution Module

The Distribution Module addresses the portion of the network extending from SAIs to the customers' premises. The module determines the lengths and sizes of distribution cable, the associated structures (poles, trenching, and conduit), the number of terminals, splices, drops, and NIDs required to provide service to the specified numbers and types of customers, and the number and type of SAIs and DLC terminals required. The module also calculates certain distances required by the Feeder Module, and, according to those calculations, determines whether to serve a given distribution area using feeder transmission facilities consisting of copper wire pairs, or using DLC running over optical fiber cable. The model selects fiber feeder if any of following five criteria are met:

a) the feeder distance exceeds a user-adjustable crossover distance (set to a default value of 9,000 feet) that limits maximum distance of any copper feeder run;

b) the total copper loop length, including feeder and distribution cable, for customer locations within a main cluster, exceeds a user-adjustable maximum analog copper distance whose default value is 18,000 feet;[17]

c) the main cluster has at least one outlier cluster subtending it;

d) an analysis of the life-cycle costs of fiber vs. copper feeder shows that fiber feeder is the more economical choice, or

e) the "wireless" investment cap is invoked.

These criteria are described in greater detail in Section 6.3.5. If, based on these criteria, copper feeder is chosen, it extends out to an SAI located at the centroid of the main cluster. Copper distribution cable then extends from the SAI to all customer premises in the cluster. If fiber feeder is chosen, it extends from the wire center out to the centroid of the main cluster. From this point, one of two configurations is used to serve the customer locations within the main cluster. If the distance to the farthest customer location in the

[16] Model versions prior to HM 3.0 used Microsoft Excel's Pivot Table feature to summarize various results at the wire center and density zone levels. Although this feature was quite flexible, applying pivot tables to the very large arrays of data required by the model led to very slow execution times.

[17] The analog copper distance refers to the distance over which signals are transmitted in analog voiceband form on copper cable.

main cluster is less than the user-adjustable maximum analog copper distance, a single DLC RT is located at the cluster centroid, and copper distribution cable extends from this DLC RT to all customer premises in the main cluster. If the distance to the farthest location in the main cluster exceeds the maximum analog copper distance, then fiber connecting cable extends vertically and/or horizontally from the centroid to two or more DLC RTs, each of which serves a portion of the main cluster and is located to ensure the longest remaining distance is less than the maximum analog copper distance. From these multiple DLC RTs, copper distribution cables extend to the customer premises in the portion of the main cluster they are responsible for serving.[18]

The HM 5.0a Distribution Module serves outlier clusters that subtend main clusters with analog copper cable if their distance from the DLC RT in the main cluster does not exceed the user-adjustable maximum analog copper distance parameter, and if this outlier cluster has no other outlier clusters either subtending it, or lying between it and the main cluster.[19] If the distance to the farthest subscriber within an outlier cluster would exceed this threshold, the Distribution Module serves the outlier cluster with digital loop carrier equipment using copper-based T1 digital transmission.[20] Once the outlier cluster has been reached, analog copper distribution cables are used to serve the customers located in the outlier cluster.

After the module has determined the quantities of all distribution elements, it calculates the investment associated with these elements, including distribution and drop cable, structures, NIDs, terminals and splices, SAIs, and DLC terminals, using as inputs the user-adjustable unit prices of each element. The numbers and types of elements engineered can be examined in the intermediate outputs of the Distribution Module as recorded in the workfile.

4.6. Feeder Module

The Feeder Module configures the portion of the network that extends from the wire center to the SAIs. Based on information it receives from the Distribution Module, it determines the size and type of cables required to reach the SAIs located in each serving area, along with supporting structures (poles, trenching, conduit, manholes, and fiber optics pullboxes). The Feeder Module then calculates the investment associated with these elements, using as inputs the unit prices of each such element. It passes these investments to the Expense Modules. The numbers and types of network elements required can be examined in the intermediate outputs of the Feeder Module as recorded in the workfile.

[18] If, however, the model invokes a wireless local distribution system, fiber feeder extends to the radio base station located in main cluster, and final distribution is made to customers in outlier clusters over-the-air.

[19] Such an outlier cluster is termed a “first order” outlier.

[20] This technology does not require the use of loading coils or coarse-gauge cable, and it also permits basic rate ISDN and other advanced narrowband services to be provided to all subscriber locations in the model.

4.7. Switching and Interoffice Module

The Switching and Interoffice Module computes investments for end office switching, tandem switching, signaling, and interoffice transmission facilities. In HM 5.0a the user can designate specific wire center locations that house host, remote, and stand-alone switches, respectively, as well as specify inputs for the per-line investments associated with each type of switch. HM 5.0a will then calculate switching investments taking into account the switch arrangements that the user designates.

The switching module determines the required line, traffic, and call processing capacity of switches based on line totals by customer type across all serving areas belonging to the wire center, and based on ARMIS-derived traffic and calling volume inputs. It also determines the required capacity and distances of interoffice transmission facilities, using the traffic data and the interoffice distances that are input to the Module. In doing so, it uses wire center locations and interoffice distances to determine an efficient mix of interoffice SONET fiber rings and redundant point-to-point fiber links. Rings are separately provided for linking host switches to their subtending remotes, and for linking host switches to each other, to stand-alone switches and to the tandem switches on which they home.[21] The numbers and types of elements involved can be examined in the intermediate outputs of the Switching and Interoffice Module as recorded in the workfile.

4.8. Expense Modules

There are four different versions of the HM 5.0a's Expense Module – one for each of the four levels of granularity at which the user can elect to have cost results displayed: by line density range (which also displays total study area costs), by wire center, by CBG, or by customer cluster.[22] Each version calculates the monthly costs for unbundled network elements, universal service, and carrier access and network interconnection. These costs include both the capital carrying costs associated with the investments, and the costs of operating the network. Capital carrying costs include depreciation, return on the debt and equity investment required to build the network, and income taxes on equity return. Network-related expenses include maintenance and network operations. Non-network related expenses include customer operations expenses, general support expenses, other taxes and variable overhead expenses.

Several sources provide information to the Expense Modules. The Distribution, Feeder, and Switching and Interoffice Modules provide network investments by specific plant

[21] At the user's option, small standalone wire centers serving fewer lines than a user-adjustable threshold (default value: one line) may be excluded from being placed on rings, and instead linked directly to its serving tandem using point-to-point links. In this case, the model attempts to physically route these point-to-point circuits through a nearby large wire center, and then over the fiber rings it has otherwise engineered for interconnecting larger offices and tandems.

[22] Although the HM 5.0a engineers no plant based on CBG granularity, the results of its engineering to individual clusters may be rolled up to display cost results at the CBG level. The association between clusters and CBGs is made based on the relative number of lines each cluster contributes to a CBG's total.

category. ARMIS and other sources are used to derive information on network operating and maintenance expense relationships.

The Expense Modules produce reports (either by density zone, wire center, CBG, or cluster) showing the key outputs of the model, including the costs of providing universal service, unbundled network elements, interconnection and IXC access. Further detail about network investments and costs is available from the workfile associated with a model run.

5. Input Data

To accommodate HM 5.0a's evolution to modeling local telephone networks based on actual clusters of customer locations, the input data used in HM 5.0a are much more granular than the CBG input data used in HM 4.0 and earlier. Flowcharts describing the development processes used to prepare these input data for HM 5.0a are attached as Appendix C to this document.

5.1. Line Type Counts by Study Area

Counts of access lines by type (i.e., residence, single line business, multiline business, public telephone and special access lines) for each distinct NECA Study Area for calendar year 1996 are developed from several data sources. These include:

ARMIS 43-08: 1996 data, released 10/01/97;
ARMIS 43-01: 1996 data, released 10/01/97;
NECA USF Loops filing: 1996 data;
USTA report: 1995 data;
RUS report: 1995 data;
USF Data Request: 1993 data;
ARMIS-based line factors.

The rules by which the best of these data are selected are as follows.

a) When NECA Study Area name matches exactly ARMIS Company name, populate line types directly from ARMIS data for business lines (43-08), single line business lines (43-01), residence lines (43-08), special access lines (43-08), and public lines (43-08) data.

b) For remaining ARMIS Companies, determine counts of line types for NECA Study Area name by applying ARMIS line type distributions to total reported NECA USF Loops.

c) For non-ARMIS Companies, match NECA Study Area name to best available data source (i.e., USTA, RUS or USF Data Request) for residence and business line splits.

d) When no company-specific line type data exist, apply average ARMIS line type distributions to reported NECA USF Loops for NECA Study Area name.

5.2. Wire Center List

The source of the wire center information used in PNR's National Access Line Model is Bellcore's LERG database, dated August 1, 1997.[23] The portions of these LERG data that are used in the HAI model are an extract of key data from the LERG called the Special LERG Extract Data ("SLED") – which has been licensed from Bellcore by the HAI model developers.

Certain switching entities (wire centers) in the SLED with Common Language Location Identifier ("CLLI™") codes not marked as end offices, hosts or remotes are then removed from this wire center database. In addition, switching entities that are inactive, or owned by wireless, long distance or competitive access providers are removed as well.

In a few instances, the SLED assigns wire centers to multiple local carriers. This may result from switch collocation. Because the HAI Model requires wire center entries to be unique, such wire centers are assigned to the local carrier having the greatest number of active NPA-NXX codes. If active NPA-NXX codes are equal among companies, assignment is to the carrier having the greatest number of residential lines.

Multiple occurrences of 8-character CLLIs may also occur in the SLED due to placements of several switches at a single wire center location. Because the HAI Model itself engineers multiple switches in a wire center if demand requires it, duplicate occurrences of 8-character CLLIs are removed from the model's wire center list.

5.3. Customer Counts by Census Block and Wire Center

Customer locations must be associated both with CBs, as well as their serving wire center ("WC"). The PNR National Access Line Model, Version 2.0 ("NALM") performs both of these tasks. The PNR NALM uses PNR survey information, Bellcore's LERG, BLR wire center boundaries, Dun & Bradstreet's ("D&B") business database, Metromail's household database, Claritas' 1996 demographic database, and U.S. Census estimates to calculate both the number of residential and business locations and access lines in each CB, and in each wire center in the United States. This summary describes the methodology, data and assumptions used in developing these location and line estimates in the NALM.

5.3.1. Residence Counts

Residential customer location counts are developed by applying the following process.

a) The Metromail household database (described in section 5.4.1, below) is geocoded to the "point" level.[24] In addition to recording the precise six-decimal place latitude and longitude of this household, the CB associated with its location

[23] These LERG data are augmented by data from NECA Tariff 4.

[24] As described in more detail in Section 5.4.3, below, geocoding to the "point" level means that the geocoding software has both found the housing unit's address in its location files and determined a latitude and longitude for the location down to six decimal places of a degree.

is recorded as well. Duplicate household information is identified and eliminated. If two records appear with an identical latitude, longitude and phone number, one of the two records is eliminated.

b) Implied residential household counts are evaluated by comparing Metromail counts to Claritas' 1996 CBG-level projections of households with telephones. When Metromail households exceed Claritas households, Metromail households are used. When Claritas households exceed Metromail households, Claritas households are used, and the total differences are distributed to the constituent CBs in proportion to 1990 U.S. Census household distributions.

c) Access line counts are determined from household counts using probabilities, that is, how likely is it that a household will have a first or second telephone line installed? First line probabilities are provided by Claritas based on demographic age and income profiles by CBG. Second line probabilities are based on a logistic regression using similar demographic information and developed by PNR using its ReQuest™ III residential survey. Multiplicative probability factors are applied to the household counts defined above to derive residential line counts.

d) The above derived residential line counts by CB are then normalized to sum to Study Area wide data on total residential line counts developed in Section 5.1, above.[25]

e) This lines normalization factor is applied to the residential customer location counts in each CB, as well.

The implications of the forgoing process are as follows. Because the primary source of residential location counts is Metromail – which includes all residences that receive direct mail regardless of whether they have telephones or not – the universe of "populated" CBs that the data process captures may include CBs where telephone service is not currently offered or accepted. Thus, the "breadth" of the telephone network that these data will instruct the HM 5.0a to construct is likely greater than the embedded networks of the ILECs. However, because the counts of lines and locations in each CB are normalized to sum to given Study Area wide totals, the "depth" of the constructed network will be consistent with current levels of actual telephone demand.[26]

5.3.2. Business Counts

[25] If comprehensive LEC data on residential line counts by individual wire center are available, normalization can be done at the individual wire center level.

[26] In addition, note that these primary source residential location counts derive from precisely geocoded 1997 Metromail data. Thus, these data provide 1997 information on location counts at the CB level. As a result, the model's reliance on noncurrent or nonCB-specific location data (e.g., Claritas 1996 CBG-level projections, 1990 U.S. Census CB counts, or 1995 U.S. Census Update county-level projections) is limited to those locations that show up in such counts that are in excess of the Metromail counts.

Business location counts are developed by applying the following process.

a) The D&B national business database (described in Section 5.4.2, below) is geocoded to the "point" level. In addition to recording the precise six-decimal place latitude and longitude of this business, the CB associated with its location is recorded as well.

b) From the D&B national database, the total number of business lines, as well the probabilities of these lines being single line business lines and multiline business lines such as Centrex and PBX lines are developed. This model is based on an 800,000 firm sample.

c) Because the D&B national business database contains records for only about 11 million out an estimated total of 12 million U.S. businesses, and because the businesses that it misses are almost certainly small businesses, an additional 1 million nonD&B business locations are added to CB counts in proportion to D&B businesses located in the CB. The lines associated with these added business locations are projected by PNR based on an assumption that they employ, on average, between 1 and 4 employees, each.[27]

d) The above derived business line counts by CB are then normalized to sum to Study Area wide data on total business line counts developed in section 2.1, above.[28]

5.3.3. Location and Line Counts by Wire Center

HM 5.0a uses WC boundaries provided by BLR as its primary source to define wire center service areas. These boundaries conform to CB boundaries, and customer locations contained within all of the CBs associated with a WC are then assumed to be served by that WC. Telephone number information (NPA-NXX) continues to be used for backup and data scrubbing purposes when anomalies arise in the BLR geographical assignment process – as can occur if one wire center's boundaries fall completely within another wire center's boundaries.

5.4. Customer Location

The customer location approach used in HM 5.0a is fundamentally different from that of HM 4.0 – or any other approach that uses arbitrary geographic delineators such as CBs, CBGs or latitude and longitude grid cells. Because HM 5.0a's approach identifies the actual locations (accurate to within 50 feet) of most telephone customers, it produces the

[27] To the extent that the D&B database contains firms that are not locatable to the CB-level, these firms are assumed to be distributed across CBs in proportion to located firms within D&B. Their line counts are calculated based on the company characteristics (e.g., employees, SIC) that they report to D&B.

[28] Again, if comprehensive LEC data on business line counts by individual wire center are available, normalization can be done at the individual wire center level.

most sophisticated demographic data set of its type. The process first develops a database of about 109 million customer address records. These addresses are then geocoded (assigned latitude and longitude coordinates). These locations are then divided among wire center serving areas based on geocoded customer location and the BLR wire center boundaries.

5.4.1. Residence Location Data

Data for residence locations are provided by Metromail, Inc. The Metromail National Consumer Database© ("NCDB") is a large, nationally compiled file of U.S. household-level consumer information that includes both deliverable postal addresses (and telephone numbers, when available). The file consists of close to 100 million records – which constitute over 90% of all residential housing locations that the U.S. Bureau of the Census reported for 1995.[29]

To ensure that the data captured are the most current available, this file is updated 65 times per year, and undergoes numerous "hygiene" measures to ensure its continued high quality for direct marketing purposes. Such purposes require the data to reflect postal address standardization practices, incorporate National Change of Address ("NCOA") processing, and permit postal geocoding to street address, ZIP+4 or Carrier Route levels.

The file is compiled primarily from telephone white pages directory data, but also utilizes many other primary sources of information, such as household mover records, voter registration data, motor vehicle registration information, mail-order respondent records, realty data, and home sales and mortgage transaction information, to build a large repository of verified household-level data.

5.4.2. Business Location Data

Dun & Bradstreet collects information on more than 11 million business establishments nationwide. Information is gathered from numerous sources such as business principals, public records, industry trade tapes, associations, directories, government records, news sources, trade organizations, and financial institutions. This information is validated each night. Additionally, D&B conducts millions of annual management interviews to help improve the timeliness and accuracy of its information.

The information is organized by D-U-N-S number, a nine digit identification sequence which allows for the placement of companies within larger business entities according to corporate structures and financial relationships. A D&B family tree may be used to relate separate operating companies to each other, and to their ultimate parent company. D&B also provides "demographic" information on each of the firms in its database. Such information includes counts of employees and the SIC code of the establishment.

[29] This number is also very close to the 101 million households that the FCC finds in 1996, and exceeds the 95 million households that the FCC reports had telephones in that year. See, *Trends in Telephone Service*, FCC Common Carrier Bureau, Industry Analysis Division, March 1997, Table 1.

5.4.3. Geocoding

Geocoding is used in order to most accurately assign known customer locations to actual, physical locations. Geocoding is also known as location coding. It involves the assignment of latitude and longitude coordinates to actual street addresses. Geocoding software is sophisticated enough to provide information regarding the source and precision of the lat/long coordinates selected. This precision indicator allows PNR to select only those addresses that have been geocoded to a highly precise point location. Geocoding also allows customer location points to be assigned less granularly to the CBG level, or higher. Almost uniformly, geographical address locations are derived from enhanced versions of the USGS' TIGER database.

To perform its geocoding, PNR uses a program by Qualitative Marketing Software called Centrus™ Desktop. The enhanced data behind Centrus is provided by GDT. Premium GDT data are updated bi-monthly to ensure accuracy. These data integrate new information from US Postal Service ("USPS") databases and private sources so that new streets and additions and changes to ZIP codes, street names, and address ranges are included as soon as possible.

Centrus™ Desktop allows geocoding on two levels. The first is a match to the actual address -- which is the only type of geocoding used in HM 5.0a customer location. The second is a match to a ZIP code (ZIP, ZIP+4, ZIP+2) level. Because of the lesser accuracy in the second method, these geocodes are not used in PNR's process of assigning customer locations.

Within the geocode process, there are a number of options available to the user. Each of these options determine the quality of the matches allowed in the end-use geocode. For purposes of customer location, addresses are always matched to the "Close" setting. "Close" allows for minor misspellings in addition to incorrect or missing directionals (North, East, etc.) or street types (street, road, etc.). Although ZIP-based geocodes are generally accurate enough for most applications, they are not considered good enough for actual customer locations and are not used to develop and locate customer clusters in HM 5.0a.

Data hierarchy in address geocoding starts with the State. The hierarchy continues with City, Street Name, Street Block, and finally, House Range. Typically, a Street Block is the same as an actual physical block but it can also represent a partial block as well. The House Range displays address information from the USPS. Additionally, where there are gaps in the actual address range, the House range will account for these gaps.

Initially, the address coding module in Centrus™ Desktop compares the street addresses from the input file to the records contained in the USPS ZIP+4 directory and the enhanced street network files. If the address is located in the USPS files, the address is standardized and a ZIP+4 is also returned. If this address is also found in the street network files, Centrus™ Desktop determines a latitude and longitude for the location.

Optionally, if the address is not found in the street network files, location information may be applied from the ZIP level.[30]

Location codes generated by Centrus™ Desktop indicate the accuracy of the geocode. For purposes of customer location clustering in the HM 5.0a only those geocodes assigned at the 6-decimal place point location made directly to the street segment are used.[31]

While the software and data used allow for a much more comprehensive output of data elements, for use in HM 5.0a customer location, the following addressing elements are extracted:

Address
City
State
ZIP
ZIP+4
Latitude
Longitude
Census Block
Match Code
Location Code

5.4.4. Gross-up

The above-derived precisely geocoded locations are then counted by CB. These geocoded location counts by CB are then compared to target total line counts for that CB derived by the PNR NALM (as described in section 2.3, above). If the geocoded location counts are less than the target count, the residual number of customer location points is then computed, and geographical locations for these points are generated. This process is performed by PNR using TIGER file CB boundaries. Each of the additional number of customer location points that a CB requires to total to its target count is generated and assigned a geocode so as to place these "surrogate" points uniformly along the CB's boundary. While these boundary-assumed locations for the gross-up or surrogate points are plausible – because most CBs are bounded by roads – this is also a conservative placement of the gross-up points because it assumes they are maximally separated from one another.

[30] Note that ZIP+4 codes may be very precise. In general, they are specific to the face of single city block. While it may turn out that accuracy to the street block face is quite sufficient for accurate cost modeling of local telephone networks, in the interest of conservatism, these type of geocodes are not presently used in HM 5.0a data.

[31] Furthermore, placement of the address along the street segment is quite precise. The Centrus geocoding software and reference data also make use of USPS determinations of whether the segment contains a continuous or discontinuous range of address numbers. Thus, if the addresses on a block face run from 200 to 250 and 274 to 298 (with the range between 252 and 272 missing), an address of 250 will be geocoded, it will not simple be geocoded as at midblock.

As a result of this gross up process, the customer location file now contains records for each of the U.S.'s more than 100 million customer locations with a geocode (either calculated precisely or through the gross up process) associated with it.

5.5. Customer Location Clustering

5.5.1. General Criteria

The input development process next identifies all customer locations within a wire center's boundaries that are close enough together to be efficiently engineered as a single telephone plant serving area. This process is called clustering. While there are many available off-the-shelf clustering algorithms, efficient determination clusters of customer locations that are consistent with telephone engineering practices requires that certain engineering restrictions be imposed during the clustering process, and not afterward. Customer locations must meet the following criteria to be considered members of a particular cluster.

- No point in a cluster may be more than 18,000 feet distant (based on right angle routing) from the cluster's centroid.
- No cluster of nondegenerate area may exceed 1800 lines in size.[32]
- No point in a cluster may be farther than two miles from its nearest neighbor in the cluster.

Note that other than for the wire center boundary restriction, these criteria do not include any arbitrary geographic restrictions, such as clusters being restricted to lie within a single CBG, CB, or latitude/longitude grid cell. Thus, clusters developed pursuant to this process are likely to be the most closely representative of actual telephone distribution areas as determined by outside plant engineers. Note, however, that the last of these restrictions – no point in a cluster may be farther than 2 miles from its nearest neighbor – is not an absolute engineering limitation. It is used to ensure that customer locations that are separated by the given distance are not required to be clustered together. It is possible that efficient engineering of telephone distribution plant would suggest that a different, possibly larger value be chosen.[33]

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[32] This restriction is based on the maximum unconcentrated lines capacity of an OC-3 fiber optic transmission system used to feed a DLC remote terminal (adjusted for a 90% rate of fill). This is consistent with current HM 5.0a practice that provides a separate channel for each line served by a DLC system. Because it is reasonable engineering practice to concentrate traffic on these large fiber optic DLC systems, future versions of the model may assume that traffic is concentrated on the fiber optic systems feeding DLC remote terminals. When such revisions to the HM become available, the customer location data will be reclustered with the appropriately enlarged maximum limit on cluster size. In all events, if single customer locations, such as a large office or apartment building, by themselves exceed 1800 lines, such clusters are not split. Rather, multiple DLC RTs/SAIs will be placed to serve such "oversized" clusters.

[33] Testing of different parameterizations for the maximum distance to a cluster point's nearest neighbor suggests that 2 miles is a reasonable national value.

5.5.2. Clustering Algorithm

The process used by the PNR clustering algorithm is as follows.

a) First, to provide a uniform geographic unit for clustering operations, all customer location geocodes associated with a particular wire center are “rasterized” into 150 foot cells that overlay the geographic rectangle covering the wire center’s service area.[34]

b) The algorithm then inspects all neighboring cells (e.g., all cells that have their center within a 150 foot radius of the center of the initial cell) to see if any are populated with customer locations. If one of these neighboring raster cells is populated, the algorithm first checks to see whether clustering that cell (and its immediately surrounding neighbors) with the initial cell would violate any of the clustering restrictions (i.e., create a cluster that has points more than 18,000 feet from the cluster centroid, create a cluster of more than 1800 lines, or include a point more than 2 miles from its nearest neighbor).[35] If none of these conditions would be violated, the adjoining cell plus its immediate neighbors will be added to the initial cell’s cluster

c) This process continues on to the next unclustered populated cell and performs the analysis described in step (b), above. This repeats until no more unclustered cells exist.

d) The process then restarts at step (b), but uses a 300 foot search for populated neighboring cells.

e) This continual enlargement of the search for neighboring populated cells continues on until no more cells can be added to the cluster without violating one or more of the engineering requirements. At this point, the algorithm is complete.

Clusters that contain five or more customer locations are classified as “main” clusters. Clusters that contain from one to four customer locations are called “outlier” clusters. Outlier clusters may be linked to their “home” main cluster via “chains” that string together other outlier clusters that home on the same main cluster. The process of determining the routing of the chain is as follows.

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[34] Rasterization at this level is a process whereby all customer locations that are within the 150 foot square cell are counted as being placed at the center of the cell. Rasterization to 150 foot square cells ensures that the mathematical clustering process can proceed efficiently, and that nonmeaningful distinctions in customer location are ignored. Increasing the raster to 300 or 500 feet would speed up the clustering process dramatically, and still provide a very acceptable level of precision in cluster formation. Note, too, that the PNR calculation of 150 foot raster cells is precise – based on the local latitude of the cell. Thus, raster cells do not enlarge as one moves south toward the equator.

[35] Because the rasterization into 150 foot square cells may cause customer locations that actually are in the farthest corner of a cell to be considered at the cell’s center, the clustering algorithm will actually check to ensure that no cells added to a cluster exceed 17,700 (= 18,000 - 2∗150) feet from the cluster’s centroid.

a) The clustering algorithm first calculates the distance between each cluster and every other cluster in the wire center service area.

b) The algorithm then determines the shortest distance between any two clusters, and associates these two clusters together.

c) Next, the algorithm determines the next shortest distance between any two clusters or cluster chains, and associates these together.

d) This process continues until all outliers are chained to a main cluster.

In addition to creating chains to associate outlier clusters to a main cluster; the clustering algorithm calculates the centroid location, “aspect ratio” and area of the rectangle that overlays the convex hull of each cluster; and that has the same centroid location, aspect ratio and area as this convex hull.[36]

When this process is completed, the main cluster and its subtending outliers are considered to constitute one serving area.

The description the HM 5.0a Distribution Module in Section 6.3 provides greater detail on the model’s engineering of outside plant to serve main and outlier clusters.

5.6. PointCode Translation Processes

PointCode is a Microsoft Access ‘97 database process that translates between coordinate systems, computes distances and assigns additional characteristics to cluster records. Among the activities executed by PointCode are the following.

Convert the latitude and longitude coordinates provided by PNR for cluster centroids to V&H coordinates. Ensure that modeled distribution rectangles have an aspect ratio and area that reflects a minimum dimension equal to twice the default drop length for that lines density range. Calculate radial distances between main clusters and their serving wire center. Calculate radial distances between outlier clusters and main clusters.

Compute omega angles between main feeders and the clusters they serve and compute alpha angles between clusters and their subfeeders. Calculate rectilinear (right angle) distances between main clusters and their serving wire center, and between outlier clusters and main clusters.

On the basis of the characteristics of the covering CBG, assign terrain and lines density zone characteristics to the cluster.

[36] The convex hull of the cluster is the convex polygon that has as its boundary the outermost points of the cluster – as such, it covers all of the points in the cluster. The aspect ratio is the ratio of the North-South length to the East-West length of the convex hull of the cluster.

6. Module Descriptions

6.1. Input Data Files

6.1.1. Demographic and Geological Parameters

Demographic and geological parameters are obtained from a database developed by PNR and Associates of Jenkintown, PA. Section 5, above, explains in detail how these data are developed. The data file resulting from these processes is organized by state and telephone company (study area). Each customer location cluster (both main and outlier) identified in the wire center service areas of the LEC modeled appears as a separate record in this Microsoft Access 97 database. Each of these cluster records contains the following information:

- Identity of the LEC and wire center serving the cluster;
- Locational information about the cluster relative to its wire center, the predominant CBG in which it falls, its nearest neighboring cluster and associated distances;
- Area and dimensional measurements of the cluster and its lines density;
- Terrain and geological parameters;
- Number of telephone lines by type;
- Number of households and number and type of housing units;
- Number of business firms and employees;
- Information about the fraction of a wire center’s total lines are represented by this cluster, the average loop distribution distance of its subtending outlier clusters and total number of outlier lines.

The complete list of data fields in the Cluster Input data table is as follows:

Cluster Input Data Table		
State	Total Area	1-HU detach
CLLI	Aspect Ratio	1-HU attach
Company	Company State	HU-2
Neca_ID	Density Lines/SQ Mile	HU-4
Group	Rock Depth	HU-5-9
CBG	Rock Hard	HU-10-19
Cluster Group	Surf Text	HU-20-49
Overall Quad	Water Depth	HU-50+
Overall Omega	Total Lines	Mobile
Overall Alpha	Total Bus Lines	Other
Radial Dist Feet	Total Res Lines	Firms
Cluster or Outlier Check	Special Lines	Employees
Outlier Quad	Public Lines	FracWCLine
Outlier Omega	Single Line Business	AvgLoopDist
Outlier Alpha	Households	TotOutLine
Outlier Radial Distance		

6.1.2. Wire Center Locations and Interoffice Distances

Calculations to determine total route-miles of interoffice facilities require as inputs several distance measures. These include the distances between each LEC EO and the tandem switch that is assumed to serve it, the distance between the EO and the STP pair that serves it, distances between STPs, distances between tandem offices, and the V&H (vertical and horizontal) coordinates of each switching entity. These data are calculated from a database licensed from Bellcore, referred to as the Special LERG Extract Data ("SLED") file which contains information from the Local Exchange Routing Guide ("LERG"). The SLED includes the V&H coordinates of each switching entity, and the nature of the entity, e.g., end office, tandem, STP, multiple use, etc. Appendix D provides an outline of the process used to develop these distance measures.

6.1.3. ARMIS Data

These data are obtained from the 1996 ARMIS 43-08 Operating Data Reports. ARMIS data are submitted to the FCC annually by all Tier 1 LECs.[37] The following elements of these data are extracted.

[37] 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. This includes over 50 carriers.

- The number of residential access lines, including all residential switched access lines, including those with flat rate (1FR) and measured rate (1MR) service.

- The number of business access lines, including analog single business lines, analog multi-line business lines and digital business lines; these totals include flat rate business (1FB) and measured rate business (1MB) single lines, PBX trunks, Centrex lines, hotel/motel, long distance trunks and multi-line semi-public lines.[38]

- Analog and digital special access lines, including dedicated lines connecting end users' premises to an IXC POP, but do not include intraLATA private lines.

- Public access lines, which include lines associated with coin (public and semi-public) phones, but exclude customer owned pay telephone lines.[39]

For companies that do not report ARMIS, HM 5.0a makes use of data reported in various sources listed earlier in Section 5.1.

6.1.4. User Inputs

This category comprises over 1400 user-definable values. These range from the price of network components, to the percentage of joint-use end offices and tandem offices to capital structure. HAI has supplied default values for each of these variables based on its collective judgment, as augmented by subject matter experts in various areas of network technology, operations and economics. Users can vary these default parameters to reflect unusual local conditions. Appendix B contains a complete description of these variables, along with the default values that have been assigned to them.

6.2. Outside Plant Engineering

The Distribution and Feeder Modules are the main modules controlling the engineering of outside plant. While Sections 6.3 and 6.4 below discuss the unique aspects of each of these modules, this section describes several features and assumptions common to both modules.

Figure 5 shows the basic outside plant serving configuration used by HM 5.0a.

[38] *Id.* at 1-2.

[39] *Id.* at 2.

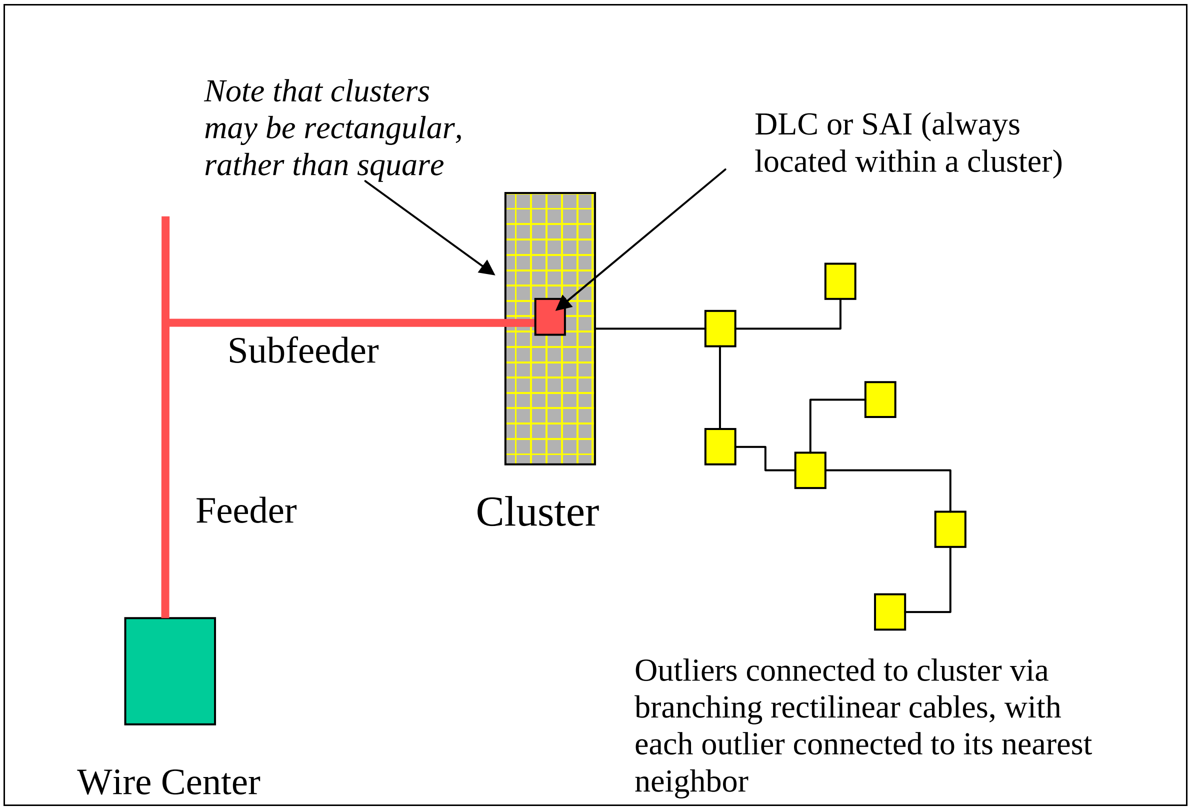

Figure 5 Loop Outside Plant Configuration

The Model assumes a main cluster and its subtending outlier clusters constitute a serving area. Main feeder cable (that may be shared with other main clusters) and subfeeder cable extend from the wire center to the centroid of the main cluster. If the main and subfeeder cable are copper, the subfeeder cable terminates in an SAI. If the feeder and subfeeder are fiber, the subfeeder either terminates at a single DLC RT and adjacent SAI located at the centroid of the main cluster, or extends via fiber "connecting cables" from the centroid to two or more DLC RTs and adjacent SAIs located within the cluster so as to ensure no copper distribution cable length exceeds the user-adjustable maximum analog copper distance. The choice between copper and fiber main feeder and subfeeder is made according to the criteria discussed in Section 6.3.5, below. In all cases, analog copper distribution cables extend from the SAI(s) to their subtending customer locations within the main cluster in a backbone and branch fashion. The data process used to locate customers and identify population clusters also determines the "aspect ratio" of the overlying rectangle that defines the boundary of a main cluster, and is used in determining the location of the fiber DLC RTs and layout of the backbone and branch distribution arrangement.

From the centroid of a main cluster, copper cables extend to each outlier cluster that is served from that main cluster, with each outlier cluster connected to its nearest neighbor (either the main cluster or another outlier cluster), via a right-angle route. These copper cables terminate either at an SAI or T1 remote terminal at the centroid of the outlier cluster – depending on whether the distance the signal needs to be carried falls short of, or exceeds, a user-adjustable 18,000 foot threshold. Subscribers in outlier clusters are assumed to be located on routes within the outlier cluster that may be distinct from the route traveled by the cable feeding the outlier's SAI or T1 remote terminal from the main cluster. Because of this, a separate analog copper distribution cable is run from the centroid of the outlier to individual customer locations. The model does, however, assume a moderate amount of structure sharing between these two cables within the outlier cluster because of the partial coincidence of their routes.

6.2.1. Outside Plant Structures

Outside plant structure refers to the set of facilities that support, house, guide, or otherwise protect distribution and feeder cable. There are three types of structure: aerial, buried and underground.

1) *Aerial Structure*

Aerial structure typically consists of poles.[40] Pole investment is a function of the material and labor costs of placing a pole. A user-adjustable input allows the customization of the labor component of pole investment to local conditions. HM 5.0a computes the total investment in aerial distribution and feeder structure within a CBG by evaluating relevant parameters, including the distance between poles, the investment in the pole itself, the total cable sheath mileage, and the fraction of aerial structure along the route.

The model assumes forty-foot Class 4 poles. The spacing between poles for aerial cable is fixed within a given density range but may vary between density ranges. The number of poles on a given route is calculated as:

1 + (route distance/pole spacing), rounded up.

2) *Buried Structure*

Buried structure consists of trenches and related protection against water and other intrusions. The additional cost for protective sheathing and waterproof filling of buried cable is a fixed amount per foot in the case of fiber cable and is a multiplier of cable cost in the case of copper cable.[41] The total investment in buried structure is a function of total route mileage, the fraction of buried structure, investment in protective sheathing and filling, and the density-range-specific cost of trenching.

[40] In the two highest density zones, most aerial structure is assumed to be intrabuilding riser cable and "block cable" attached to buildings.

[41] The default values for sheathing are $0.20 per foot for fiber, and a multiplier of 1.04 for copper. The different treatment reflects the fact that the outside diameter of fiber cable is essentially constant for different strand numbers, while copper cable diameter increases with the number of pairs it contains.

3) *Underground Structure*

Underground structure consists of conduit and, for feeder plant, manholes and pullboxes. Manholes are used in conjunction with copper cable routes; pullboxes are used on routes that are served exclusively by fiber cable. The total investment in a manhole varies by density zone and includes materials, frame and cover, excavation, backfill, and site delivery. Investment in fiber pullboxes is a function of materials and labor. Underground cables are housed in conduit facilities that extend between manholes or pullboxes. The total investment in underground structure is a function of total route mileage, the fraction of underground structure, investment in conduit manholes, and pullboxes, and the cost of trenching needed to hold the conduit.

In each line density range, there may be a mixture of aerial, buried and underground structure. For example, in downtown urban areas, it is frequently necessary to install cable in underground conduit systems, while rural areas may consist almost exclusively of aerial or direct-buried plant. Suburban areas may have a more balanced mixture of all three structure types. Also, as described more completely in Section 6.2.5, below, the HM 5.0a permits certain amounts of substitution between buried and aerial structure based on abnormal local cost conditions.

Users can adjust the mix of aerial, underground and buried cable assumed within the model. These settings may be specified by density zone for fiber feeder, copper feeder, and copper distribution cables. Appendix B includes detailed lists of the HAI Model structure default values for aerial, buried and underground plant.

6.2.2. Terrain and Its Impact on Placement Costs

HM 5.0a incorporates the effects of geological factors on required structure investment. Terrain factors considered by the model include bedrock depth, rock hardness, surface soil type, and water depth. Each serving area is assumed to have the terrain characteristics of the CBG in which it predominately falls.[42]

If the rock depth in a serving area is less than a user-definable rock depth threshold, a rocky placement multiplier increases structure investment in poles, conduit placement, and trenching, because it is more difficult to bury cable in rock than in soil. [43] If bedrock

[42] Main clusters and their subtending subclusters are not restricted to fall entirely within a single CBG. Such a restriction would impose an artificial limitation on the “natural” serving areas being identified by the Model. As a result, the predominant CBG must be used to determine the terrain characteristics. If appropriately digitally-encoded terrain data become available, a more precise determination of the terrain characteristics of serving areas crossing several CBGs could be made.

[43] The HAI Model default maximum values for geological factors are as follows: rock depth threshold causing increased trenching cost, 24 inches; hard rock placement multiplier, 3.5; and soft rock placement multiplier, 2.0.

does not exist within the placement depth, then the surface soil texture is examined to determine if soil can be plowed, or if more expensive placement techniques must be used. The model causes the rock placement multiplier to vary with rock depth; the entire multiplier applies if the rock depth is zero, and the value tapers linearly to unity at the user-defined placement depth.

Certain kinds of surface textures may increase the cost of structure. When these are encountered, the model extracts a multiplier from a lookup table in the distribution module inputs worksheet, and applies it to the structure investment as determined by the density zone. If both difficult soil conditions and rocky conditions are encountered, the model will multiply the structure investment by the sum of the rock placement and surface texture multipliers minus one.[44]

Water table depth does not have a significant effect on trenching costs, but may affect the cost of placing manholes. The model increases manhole placement costs by a user-adjustable amount (default value of 20%) of the nominal placement cost whenever the water table depth is less than a user-adjustable minimum depth whose default value is five feet.

Labor costs for placement may be adjusted for regional variation by the application of a user-entered labor adjustment factor.

6.2.3. Structure Sharing

Outside plant structures are generally shared by LECs, CATV operators, electric utilities, and others including competitive access providers ("CAPs") and IXCs. To the extent that several utilities may place cables in common trenches, or on common poles, it is appropriate to share the costs of these structure items among these users. Furthermore, manholes may be shared by all low voltage utilities as well. The HAI model assumes sharing of structure costs among the various utilities that occupy the structure. Although assumptions concerning the degree of sharing are user-adjustable; the default values used in the HAI Model reflect best forward-looking, economic practices for the various utilities involved.

6.2.4. Lines Density Considerations

A number of parameters, such as the fill factors for distribution and feeder copper cable and the mixture of underground, buried, and aerial plant, are dependent on line density of the serving area. The line density is defined as the total number of subscriber access lines per square mile. While entire serving areas are associated with a given density zone for purposes of accumulating density zone results, HM 5.0a makes a separate density zone determination for the main cluster and the outlier clusters, based on the CBG to which each belongs, when it is selecting which density-zone-dependent factors to use in a

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[44] Section 6.2.5, below, indicates how the Model automatically will adjust the fractions of buried and aerial structure to reflect economic choices based on abnormal local cost conditions for these structure types.

calculation. In HM 5.0a, as in HM 4.0, line density is broken down into nine different density ranges.

Density Ranges (lines/sq. mile)
0 - 5
5 - 100
100 - 200
200 - 650
650 - 850
850 - 2550
2550 - 5000
5000 – 10,000
10,000 +

6.2.5. Economic Adjustment of Structure Fractions

The HM 5.0a Distribution and Feeder modules automatically adjust buried and aerial structure fractions to account for the plant placement costs occasioned by local soil and bedrock conditions. The user specifies nominal buried and aerial fractions, along with an “at risk” portion of the buried cable fraction that unfavorable cost conditions can cause to be shifted to aerial. The model calculates the local relative costs of buried and aerial structure -- including both the additional placement costs arising from local terrain conditions as well as the life-cycle maintenance and capital carrying costs of the different structure types.[45] This local relative life-cycle cost of buried versus aerial structure is then ratioed to the national norm for relative buried to aerial life-cycle cost. The model then adjusts the aerial fraction up or down (and buried fraction in inverse fashion) from its national default value by up to the full amount of “at risk” structure, depending on the degree of difference in local versus national norm life-cycle costs.

A logistic curve is used to specify the sensitivity of structure choice to differences in relative cost. The “s-curve” shape of the logistic function suggests that initial divergences of local relative structure costs from “normal” relative structure costs cause

[45] This calculation of the relative life-cycle costs of plant placed on various different structures is computed as follows. First, per-foot materials’ investment costs are calculated, and added to the per-foot investment cost of the particular structure type – adjusted for the assumed amounts of inter-utility structure sharing that apply to the particular structure type. Second, annual charge factors are developed for capital carrying costs and maintenance costs. These factors are developed within the “LCFactors” and “CCCFactor” sheets of the Distribution Module using the same methodologies described in Sections 6.6.2 (for capital carrying costs) and 6.6.3.1 (for network maintenance costs) documenting the HM 5.0 Expense Modules. Finally, the plant net investment cost is multiplied by the sum of the annual capital carrying cost and maintenance cost factors, to yield the relevant annual life-cycle per-foot cost of the particular type of plant.

more structure to be shifted across types than do further increases in this divergence. The user-adjustable default fraction of buried structure that is "at risk" to be converted to aerial structure based on adverse local life-cycle costs is 75 percent.

6.3. Distribution Module

6.3.1. Treatment of Main Clusters

HM 5.0a lays distribution plant directly over the rectangular areas where customer clusters are located. This plant extends from the SAI location (or locations) to the customer premises in the cluster. The basic distribution configuration employed by HM 5.0a for the main clusters is a "grid" topology, in which tapering backbone cables run north and south from the SAI(s), while branch cables extend east and west from the backbone cables past the individual subscriber locations.[46] The backbone cables terminate one lot depth inside the north and south boundaries of the rectangle. The branch cables run to within one lot width of the east and west sides of the rectangle.

The Module performs a test to ensure that the longest combined backbone and distribution cable run does not exceed a user-adjustable maximum copper distance whose default value is 18,000 feet. If the maximum distance would otherwise be exceeded, the model will extend fiber subfeeder "connecting cables" from the centroid of the cluster to two or more DLC RTs (and adjacent SAIs) positioned to ensure the maximum distance is not exceeded. The number of RT/SAI locations is determined by separately checking that the backbone and branch cable lengths do not exceed a fraction of the maximum distance calculated from the aspect ratio of the cluster shape, and splitting the cluster area in either or both dimensions to create the necessary two or more subareas.

Main clusters with total areas less than 0.03 square miles and line densities greater than 30,000 lines per square mile are identified as consisting of high-rise buildings, and accorded special treatment appropriate for high rises.

This high-rise test identifies cases in which a serving area is very small, but its line density is so high as to be incompatible with any explanation other than vertical "stacking" of the customer locations. In such cases, the model assumes the distribution cable required to serve the main cluster consists of riser cable inside the high rise building, and that the SAI required for service is located in the basement of such a building. The number of floors in the high rise buildings is estimated by dividing the occupied building space by the area of the main cluster, reduced to account for streets and sidewalks.[47] The occupied building space in square feet is calculated as follows:

[46] The coordinate system used in the HM 5.0a to denote "north," "south," "east" and "west" is the Vertical and Horizontal (V & H) system that is standard in the telephone industry. These coordinates are internally consistent, but differ slightly from "true" north, south, east or west.

[47] The reduction in main cluster area for urban streets and sidewalks, expressed as a fraction; is user-adjustable with a default value of 0.2.

occupied space = 1,500 * # households + 200 * # employees.

For “regular” serving areas that do not meet the high-rise test, the model computes the plot size per customer location by dividing the effective area of the main cluster by the number of customer locations in the main cluster, as stated above. The model assumes that each customer plot is twice as deep as its frontage.

However, a refinement to this calculation is required to account for the fact that many households occupy dwelling units that cannot be characterized as single family detached homes. Likewise, structures occupied by business establishments may range from small single-tenant stores on small lots to large, multi-floor buildings (high-rise buildings are treated separately). A residence and a business methodology are adopted to represent more realistically the actual situations that may occur.

For residences, the Census database supplied by PNR identifies the number of households located in various types of buildings. HM 5.0a assumes that the space occupied by residences other than single-family detached units is half that of detached homes, and accordingly reduces the number of customer locations in calculating the effective plot size of detached homes. This reduction represents more adequately the space (including the actual living quarters, shared facilities, parking lots, and other area around buildings) that households in multi-dwelling units occupy relative to a detached single-family home. The reduction in effective customer locations is made before calculating the lot size in the manner described above. The intent is to calculate the effective lot size that detached homes would have in the main cluster, and lay out the distribution cables accordingly. The model assumes the grid pattern of cables continues throughout the areas where multi-tenant units are located; thus, there is no additional efficiency associated with serving such premises.

The assumed reduction in effective households is conservative because the model assumes multi-tenant units displace one-half of a regular-sized lot. Thus, the model will consequently underestimate the effective lot size of detached homes because it is counting too high a number of equivalent customer locations. This underestimate of effective lot size causes more lots to be assumed, and more distribution plant to be placed, than actually is necessary to serve this area.

6.3.2. Treatment of Outlier Clusters

Outlier clusters, each consisting of one or more customer locations, are served in HM 5.0a by the nearest main cluster. A main cluster and its subtending outlier clusters together constitute a serving area.

Outliers are connected to the main cluster by copper road cables extending from the centroid of the main cluster to the centroid of the outlier. A given outlier may be directly connected to the main cluster, in which case it is labeled a “first order” outlier, or it may be connected to another outlier which in turn is connected directly to the main cluster or another outlier. Such connections are depicted in Figure 5. Outliers that are not directly connected to the main cluster are considered to be “higher order” outliers.

Fiber feeder is extended to any main cluster that has at least one outlier cluster. The road cables to the first order outliers extend from the point at which the fiber feeder terminates in the main cluster. If the right-angle route distance from the main cluster to the farthest customer location in a first order outlier is less than a user-adjustable distance parameter whose default value is 18,000 feet, the road cable carries an ordinary analog voice signal, and is called “subscriber road cable.” If the farthest customer in an outlier is more than the default distance from the main cluster, or the outlier is a higher order outlier, the cable carries a digital T1 format signal to a remote T1 terminal at the centroid of the outlier, and is served by “T1 road cable.” From the T1 RT, copper cables carrying analog signals extend the remainder of the way to the customer locations within the outlier.

A T1 road cable contains copper pairs, and supports T1 signals used to provide digital connections between the fiber DLC remote terminals located at the centroid of the main cluster and subsidiary remote T1 terminals located at the centroid of each outlier cluster. The model assumes conventional T1 transmission with a user-adjustable 32 dB repeater spacing.

In HM 5.0a the cables serving subscribers from the remote terminals are assumed to be different than those that carry the T1 signals to the remote terminals. The total investment calculated for the T1 system includes the cost of the T1 interfaces in the main cluster’s DLC remote terminal.

6.3.3. Customer Drop Arrangement

No matter whether a customer is located in a main cluster or outlier cluster, the distribution arrangement at the customer’s premises is similar. At a point close to the customer's location, a splice and block terminal are installed to connect a drop cable containing several wire pairs from the distribution cable to an aerial or buried drop to the NID located on the wall of the premises.

6.3.4. Investment Cap to Reflect Potential Wireless Technologies

As requested in the FCC’s FNPRM, the HM 5.0a permits the specification of a user-adjustable cap on the model’s relevant wireline investments to reflect potentially more economical wireless distribution technologies.[48] In the HM 5.0a this cap, if invoked by the user, is implemented by placing a ceiling on the per-line investments computed in the Distribution module (i.e., NID, drop, terminal and splice, distribution cable and structure, SAI, and DLC RT) that would be replaced by the wireless system.[49]

[48] It is unclear whether such systems exist, whether their costs can be modeled accurately across all demographic and terrain situations, and whether these systems can meet the FCC’s criteria for supported universal service.

[49] It is assumed that the cost of the remote terminal electronics for the fiber feeder facilities serving the wireless radio sites would be included in the wireless system cost.

The optional cap calculation considers the cost of two different wireless systems: a "point-point" system serving customers on a one-one basis, and a "broadcast" system serving a number of customers from a shared base station. The point-point cost is assumed to be a fixed amount per line served; the broadcast system cost is structured as a fixed base station cost serving up to a given maximum number of customers, with the cost of the base station distributed among the number of customers that use it, plus a per-line cost of the radio terminal equipment at each customers' premises. Generally, the broadcast system is more expensive than the point-point system for a few lines in a serving area, but less expensive if the system is loaded to a substantial portion of its maximum capacity. The Model compares the cost of the two wireless systems to each other for a given serving area, then compares the cost of the lower-cost system to the wireline cost. If the most economical wireless system's cost is lower, the Model zeroes out the cost of the wireline distribution components for that serving area, and substitutes the cost of the wireless distribution system, while retaining the feeder portion of the wireline network.

6.3.5. Determination of Feeder Technology

Because it must calculate all of the outside plant distances, to determine the kind of road cable required, the Distribution Module also determines whether copper or fiber feeder and subfeeder are utilized for a given serving area. If fiber feeder and subfeeder are used, these extend from the wire center to the main cluster centroid. The subfeeder terminates at one or more DLC RTs and adjacent SAIs -- located to ensure that the remaining distribution cable lengths do not exceed the user-adjustable maximum analog copper length. In all cases, copper distribution cable is used to link SAIs to customer premises. The decision whether to use fiber feeder depends on whether any of the following conditions are met.

a) The total feeder and subfeeder distance from the wire center to the main cluster centroid is greater than the user-adjustable Copper Feeder Max Distance value, whose default is 9,000 ft.

b) A life-cycle cost analysis of fiber versus copper feeder on the route shows that fiber is more economical.[50]

c) The longest distribution cable run from the wire center to the farthest corner of a main cluster is greater than a user-input maximum analog copper distance, whose default value is 18,000 ft.

d) There is at least one outlier cluster subtending the main cluster.

e) The wireless investment cap is invoked and leads to the conclusion that one of the two wireless systems is the least-cost solution for the serving area.[51].

[50] The life-cycle costs of fiber versus copper feeder are computed using the same methodology, as described earlier, to calculate the life-cycle costs of outside plant placements on different structure types.

6.3.6. "Steering" Feeder Routes

In HM 5.0a the user may elect to have the Feeder Module "steer" feeder routes toward the preponderance of main clusters within a quadrant. The model computes an angular offset from the cardinal default values of 0º, 90º, 180º or 270º by weighting each main cluster's angular offset coordinate by its radial distance from the wire center location, and then determining the weighted average angular displacement. When feeder cable is steered in this fashion, the Feeder Module also applies a route-to-airline (R/A) distance multiplier. The value of this multiplier may be specified by the user within an allowed range of R/A values. Subfeeder cables branch perpendicularly off the main feeder route toward main clusters. This branching is perpendicular both when feeder routes go in the cardinal compass point directions, as well as when the feeder is steered at an angular offset from these cardinal directions. Alternatively, the user may elect to "turn off" feeder route steering and have the Module calculate feeder distances using "right angle routing" in the four cardinal compass point directions -- as employed in HM 4.0.

6.3.7. Calculation of Distribution Investments

The model uses the customer location and cluster data, including cluster sizes and locations, number of lines, and lines density; and applies these demographic and architectural considerations to determine the total distribution distances involved. It then estimates the investment in distribution cable, supporting structures, terminals and splices, drops, NIDs, and SAIs.

In calculating these investments, the model requires a number of data elements which are provided to it through adjustable user inputs. These include cable sizing factors, the amount of structure sharing with other utilities, the relative mix of aerial, buried, and underground facilities, the unit material and installation costs of the various network components, the demographic factors identified in Section 6.1 above, and factors relating difficult terrain characteristics that may increase installation costs.

Appendix B defines each user input and the default value(s) for that input as set by the model developers. The set of inputs pertinent to the distribution calculations are inputs B1 through B45 (basic distribution and drop components), B58 through B69 (DLC components), B180 (structure sharing), and B197 through B201 (excavation and restoral activity frequency and costs), in Appendix B.

Three sets of the input parameters bear special attention. The first is the set of cable sizing factors appearing as item B18 in Appendix B. Sizing factors are intended to provide reserve capacity above and beyond the lines requirement determined by the model. If, for instance, a given cable segment must serve 75 lines and the sizing factor set by the model is 0.50, then the target cable size determined by the model is 75/0.5, or 150. However, cables are available only in discrete sizes, as shown in Item B9 in

[51] When wireless is used, it is assumed that a minimum of four fibers must be used to connect the radio sites to the wire center.

Appendix B. The model selects the cable size at or most closely above the minimum size calculated. In this example, this corresponds to a 200 pair cable. Thus, the achieved fill is 75/200, or 0.375. Generally, the average achieved distribution fill is significantly less than is indicated by the raw cable sizing factors shown in Item B18. The Model outputs display this average actually achieved fill both at the SAI and at the MDF.

Second, as discussed earlier, the HAI Model assumes that forward-looking practices of efficient telephone companies and other utilities will involve substantial structure sharing. The default levels of structure sharing assumed in HM 5.0a, stated as the percentage of total structure costs assigned to the telephone company, are shown in Item B180 of Appendix B. In HM 5.0a the amount of structure sharing depends both on the type of structure -- poles and trenching -- and the density zone. HM 5.0a assumes, conservatively, that there is no sharing of conduit in underground installations.

Finally, HM 5.0a offers an optional cap on distribution investment as discussed, above. This cap, enabled by Parameter B41, compares the total per-line wireline distribution costs for all distribution components to the cost of two types of wireless systems. One system's per-line cost is expressed by B42; the other system's cost is parameterized by a base station cost, B43, maximum customers served by a base station, B45, and per-line radio system equipment cost, B44.

6.3.8. Calculation of SAI and DLC Investments

The SAI in each serving area provides an interface between the feeder and distribution facilities. Each SAI consists of a cabinet, including suitable physical mounting, and a simple passive cross connect. In the case of fiber feeder there is an adjacent DLC remote terminal. SAI investment is determined by the number of distribution and feeder pairs required to be served. The model equips multiple SAIs if the pair requirement exceeds the maximum SAI capacity.

Urban areas normally have feeder cable running directly into the basement of large buildings, rather than interfacing at an SAI outside of the building. In such cases, the SAI, located in the building, is significantly less expensive than the outdoor SAI. This type of interface consists of a plywood backboard and inexpensive "punch-down blocks," rather than the heavy steel weatherproof outside terminals found in less urban areas. HM 5.0a thus differentiates between outdoor and indoor SAIs, the former being the normal case, and the latter being used when a serving area is identified as a high-rise building.

The Distribution Module sizes and calculates the investment in the SAIs required in each serving area based on the number of distribution and feeder pairs required to serve both the main and outlier clusters and the urban/non-urban characteristic of the serving area. The pertinent input parameter for the SAI is identified as B38 in Appendix B. It is the installed investment in an SAI, stated as a function of the number of distribution and feeder pairs served by the SAI. The model equips each serving area with one or more SAIs. The number required is determined by comparing the total "in" and "out" lines demand to 7,200, which is the maximum number of pairs that can be supported by a single SAI.

A given serving area may be served by either fiber feeder or copper feeder. When fiber feeder is used, one of two types of DLC equipment is selected. The first is designated "High Density" DLC, and is GR-303 compliant."[52] The second is designated "Low Density" DLC, and is also GR-303 compliant. The choice between these two types is determined for each serving area. If the number of lines is below a threshold value, "low density" DLC is used; above that threshold, "high density" DLC is assumed. The threshold is user-adjustable, with a default value of 480 lines.

The investment in DLC equipment, when it is used, is calculated in the Distribution Module. The parameters involved in this calculation are identified as Items B58 through B69 in Appendix B. For either type of DLC system, low density or high density, the investment is calculated based on user-adjustable amounts for site and powering (B58), for common equipment (B61), and for channel units (B62). Other inputs in the range of B59-B69 specify, for example, the number of fiber strands per RT, the maximum initial lines that can be served by the DLC, the number, size and additional common equipment requirement of additional line increments, and the capacity and cost of plug-in cards for POTS and coin service. The DLCs are equipped by the model with line cards of the type required to provide the appropriate grade of service on the analog and digital (T1) pairs fed off of the DLC – at the distances implied by the structure of the main and outlier clusters.

6.3.9. Calculation of Drop Investments

HM 5.0a computes a weighted average drop investment in each density zone on both a per-drop and per-pair basis. The model uses the detailed household type and business line information contained in the demographic database to compute the total drop investment in each serving area. The total drop investment is applied to the sum of all households in single family attached and detached dwellings, mobile homes and "other" dwelling types, all two- and four-household dwellings, and all single-line businesses. The per-pair drop investment applies to the remaining business lines, the adjusted private line total, and public lines, as well as to all households in multi-unit buildings containing five or more households.

6.4. Feeder Module

6.4.1. Overview

The Distribution Module produces as inputs to the Feeder Module the main feeder and subfeeder cable distances for each serving area. The Feeder Module uses these inputs to calculate the investment in feeder plant.

As seen earlier in Figure 1, feeder cable begins at the wire center and ends at the SAI located within each serving area. Figure 6 displays the basic main feeder and subfeeder

[52] GR-303 (which is also called "TR-303" in earlier documents that are still in common use in the industry) is a Bellcore requirements document dealing with interfacing a DLC system with an end office switch.

architecture assumed in the model.[53] A key difference between HM 5.0a, compared to HM 4.0, is that in HM 5.0a the unit of population served by a given feeder and subfeeder cable combination is the main cluster and its subtending outlier clusters, rather than a CBG. Note that since a given main cluster can be surrounded by outlier clusters and/or areas with no population, there may be gaps between the main clusters, as shown in the drawing. In areas of dense population, they are, however, likely to be contiguous.

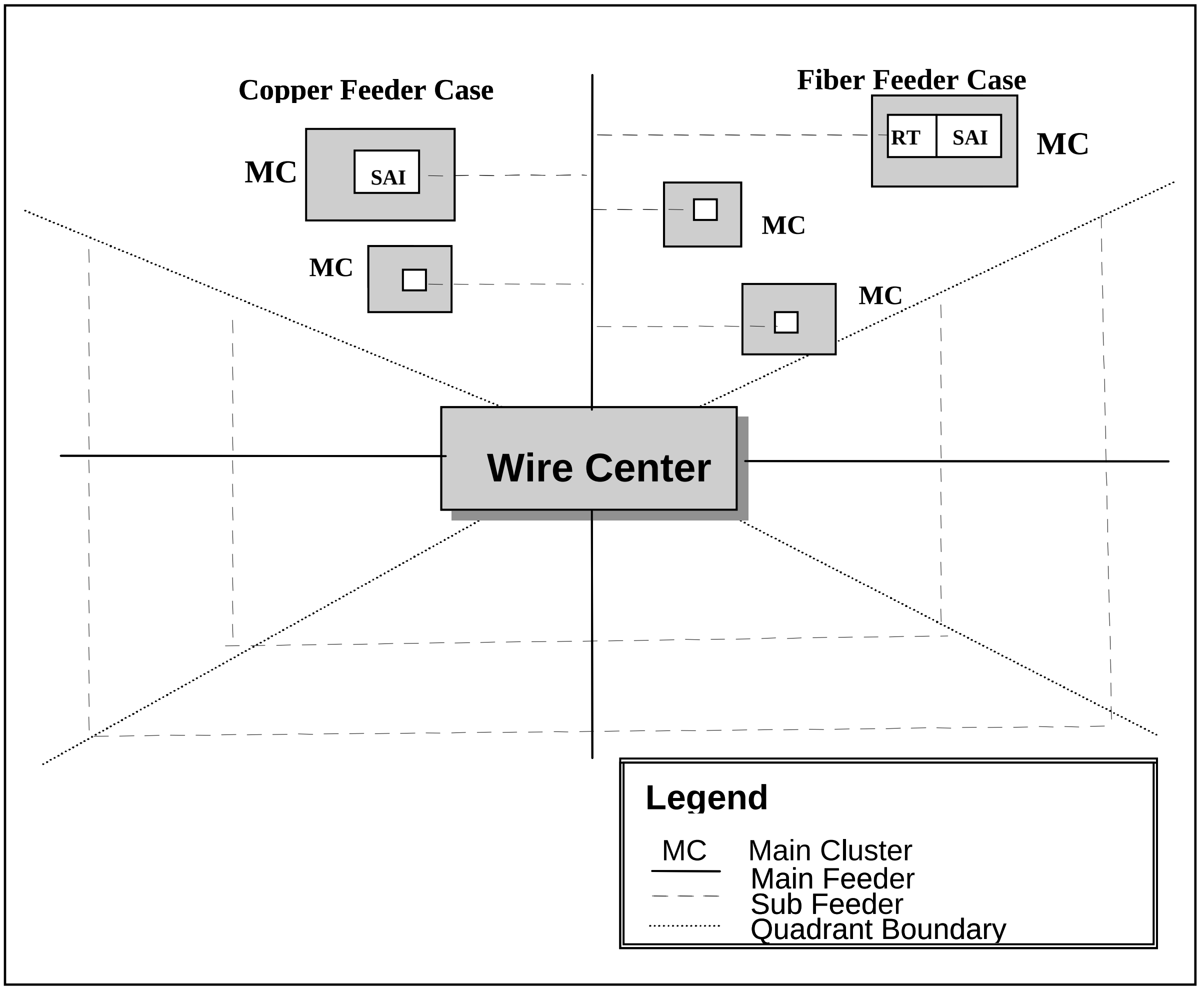

Figure 6 Feeder Architecture

As many as four main feeder routes may terminate at each wire center. Each feeder route serves one quadrant of the wire center's service area, and quadrant boundaries form

[53] As discussed previously, subfeeder may be linked at the main cluster centroid to connecting cables that run to two or more DLC RTs located at other points within the main cluster. Such connecting cables are also classified as feeder cable by the model, since telephone companies classify all cable on the wire center side of the DLC RT as feeder cable.

angles of ±45° with the main feeder routes.[54] Each main cluster is served by the main feeder route associated with the quadrant containing the centroid of the main cluster. To reach each cluster, a subfeeder branches from the main feeder at right angles and extends to an SAI within the cluster. As described in Section 6.3.6 on the Distribution Module, each of the four main feeders may, at the user's option, be "steered" towards the preponderance of main cluster locations within the quadrant in question, and a route-to-air multiplier applied to the "steered" feeder route distance.

The main feeder cable sizes for both fiber and copper facilities are a function of the total number of lines in each serving area, and the feeder sizing factor for those serving areas. Feeder cable sizes range from 100 to 4200 pair cable for copper, and from 12 to 216 strands for fiber. Multiple cables are installed along feeder routes when the maximum size of a single cable is exceeded. Main feeder routes taper as they pass the splice points at which subfeeder branches off to connect to the individual serving areas. Thus, the main feeder cable sizes generally decrease in increments as the distance from the wire center increases.

Both copper and fiber feeder cable may appear on a single main feeder route to provide connections to different serving areas. If they do, they share most structure, including poles, manholes and trenching. Copper and fiber cables are assumed not, however, to share conduit when they do follow the same route.

6.4.2. Development of Feeder Investments

6.4.2.1. Calculating Main Feeder and Subfeeder Distances

As was shown in Figure 6, main feeder routes extend from the wire center in as many as four directions.[55] Subfeeder cables branch from the main feeder at right angles, giving rise to the familiar tree topology of feeder routes. The points at which subfeeders branch off the main feeder delineate main feeder segments, which are the portions of main feeder cable between two branch points.[56]

The centers (centroids) of the main clusters may fall in any of the four feeder route quadrants. As shown in Figure 7, a set of parameters, including the quadrant, airline (radial) distance and angles (omega and alpha), locate the main cluster with respect to the serving wire center. With this information, HM 5.0a applies straightforward

[54] Because HM 5.0a uses V&H coordinates to locate clusters and wire centers, feeder routes are assumed to emanate from the wire center along the V&H axes. These axes are rotated slightly clockwise relative to latitude and longitude axes.

[55] If no cluster centroids fall within a given quadrant of a wire center, no feeder route will be provided in that quadrant.

[56] Splicing is required where the main feeder branches into subfeeder. The cost of splicing, including material, equipment, and labor, is included with the cost of the cable assumed in the model.

trigonometric calculations to compute main feeder and subfeeder distances.[57] The model computes sufficient subfeeder cable to connect the main feeder route to the centroid of each main cluster. Copper feeder cable always terminates at an SAI at the centroid of the main cluster. If the model calls for fiber feeder, the subfeeder terminates at an RT at the centroid, adjacent to an SAI.

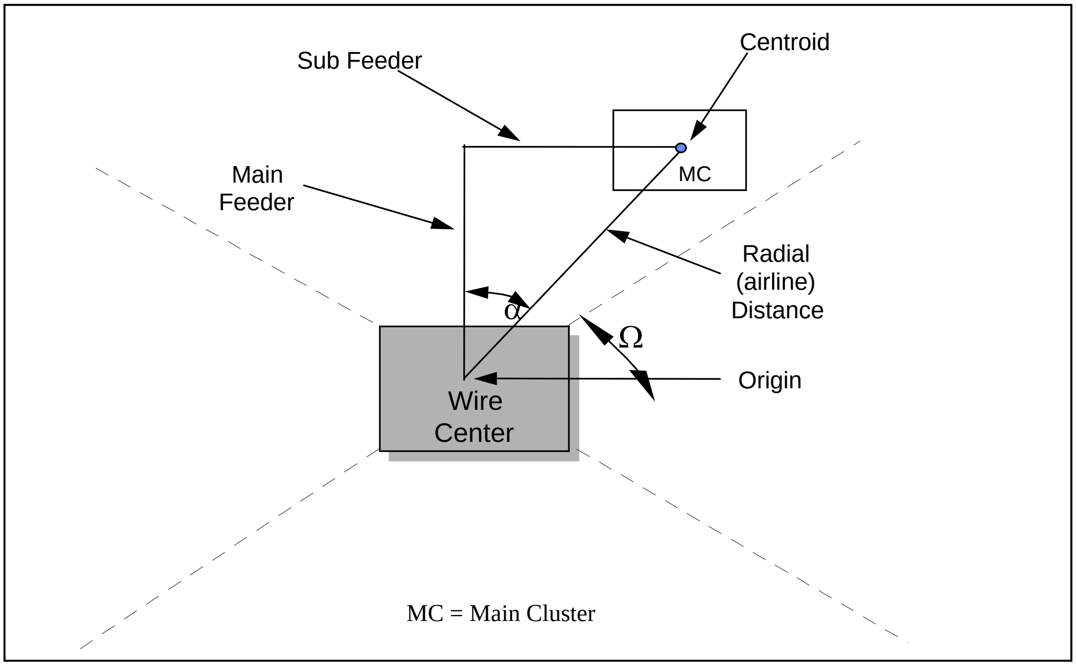

Figure 7 Determination of Cluster Locations and Distances

The criteria by which the Model decides if a main cluster is served by copper or fiber feeder cable have been discussed in the Distribution Module description, since this decision is made there.

Figure 8 demonstrates that multiple serving areas share capacity on certain segments of the main feeder route. Segments located closer to the wire center require more capacity than segments near the periphery. HM 5.0a addresses this need by tapering the main feeder facilities as the distance from the wire center increases. Thus, it must determine the various "segment distances," shown as S-1, S-2, ..., in Figure 8, so it can size the cable in each segment. The segment distances along a main route are calculated in two steps. First, the main clusters are sorted so they appear in the order of increasing distance along the main route. Segment distances are then calculated as the difference between the main feeder distances of adjacent main clusters.

[57] In rural areas where a feeder route may serve only one or two main clusters, this rectilinear routing assumption is extremely conservative relative to the efficiencies that could be realized using a steered feeder routing.

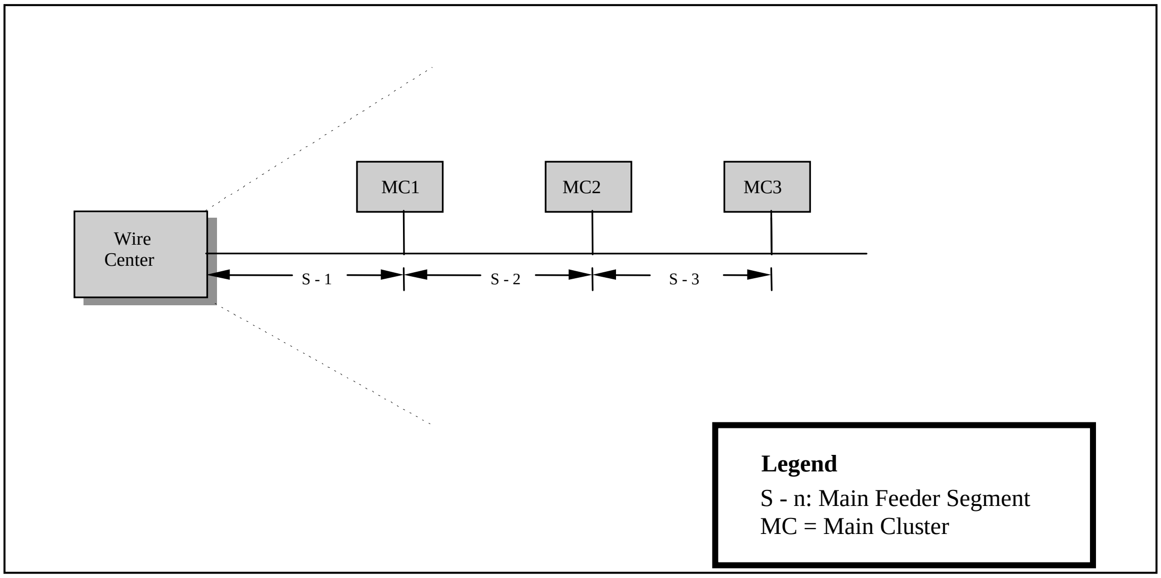

Figure 8 Main Feeder Segmentation

6.4.2.2. Copper and Fiber Subfeeder Cable Sizing

Sizing copper subfeeder cable for individual serving areas is a function of two parameters: the total number of lines within the serving area and the copper feeder sizing factor. To select the appropriate cable size, the required line capacity is computed by dividing the total number of lines in the serving area by the sizing factor. The model then chooses the smallest cable size that meets or exceeds this quotient. For instance, if the number of lines is 200 and the sizing factor is 0.80, the next cable size larger than 200/0.80 is selected. Since 200/0.80 equals 250, the 400 pair cable is selected. As with distribution cable, this may lower substantially the average effective fill compared to the input value entered. Multiple cables are used in cases where the maximum cable size is surpassed.

The number of optical fibers needed to serve a given serving area is calculated by multiplying the number of DLC RTs in that serving area by the number of strands per RT. The strands per RT is a user-adjustable quantity, with a default value of four.[58] In the subfeeder to a particular serving area, the model chooses the smallest optical fiber cable size that meets or exceeds the required number of strands, with a minimum cable size of twelve fiber strands. In the main feeder, the fiber cable on each segment is sized to meet the aggregate demand of serving areas beyond that segment, taking a user-adjustable fiber strand fill factor into account.

6.4.2.3. Main Feeder Segment Sizing

[58] Because a DLC terminal requires a minimum of two fibers, one for each direction of transmission, the HM 5.0a default of four fibers provides complete redundancy.

Each segment in the main feeder is sized to meet the requirements of all the serving areas located past the segment. For example, in Figure 8, segment 1 is sized with adequate capacity for serving areas 1, 2, and 3. Segment 3 will be sized with less capacity than segment 1 since it serves only serving area 3. Thus, the individual cable requirements for serving areas at and beyond the end of a particular main feeder segment are aggregated to determine the required cable size for that main feeder segment. When the maximum cable size is exceeded on a given segment, multiple cables are installed.

6.4.2.4. Structure Investments

The fraction of aerial, buried and underground plant may be set separately for all density ranges and for each feeder cable type, copper or optical fiber. Based on these fractions, the distances involved, and the cost of various structure components, the Feeder Module calculates the investment in feeder structure.

In addition to the sharing of structure between telephone companies and other utilities, there are two other forms of structure sharing relevant to feeder plant. First, with the exception of conduit, structure is shared between copper and fiber feeder cables along main feeder routes. Second, structure is shared between feeder and interoffice facilities. A detailed discussion of the latter type of sharing is presented in the interoffice section of this document.

6.4.2.5. Allocation of Main Feeder Investments

All the feeder facility investments are computed on a per-serving area basis. To do this, it is necessary to assign the appropriate amount of investment in each segment of the main feeder route to the individual serving areas that are served by that segment. The portion of a main feeder segment investment assigned to a serving area whose lines are carried on that segment is computed using the ratio of lines in that serving area to total number of lines in all serving areas carried on that main feeder segment. This is done separately for the copper and fiber feeder that may coexist on a given route.

6.4.2.6. Relevant Input Parameters

The set of user inputs and default values used in feeder calculations appear as inputs B46-B57 and B70-B71, described in Appendix B. The Feeder Module also calculates terrain impacts using inputs B20-B23. It allows the user to enable feeder steering and to set the route/air ratio using B26 and B27, respectively; can override the calculated aspect ratio of the main cluster and thereby force main clusters to be square using B27a; and specifies excavation and restoration costs (jointly with distribution) using B197 through B201.

6.5. Switching and Interoffice Module

6.5.1. Overview

This Module produces network investment estimates in the following categories:

a) *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, power systems and distributing frames.

b) *Signaling network investment* -- This includes investment in STPs, SCPs and signaling links.

c) *Transport investment* -- This category consists of investment in transmission systems supporting local interoffice (common and direct) trunks, intraLATA toll trunks (common and direct) and access trunks (common and dedicated).

d) *Operator Systems investment* -- This includes investments in operator systems positions and operator tandems.

6.5.2. Description of Inputs and Assumptions

For the Switching and Interoffice Module to compute required switching and transmission investments, it requires as inputs total line counts for each wire center, distances between switches, and traffic peakedness 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 takes as data inputs minutes and calling volumes from ARMIS, overall line counts obtained from the PNR database for the serving areas belonging to that wire center, and wire center locations and interoffice distances from the distance file for the calculation of transmission facilities investments.[59] It also requires many user-adjustable input assumptions. The set of user inputs and default values described in Appendix B and used in various phases of the module include:

- B74-B85 and B176-B177, for end office switching;
- B86-B91, for the wire center in which the end office switches and tandems are housed.
- B107-B130, for interoffice transmission terminals, media and structures;
- B143-B149, for tandem switching;
- B150-B163, for interoffice signaling; and
- B164-B167, for operator services and public telephone.

In addition, various traffic parameters are provided by inputs B92-B106, and miscellaneous parameters, such as the percent of traffic that requires operator assistance, percent that is interoffice, and percent that is routed directly between end offices, are provided by B131-B142. Finally, there is a set of inputs representing surrogate per-line investment in various switching and signaling equipment components by small

[59] HM 5.0a includes a set of interoffice distance calculations produced from wire center location information from Bellcore's Local Exchange Routing Guide (LERG) and from NECA Tariff 4.

independent telephone companies ("ICOs"), appearing as B168-B175. These are used in lieu of the results that would be calculated by the model for small ICOs with less than fifty wire centers, and better reflect these ICOs' typical practice of purchasing usage of such components from larger LECs.

Many of the calculations in the Switching and Interoffice module rely on traffic assumptions suggested in Bellcore documents.[60] These inputs, which the user may alter, assume 1.3 busy hour call attempts ("BHCA") per residential line and 3.5 BHCA per business line. Total busy hour usage is then determined based on published Dial Equipment Minutes ("DEM") information. Other inputs, which may be changed by the user, specify the fraction of traffic that is interoffice, the fraction of traffic that flows to operator services, the local fraction of overall traffic, as well as breakouts between direct-routed and tandem-routed local, intraLATA toll, and access traffic.

6.5.3. Explanation of Calculations

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

6.5.3.1. End Office Switching Investments

The Module places at least one end office switch in each wire center. It sizes the switches placed in the wire center by adding up all the switched lines in the CBGs served by the wire center, applying a user-adjustable administrative line fill factor, and then comparing the resulting line total to the maximum allowable switch line size. The maximum switch line size parameter is user-adjustable; its default setting is 80,000 lines plus trunks. The model will equip the wire center with a single switch if the number of ports (lines and trunks) served by the wire center is no greater than a user-adjustable maximum size – that defaults to 80,000. If a wire center must serve, say, 90,000 ports, the model will compute the investment required for two 45,000-port switches.[61]

The wire center module performs two additional capacity checks. First, it compares the BHCA produced by the mix of lines served by each switch with a user-adjustable processor capacity (default set at a maximum of up to 600,000 BHCA, depending on the size of the switch) to determine whether the switch is line-limited or processor real-time-limited. In making this calculation, the per-line BHCA input is multiplied by a user-adjustable processor feature loading multiplier. The default value of the feature loading

[60] Bell Communications Research, *LATA Switching Systems Generic Requirements, Section 17: Traffic Capacity and Environment,* TR-TSY-000517, Issue 3, March 1989.

[61] If multiple switches are required in the wire center, they are sized equally to allow for maximum growth on each switch.

multiplier varies between 1.2 and 2.0, depending on business line penetration,[62] to reflect additional processing loads caused by features.

Second, the module compares the offered traffic, expressed as BHCCS, with a user-adjustable traffic capacity limit (default set at a maximum of up to 1,800,000 BHCCS, depending on the size of the switch). To make this comparison, the per-line traffic estimate calculated from the reported DEMs is multiplied by a user-adjustable holding time multiplier, which can be separately set for business and residence customers. Default values of the business and residential holding time multipliers are 1. They can be increased above that value to reflect the incidence of calls that have longer than normal holding times, and thus increase the traffic load on the switch. A example could be heavy Internet access via the voice network. If either of these processor or traffic capacity tests leads to the corresponding limit being exceeded, the model will compute the investment required for additional switches, each serving an equal number of total lines.

HM 5.0a is capable of engineering and costing end office switching systems comprised of explicit combinations of host, remote and standalone switches. But, because accurate data on the purchase prices of a portfolio of host, remote and standalone switches of varying capacities may not be available to the user, the HM 5.0a Switching and Interoffice Module defaults to computing end office switching investments using input values that average per-line investments over an efficient portfolio of host, remote, and standalone end office switches. Thus, the model's calculated end office switching investments and corresponding costs subsume either explicitly specified switch technologies on a wire center by wire center basis, or a blended overall efficient mixture of host, remote, and standalone switches within the modeled network.

If the user selects the explicit host, remote, standalone option, the user must specify for each wire center whether the housed switches are hosts or remotes, as well as assign correspondences between hosts and remotes. The model will designate all remaining wire centers as housing standalone switches. The model then places the hosts and their subtending remotes on SONET rings separate from the interoffice rings discussed below. Host switches may therefore appear on two rings -- their local host/remote ring, and (if the host directly serves more than the user-specified small office line limit) a larger interoffice ring interconnecting end offices and tandem locations.

The model sizes the host-remote rings to accommodate host-remote umbilical trunk and control link requirements. It then computes investment in SONET add/drop multiplexers ("ADMs") and digital cross connects ("DCSs") for the host/remote ring and calculates the average ADM and DCS investment per line for all lines in the system. The host interoffice calculations also are adjusted to account for the increased trunk and signaling capacity requirements imposed by the remotes served by the host.

[62] The multiplier is set at 1.2 up to a business penetration (i.e., % business lines) threshold set by the user, then increases linearly to 2.0 at 100% business penetration.

End office switching investment calculations obtain common equipment and per-line investments for all three switch types from a user-adjustable investment table, which contains end office investment entries for both large and small LECs. Once the model computes investments for each switch in a host/remote system, it calculates the average investment per line for all of the lines in the system.

In more detail, the costing process is as follows. When the host-remote option is selected, switching curves that correspond to host, remote and standalone switches are used to determine the appropriate switching investment. These new switching curves incorporate a fixed plus variable investment per line for each switch type. It is recognized that there are large and small host and standalone switch technologies, and that remotes are available in multiple line sizes. Remote switches cause incremental variable investments primarily associated with the umbilical trunk ports necessary to carry traffic originating and terminating on the remote lines to the host switch. The user adjustable fixed and variable investments for host, standalone and remote switches have been scaled accordingly. In accordance with the FCC's Public Notice guidelines, the cost of an entire switching system consisting of a host and its associated remotes, is allocated evenly over all lines served by the host-remote configuration.

In default mode, the model assumes a blended configuration of switch technologies. The switching cost curves for this blended configuration were developed using typical per-line prices paid by BOCs, GTE and other independents as reported in the Northern Business Information ("NBI") publication, "U.S. Central Office Equipment Market: 1995 Database."[63] In addition, public line and switch data from the ARMIS 43-07 and responses to the USF NOI data request from 1994 are also employed.

The module uses a large telephone company switching investment curve that is based on the RBOC and GTE average switching costs per line reported in the NBI study. These two switching cost points were paired with the average sizes of current RBOC and GTE switches derived from 1995 ARMIS 43-07 line and switch data. A third cost point for large switches of 80,000 ports was developed from other industry sources. A logarithmic curve was then fit to these data using least-squares regression. As demonstrated in Figure 9, this functional form fits the data very closely.

The 1993 USF NOI (Universal Service Fund Notice of Inquiry) data was used to estimate an average line size for small LEC switches. A 1995 average line size was estimated by assuming the ICOs have experienced growth in average lines per switch between 1993 and 1995 similar to that experienced by GTE. The value on the large LEC curve corresponding to this 1995 small LEC average line size was compared to the ICO per line value from the NBI report. This produced a 1.7 factor which was applied to the constant term in the logarithmic functional form to produce a curve of identical shape, but shifted upward by $173 per line compared to the large LEC curve. The "slope" multiplier

[63] Northern Business Information study: U.S. Central Office Equipment Market -- 1995, McGraw-Hill, New York , 1996

(default of -14.922 in Figure 9) and the constant term (default of 242.73 in Figure 9 for large LECs and default of 416.11 for small ICOs) are user adjustable.

The per-line investment figures from the NBI study are for the entire end office switch, including trunk ports. The investment figures are then reduced by $16 per line to remove trunk port investment based on NBI's implicit line to trunk ratio of 6:1. The actual number of trunks per wire center is calculated in the transport calculation, and the port investments for these trunks are then added back into the switching investments. Figure 9 shows the switching investment curves for large LECs resulting from this methodology.

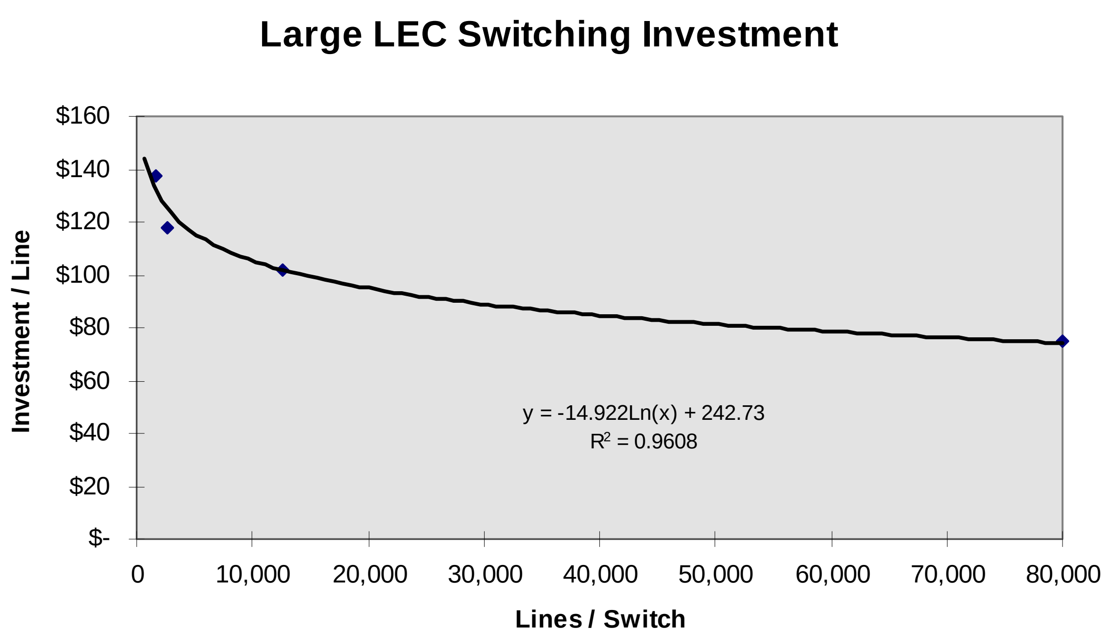

Figure 9 **Blended Switch Investment Curve**

Wire center investments required to support end office and tandem switches are based on assumptions regarding the room size 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.

6.5.3.2. Transport Investments

The traffic and routing inputs listed previously, along with the total mix of access lines served by each switch, form the basis for the model's transport calculations. The model determines the overall breakdown of traffic per subscriber according to the given traffic assumptions and computes the numbers of trunks required to carry this 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 dedicated 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 offered load assumptions. The model computes the total offered load per wire center for various classes of trunks – e.g., local direct-routed trunks. It then compares the offered load for a trunk class to a traffic engineering threshold. If the offered load exceeds the threshold, the computed number of trunks is just the quotient of the total offered load divided by the user-specified maximum trunk occupancy (default = 27.5 CCS). If the traffic load is less than the threshold, the model obtains the correct number of trunks using Erlang B assumptions and 1% blocking from a lookup table.

The traffic engineering threshold value is determined from the user-specified maximum occupancy value through another table lookup which determines the number of trunks that will carry the specified maximum occupancy at 1% blocking. The threshold value is the product of the input maximum occupancy and the corresponding number of trunks. The user may enter maximum occupancies between 17.5 and 30 CCS.

HM 5.0a assumes that, with some exceptions, all interoffice facilities take the form of a set of interconnected Synchronous Optical Network (SONET) fiber rings. It uses a program written in Visual Basic for Applications (VBA) and the wire center locations specified as V&H coordinates to compute a set of rings comprising the interoffice network. These ring calculations apply to all operating companies that have at least one tandem.

The interoffice network of rings consists of two ring classes: host/remote and tandem/host/standalone. If the user invokes the feature that allows hosts and remotes to be specified, host/remote rings are used to interconnect remote switches to their serving host. Tandem/host/standalone rings interconnect hosts and standalone wire centers to their serving tandem. The methodology that the Model uses to determine the rings is the same for both classes of rings, with hosts serving as the homing point in the network of hosts, remotes and tandems serving as the homing point in the network of tandems, hosts, and standalone wire centers. Any discussion in the following section is applicable to both the host/remote and tandem/host/standalone classes, unless otherwise noted.

The interoffice distance calculations in HM 5.0a are considerably more sophisticated than earlier versions of the Hatfield/HAI Model.[64] To compute the set of interoffice rings, the HM begins with a case where all wire centers are directly connected to their serving tandem via redundant paths. Each wire center is then examined to determine whether it is more advantageous to leave the wire center directly connected to the tandem or incorporate it into a ring. To make this determination, the HM compares the investment associated with directly connecting the wire center to the tandem with the investment

[64] See Appendix D for a fuller description of these calculations.

associated with placing the wire center on a ring. For direct connections, the investment is a function of the distance from the wire center to the tandem. When determining the investment that is required to add a wire center to a ring, the distance between interconnected wire centers and the additional cost of multiplexing are considered. If the investment on the ring is less than the investment associated with directly connecting to the tandem, the office will be placed on the ring.

The HM 5.0a incorporates an optimizing algorithm to ensure that it constructs rings in an efficient fashion. The savings that are generated by placing a wire center on a ring are computed as the difference between on-ring and directly connected investment. The HM places the offices that produce the greatest savings on the ring first. When no more savings are possible, the process of creating rings is complete.

When computing rings, the greatest savings often is realized by allowing a set of wire centers to form their own standalone ring that does not include the serving tandem as a node. The algorithm requires the tandem to be placed on at least one ring. But since all wire centers must have a communications path to their serving tandem, standalone rings are connected to the tandem through a series of ring connectors that provide paths either between rings, or between a standalone ring and the tandem. The location of each ring connector is determined by identifying the smallest distance from each node on the standalone ring to either the tandem itself, or to any other ring that has tandem connectivity. All ring connector distances and connector terminal costs are doubled to reflect the installation of redundant facilities.

Since rings are interconnected, traffic between wire centers on two rings may “transit” one or more additional rings. Thus, the calculated capacity of a ring, based on the traffic originating/terminating in wire centers on the ring, must be increased to reflect the requirement that the ring also be able to handle transiting traffic. The actual amount of such transiting traffic on a ring is highly dependent on (1) the position of that ring in the overall configuration of rings serving a given area; and (2) the amount of traffic generated (or terminated) by wire centers on a given ring that is destined for wire centers on another ring, and therefore “leaks” out of the originating ring. The model increases the capacity of each ring to handle transiting traffic based on a user-adjustable “transiting factor,” whose default value is 0.4. This factor represents the percentage of additional ring capacity consumed by transiting traffic. Thus; the model increases the calculated ring capacity requirement by (1 + transiting factor).

There are two user-adjustable parameters that govern the creation of rings. First, it is possible to set the maximum number of wire centers that may share the same ring – see parameter B142 in Appendix B. The default number is 16. Once this limit has been reached, no additional wire centers will be absorbed by the maximally sized ring – even if doing so would produce a network with a smaller total investment. The second, which applies only to host/standalone/tandem rings, is a threshold value dictating the minimum number of switched plus special lines a wire center must serve to be eligible to be placed on a ring. This threshold corresponds to Parameter B139 in Appendix B; its default value is one.

Wire centers that serve fewer than this threshold total line count will either: 1) directly connect to the tandem; or 2) connect to the nearest standalone or host wire center that is on a ring. The option that yields the shortest spur distance is selected. In either case, redundant facilities are provided.

At the highest level in the ring network, the HM must provide a path for tandem to tandem traffic for tandems that are located in the same LATA. This is accomplished through the use of inter-ring-system connectors.[65] The inter-ring-system connectors facilitate a fully interconnected mesh of all the ring systems that exist within a LATA. Ring systems may be connected to other ring systems either through direct tandem to tandem paths, or through any of the on-ring nodes served by those tandems. Inter-ring-system connectors always follow route-diverse paths and will, in most cases, terminate at unique nodes within each of the ring systems. The nodes and paths selected are those that produce the shortest two paths between ring systems. . To ensure tandem switches are sized to handle inter-tandem traffic, there is a user-adjustable parameter (default value 0.10), identified in Appendix B as "Intertandem Fraction of Tandem Trunks," and expressed as a multiplier of the number of tandem trunks calculated from traffic volumes, that increases the calculated capacity of the tandem switches.

The result of the ring-calculating process is a list of the computed host/remote and tandem/host/standalone ring configurations. These ring configurations are broken out by each tandem or host, and the wire centers they serve through the ring network. The following information is reported in the workfile "ring_io" worksheet for each set of rings: 1) the set of wire centers that comprise the ring; 2) the identification of each wire center and the nodes (other wire centers) to which it connects; 3) the distance between each wire center and the nodes to which it connects; 4) a list of the wire centers served by spurs and their associated spur distance; 5) a list of the wire centers that serve as inter-ring-system connector nodes and their associated inter-ring-system connector distance; and 6) a list of the wire center pairs that serve as ring connectors and the their associated ring connector distances. In addition to the ring distance associated with each wire center, several ring parameters are aggregated by company. These include: 1) the total number of ring connectors; 2) the total ring connector distance; 3) the total number of inter-ring-system connectors; 4) the total inter-ring-system connector distance; and 5) the total number of rings that include the tandem as a node. The model equips each ring connector with the maximum rate SONET equipment (OC-48) in current common use by the LECs. Spur terminals operate at OC-3, a sufficient capacity given the 5000 line threshold for the smaller wire centers being placed on a spur.

Once the model determines the total interoffice distances, considering rings, connectors, and point-to-point links for small offices, it calculates the costs of installed cable and structure based on user-definable inputs for cable costs, structure costs and configurations (e.g., pullbox spacing), the mix of different structure types, and the amount of structure sharing between interoffice and feeder plant. To account for this structure sharing, the model determines the smaller of the investment in feeder and the investment in

[65] A ring system is defined as the set of nodes, connectors, spurs, and ring connectors associated with a particular tandem.

interoffice facilities, and applies the user-specified sharing percentage to the smaller value to calculate the amount of shared structure investment. The model then subtracts this amount of investment from both the interoffice and feeder investment, and reassigns it back to feeder and interoffice according to the relative amounts of investment in feeder versus interoffice. It does this separately for underground, buried, and aerial structure.

Interexchange access facilities require additional treatment. Because interexchange carrier POPs are typically not located on LEC fiber rings, dedicated entrance facilities must be engineered. It is not possible to compute the route miles between wire centers (or tandems) and IXC POPs to size the lengths of these entrance facilities, because in general the locations of IXC POPs are not publicly available. Therefore, the number of POPs per tandem, and the average entrance facility distance, are user-adjustable, with default values of 5 and 0.5 miles, respectively.

6.5.3.3. Tandem Switch Investments

Tandem and operator tandem switching investments are computed according to assumptions contained in an AT&T cost study.[66] The investment calculation assigns a price for 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 above.

The module scales the investment in tandem switch common equipment according to the total number of tandem trunks computed for the study area. By doing so, it avoids equipping maximum-capacity tandems whenever a LATA is served by multiple tandems. The calculations also recognize that a significant fraction of tandems are “Class 4/5” offices that serve both tandem and end office functions. The amount of sharing assumed is user-adjustable, with a default value of 40%. Tandem wire center calculations assume the maximum switch room size, and further assume the tandem will reside in a wire center that contains at least one end office switch.

6.5.3.4. Signaling Network Investments

The Module computes signaling link investment for STP to end office to or tandem “A links,” “C links” between the STPs in a mated pair, and “D link” segments connecting the STPs of different carrier's networks. All links are assumed to be carried on the interoffice rings.

The model always equips at least two signaling links per switch. It also computes required SS7 message traffic according to the call type and traffic assumptions described earlier. User inputs define the number and length of ISDN User Part (“ISUP”) messages required to set up interoffice calls. Default values are six messages per interoffice call attempt to set up, with twenty-five octets per message.

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[66] 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, and its predecessor, “A Study of AT&T’s Competitors’ Capacity to Absorb Rapid Demand Growth,” June 20, 1990. ("AT&T Capacity Cost Study").

Other inputs define the number and length of Transaction Capabilities Application Part ("TCAP") messages required for database lookups, along with the percentage of calls requiring TCAP message generation. Default values, obtained from the AT&T Capacity Cost Study, are two messages per transaction, at 100 octets per message, and 10% of all calls 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.

STP capacity is expressed as the total number of signaling links each STP in a mated pair can terminate (default value is 720 with an 80% fill factor). The maximum investment per STP pair is set at $5 million, and may be changed by the user. These default values derive from the AT&T Capacity Cost Study. The STP calculation scales this investment based on the number of links the model requires to be engineered for the study area.

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. The total TCAP message rate in each LATA is then used to determine the total SCP investment. The default SCP investment is $20,000 per transaction per second, based on a number reported in the AT&T Capacity Cost Study.

6.5.3.5. Operator Systems Investments

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 occupancy value of 27.5 CCS discussed above. Operator tandem investment assumptions are the same as for local tandems.

Operator positions are assumed to be based on current workstation technology. The default operator position investment is $6,400. The Model includes assumptions for maximum operator "occupancy" expressed in CCS. The default assumption is that each position supports 32 CCS of traffic in the busy hour. 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 10 implies that one out of ten calls will require human intervention).

6.6. Expense Modules

6.6.1. Overview

HM 5.0a contains four Expense Modules in order to allow the user to display results by line density range, by wire center, by CBG or by cluster.[67] Each of the Expense Modules

[67] Although the HM 5.0a engineers no plant based on CBG granularity, the results of its engineering to individual clusters may be rolled up to display cost results at the CBG level.

receive from the other modules all the network investments, by type of network component necessary to provide UNEs, basic universal service and network interconnection and carrier access in each study area. The Expense Modules estimate the capital carrying costs associated with the investments as well as the costs of operating this network. Capital carrying costs include depreciation, return on the debt and equity investment required to build the network and a gross-up to pay for the income taxes imposed on equity returns. Network-related operating expenses include maintenance and network operations. Non-network-related operating expenses include customer operations expenses, general support expenses, other taxes, uncollectibles and variable overhead expenses.

The Expense modules require a number of user inputs. These inputs, and their corresponding default values, appear as inputs B178-B196 in Appendix B.

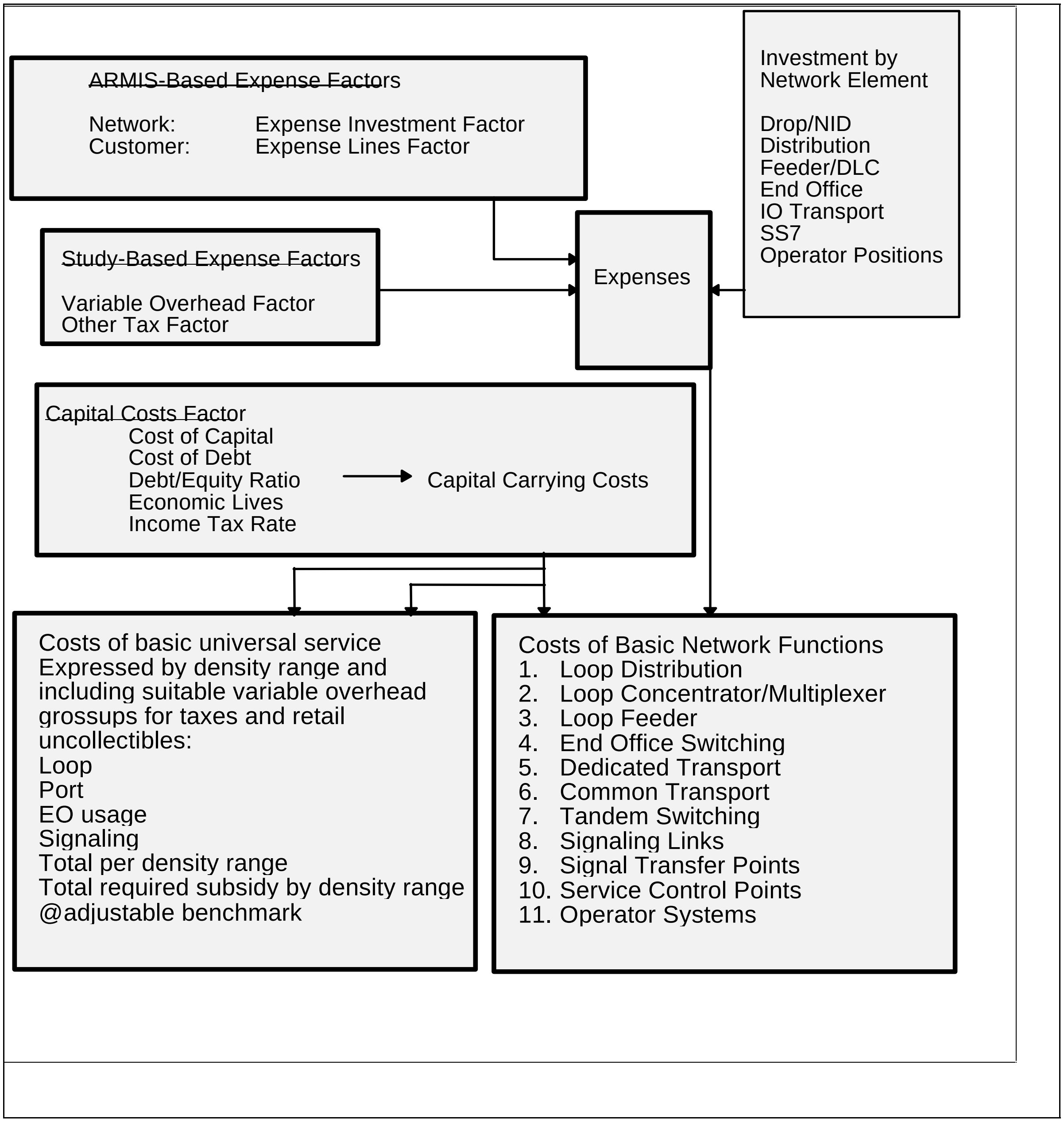

Figure 10 Expense Module Flows

6.6.2. Capital Carrying Costs

Estimating forward-looking capital carrying costs is relatively straight-forward. The FCC and state regulators have developed standard practices that are based on sound economics to perform this function. The model calculates annual capital cost for each UNE component based on:

a) Plant investment for that component from the relevant investment modules,

b) The return to the net asset;

c) An income tax gross-up on the equity component of the return, and

d) The expected service life adjusted for net salvage value (depreciation) of the component.

Each of these elements of the capital carrying cost estimate is discussed below.

The weighted average cost of capital (return) is built up from several components. A 45/55 debt/equity ratio is assumed, with a cost of debt of 7.7 percent and a cost of equity of 11.9 percent, for an overall weighted average cost of capital of 10.01 percent.[68] The equity component of the return is subject to federal, state and local income tax. As a consequence, it is necessary to increase the pre-tax return dollars, so that the after-tax return is equal to the assumed cost of capital. A user-adjustable assumed combined 39.25 percent federal, state and local income tax ("FSLIT") rate is used "gross up" return dollars to achieve this result.

The model assumes straight-line depreciation and calculates return on investment, tax gross-up and depreciation expenses annually on the mid-year value of the investment. Because capital carrying costs are levelized, substitution of nonlinear or accelerated depreciation schedules for straight-line depreciation would have only a modest net effect on calculated annual capital carrying costs (aside from favorable tax effects). Default values for the service lives of the 23 categories of equipment used in the Model are based on their average projection lives adjusted for net salvage value as determined by the three-way meetings (FCC, State Commission, LEC) for 76 LEC study areas including all of the RBOCs, SNET, Cincinnati Bell, and numerous GTE and United companies. The table below shows the plant categories, their economic lives, their percent net salvage value, and the resulting adjusted projection lives upon which depreciation is based. These economic lives and net salvage percents are user-adjustable.

[68] This assumed cost of capital is conservatively high. Current financial analyses show LEC cost of capital to range between 9 and 10 percent. See, AT&T ex parte filing of February 12, 1997, "Estimating the Cost of Capital of Local Telephone Companies for the Provision of Network Elements," by Bradford Cornell, September, 1996.

Account	USOA Category	Economic Lives	Net Salvage Percent	Adjusted Projection Lives
2112	Motor Vehicles	8.24	0.1121	9.28
2115	Garage Work Equipment	12.22	-0.1071	11.04
2116	Other Work Equipment	13.04	0.0321	13.47
2121	Buildings	46.93	0.0187	47.82
2122	Furniture	15.92	0.0688	17.10
2123.1	Office Support Equipment	10.78	0.0691	11.58
2123.2	Company Comm Equipment	7.40	0.0376	7.69
2124	Computers	6.12	0.0373	6.36
2212	Digital Switching	16.17	0.0297	16.66
2220	Operator Systems	9.41	-0.0082	9.33
2232.2	Digital Circuit Equipment	10.24	-0.0169	10.07
2351	Public Telephone	7.60	0.0797	8.26
	NID, SAI			19.29
2411	Poles	30.25	-0.8998	15.92
2421-m	Aerial Cable - Metallic	20.61	-0.2303	16.75
2421-nm	Aerial Cable - Non-Metallic	26.14	-0.1753	22.24
2422-m	Underground - Metallic	25.00	-0.1826	21.14
2422-nm	Underground - Non-Metallic	26.45	-0.1458	23.08
2423-m	Buried - Metallic	21.57	-0.0839	19.90
2423-nm	Buried - Non-Metallic	25.91	-0.0858	23.86
2426-m	Intrabuilding - Metallic	18.18	-0.1574	15.71
2426-nm	Intrabuilding - Non-Metallic	26.11	-0.1052	23.62
2441	Conduit Systems	56.19	-0.1034	50.92
	Average Metallic Cable (calculated)			19.29

Return is earned only on net capital, but because depreciation results in a declining value of plant in each year, the return amount declines over the service life of the plant. To ensure that a meaningful long run capital carrying cost is calculated, the return amount is levelized over the assumed life of the investment using net present value factors. An annual capital carrying charge factor is developed for economic depreciation lives from 1 to 80 years. (*see*, "CCCFactor" worksheet in the Expense Module). These factors (which are also disaggregated into their depreciation, return and tax components) are then applied to investment in each plant category (with interpolation to account for fractional year values for economic life) to determine the annual capital carrying cost for each plant category.

6.6.3. Operating Expenses

Estimating LEC operating costs is more difficult than estimating capital costs. Few publicly available forward-looking cost studies are available from the ILECs. Consequently, many of the operating cost estimates developed here must rely on relationships to and within historical ILEC cost information as a point of departure for estimating forward-looking operating costs. While certain of these costs are closely linked to the number of lines provided by the ILEC, other categories of operating expenses are related more closely to the levels of their related investments. For this reason, the Expense Module develops factors for numerous expense categories and applies these factors both against investment levels and demand quantities (as appropriate) generated by previous modules.

The HM 5.0a density zone Expense Module now includes a USOA Detail worksheet that breaks out the HM 5.0a investments and expense results by Part 32 account for comparison with embedded ARMIS data. There is also an Expense Assignment worksheet that allows the user to vary the proportion of total expenses that are assigned to loop network elements (i.e., NID, distribution, concentration and feeder) based on relative number of lines versus based on the relative amount of direct expenses (direct expenses include maintenance expenses and capital carrying costs for specific network elements).

The operating expenses can be divided into two categories -- network related and non-network related. Network-related expenses include the cost of operating and maintaining the network, while non-network expenses include customer operations and variable overhead.

The cost categories contained in the FCC's USOA are used as the point of departure for estimating the operating expenses associated with providing UNEs, basic universal service and carrier access and interconnection. The major expense categories in the USOA are Plant Specific Operations Expense, Plant Non-Specific Operations Expense, Customer Operations Expense and Corporate Operations Expense. The first two are network-related, the latter are not.

LECs report historical expense information for each of these major categories through the FCC's ARMIS program. The ARMIS data used in the Expense Module include investment and operating expenses and revenues for a given local carrier and state. As noted above, forward-looking expense information for these categories is not publicly available from the ILECs. A variety of approaches are used to estimate the forward-looking expenses.

6.6.3.1. Network-Related Expenses

The two major categories under which network-related expenses are reported by the ILECs are plant-specific operations expenses and non plant-specific operations expenses. The plant-specific expenses are primarily maintenance expenses. Certain expenses, particularly those for network maintenance, are functions of their associated capital investments. The Expense Module estimates these from historic expense ratios calculated from balance sheet and expense account information reported in each carrier's ARMIS report. These expense ratios are applied to the investments developed by the Distribution, Feeder, and Switching and Interoffice Modules to derive associated operating expense amounts. The ARMIS information used to perform these functions is contained in the "ARMIS Inputs" worksheet, and the expense factors are computed in the "'96 Actuals" worksheet of the Expense Module.

Other expenses, such as network operations, vary more directly with the number of lines provisioned by the ILEC rather than its capital investment. Thus, expenses for these elements are calculated in proportion to the number of access lines supported.

The Expense Module estimates direct network-related expenses for all of the UNEs. These operating expenses are added to the annual capital carrying cost to determine the total expenses associated with each UNE. Each network-related expense is described below:

a) *Network Support* -- This category includes the expenses associated with motor vehicles, aircraft, special purpose vehicles, garage and other work equipment.

b) *Central Office Switching* -- This includes end office and tandem switching as well as equipment expenses.

c) *Central Office Transmission* -- This includes circuit equipment expenses applied to transport investment.

d) *Cable and Wire* -- This category includes expenses associated with poles, aerial cable, underground/buried cable and conduit systems. This expense varies directly with capital investment.

e) *Network Operations* -- The Network Operations category includes power, provisioning, engineering and network administration expenses.

The Expense Module uses specific forward-looking expense factors for digital switching and for central office transmission equipment; these values derive from a New England Telephone cost study.[69] The Module similarly computes a forward-looking Network Operations value based on the corresponding ARMIS value. The total Network Operations expense is strongly line-dependent. The model thus computes this expense as a per-line additive value based on the reported total Network Operations expense divided by the number of access lines and deducting a user-adjustable 50 percent of the resulting quotient to produce a forward-looking estimate.

6.6.3.2. NonNetwork-Related Expenses

The Expense Module assigns non-network related expenses to each density range, census block group, or wire center (depending on the unit of analysis chosen) based on the proportion of direct expenses (network expenses and capital carrying costs) for that unit of analysis to total expenses in each category. Each of these expenses is described below:

[69] New England Telephone, 1993 New Hampshire Incremental Cost Study, Provided in Compliance with New Hampshire Public Utility Commission Order Number 20, 082, Docket 89-010/85-185, March 11, 1991.

a) *Variable support* -- Certain costs that vary with the size of the firm, and therefore do not meet the economic definition of a pure overhead, are often included under the classification of General and Administrative expenses by ILECs. For example, if a LEC did not provide loops, it would be a much smaller company, and would therefore have lower overhead costs. Some of these costs are nonetheless attributed to overhead under current ILEC accounting procedures. Therefore, the model includes a portion of these "overhead" costs in the TSLRIC estimates.

   Such variable support expenses for LECs currently are substantially higher than those of similar service industries operating in more competitive environments. Based on studies of these variable support expenses in competitive industries such as the interexchange industry, the model applies a conservative, user-adjustable 10.4 percent variable support factor to the total costs (i.e., capital costs, network-related operations expenses and non-network-related operating expenses) estimated for unbundled network elements, as well as basic local service.

b) *General Support Equipment* -- The module calculates investments for furniture, office equipment, general purpose computers, buildings, motor vehicles, garage work equipment, and other work equipment. The Model uses actual 1996 company investments to determine the ratio of investments in the above categories to total investment. The ratio is then multiplied by the network investment estimated by the Model to produce the investment in general support equipment. The recurring costs -- capital carrying costs and operating expenses -- of these items are then calculated from the investments in the same fashion as the recurring costs for other network components. A portion of general support costs is assigned to customer operations and corporate operations according to the proportion of operating expense in these categories to total operating expense reported in the ARMIS data. The remainder of costs is then assigned directly to UNEs.

c) *Uncollectible Revenues* -- Revenues are used to calculate the uncollectibles factor. This factor is a ratio of uncollectibles expense to adjusted net revenue. The Module computes both retail and wholesale uncollectibles factors, with the retail factor applied to basic local telephone service monthly costs and the wholesale factor used in the calculation of UNE costs.

6.6.4. Expense Module Output

The Density Zone and Wire Center expense modules display results in a series of reports which depict detailed investments and expenses for each UNE for each density zone and wire center, summarized investments and expenses for all UNEs, unit costs by UNE and total annual and monthly network costs. In addition, the UNEs are used to estimate interexchange access costs. The Density Zone, Wire Center, CBG and Cluster expense modules also calculate the cost of basic local service and universal service support across density zones, wire centers, CBGs and clusters, respectively.

6.6.4.1. UNE Outputs (Unit Cost Sheet)

The HAI Model produces cost estimates for Unbundled Network Elements that are the building blocks for all network services. The UNEs are described below.

a) *Network Interface Device* -- This is the equipment used to terminate a line at a subscriber's premise. It contains connector blocks and over-voltage protection.

b) *Loop Distribution* -- The individual communications channel to the customer premises originating at the SAI and terminating at the customer's premises. In the HAI Model, this UNE also includes the investments in NID, drop and terminal/splice, and for long loops, the cost of T1 electronics.

c) *Loop Concentrator/Multiplexer* -- The DLC remote terminal at which individual subscriber traffic is multiplexed and connected to loop distribution for termination at the customer's premises. The HAI Model includes DLC equipment and SAI investment in this UNE.

d) *Loop Feeder* -- The facilities on which subscriber traffic is carried from the line side of the end office switch to the Loop Concentration facility. The UNE includes copper feeder and fiber feeder cable, plus associated structure investments (poles, conduit, etc.)

e) *End Office Switching* -- The facility connecting lines to lines or lines to trunks. The end office represents the first point of switching. As modeled in the HAI Model, this UNE includes the end office switching machine investments and associated wire center costs, including distributing frames, power and land and building investments.

f) *Operator Systems* -- The systems that process and record special toll calls, public telephone toll calls and other types of calls requiring operator assistance, as well as Directory Assistance. The investments identified in the HAI Model for the Operator Systems UNE include the operator position equipment, operator tandem (including required subscriber databases), wire center and operator trunks.

g) *Common Transport* -- A switched trunk between two switching systems on which traffic is commingled to include LEC traffic as well as traffic to and from multiple IXCs. These trunks connect end offices to tandem switches. Results are provided on a per-minute basis for the central office terminating equipment associated with the UNE, and for the transmission medium.

h) *Dedicated Transport* -- The full-period, bandwidth-specific interoffice transmission path between LEC wire centers and an IXC POP (or other off-network location). It provides the ability to send individual and/or multiplexed switched and special services circuits between switches. Results are provided on a per-minute basis and per-channel basis for the central office terminating equipment and entrance facilities associated with the UNE, and on a per-minute and per-channel basis for the transmission medium.

i) *Direct Transport* -- A switched trunk between two LEC end offices. Results are provided on a per-minute basis for the central office terminating equipment associated with the UNE, and on a per-minute basis for the transmission medium.

j) *Tandem Switching* -- The facility that provides the function of connecting trunks to trunks for the purpose of completing inter-switch calls. Similar types of investments as are included in the End Office Switching UNE are also reflected in the Tandem Switching UNE.

k) *Signaling Links* -- Transmission facilities in a signaling network that carry all out-of-band signaling traffic between end office and tandem switches and STPs, between STPs, and between STPs and SCPs. Signaling link investment is developed by the HAI Model and assigned to this UNE.

l) *Signal Transfer Point* -- This facility provides the function of routing TCAP and ISUP messages between network nodes (end offices, tandems and SCPs). The Model estimates STP investment and assigns it to this UNE.

m) *Service Control Point* -- The node in the signaling network to which requests for service handling information (*e.g.*, translations for local number portability) are directed and processed. The SCP contains service logic and customer specific information required to process individual requests. Estimated SCP investment is assigned to this UNE.

6.6.4.2. Universal Service Fund Outputs (USF Sheet)

The calculation of costs for basic local service is based on the costs of the UNEs constituting this service. These are the loop, switch line port, local minute portions of end office and tandem switching, transport facilities for local traffic, and the local portions of signaling costs.[70] In addition, costs associated with retail uncollectibles, variable overheads, and certain other expenses required for basic local service, such as billing and bill inquiry, directory listings, and number portability costs, are included. No operator services or SCP costs are included. The model user has the ability to select dynamically the portions of non-traffic-sensitive UNEs to be included in the supported basic local service.

The USF report in the expense module then compares the monthly cost per line used at residence or business intensity in each density range, wire center, CBG or cluster to user-adjustable "benchmark" monthly costs for local service (which includes the End User Common Line charge). If the cost exceeds the associated benchmark, the model accumulates the total required annual support relative to stated benchmarks according to the number of primary residence lines, secondary residence lines, single line business lines, multiline business lines, or public lines by density zone, wire center, CBG or cluster (depending on the unit of analysis selected).

[70] On an optional basis, the usage sensitive cost of switched access use can be included as well.

The Density Zone USF sheet now contains separate state and federal fund calculations. These permit separate state and federal cost benchmarks; as well as the opportunity to separately specify the particular services (e.g., primary and secondary residential lines, single line business, etc.) to be supported.

6.6.4.3. Carrier Access and Interconnection (Cost Detail Sheet)

The calculation of the costs for carrier access and interconnection to the ILEC's local network are displayed in the "Cost Detail" sheet of the expense module. These costs are built up from the costs of the UNEs that constitute them. In particular, the costs of IXC switched access and local interconnection are based simply on the unit costs of EO switching, dedicated transport, common transport, tandem switching and ISUP signaling messages. In addition, the sheet also displays built up costs of various signaling services that might be used by IXCs or CLECs, as well as the costs of several forms of dedicated transport.

7. Summary

In its Release 5.0a formulation, the HAI Model reliably and consistently estimates the forward-looking economic cost of unbundled local exchange network elements, carrier access and interconnection and the forward-looking economic cost of basic local telephone service for universal service funding purposes. It uses the most accurate and granular data on actual customer locations available today, and it overlays its loop distribution network on these actual customer locations.

Because all of these calculations are performed in adherence to TELRIC/TSLRIC principles, HAI Model cost estimates provide the most accurate basis for the efficient pricing of unbundled network elements carrier access and interconnection and the calculation of efficient universal service funding requirements.

Like its predecessor, the HM 5.0a methodology is open to public scrutiny. To the extent possible, it uses public source data for its inputs. When documentable public source data is lacking, these default input values represent the developers' best judgments of efficient, forward-looking engineering and economic practices. In addition, because these inputs are adjustable users of HM 5.0a can use the model’s automated interface to model directly and simply any desired alternative.

Appendix A

History of the Hatfield/HAI Model

Appendix B

HM 5.0a Inputs, Assumptions and Default Values

Appendix C

HM 5.0a Input Data Development Flow Charts

Appendix D

General Rules Governing the Creation of the HM 5.0a Distance Files

Appendix E

Equation Listings for the HM 5.0a Network Engineering Logic Modules:

Distribution
Feeder
Switching and Interoffice

History of the Hatfield/HAI Model

The Hatfield/HAI Model was originally developed to produce estimates of the TSLRIC of basic local telephone service as part of an examination of the cost of universal service. This original model was a "greenfield" model in that it assumed all network facilities would be built without consideration given to the location of existing wire centers. When the original Benchmark Cost Model ("BCM1")[1] became available, HAI revised the original Hatfield Model to incorporate certain loop investment data produced by BCM1. As a result, the Hatfield Model adopted BCM1's "scorched node" methodology of assuming that network wire centers will remain at their current locations. Investment outputs from the BCM1 loop modeling process, substantially modified by including the cost of items that were not included in the BCM1, were then combined with extensive wire center and interoffice and expense calculations enhanced from the earlier Hatfield Model to develop a complete set of TSLRIC estimates for basic local service.

An expanded version of earlier Hatfield Models, referred to as the Hatfield Model, Version 2.2, Release 1, was developed early in 1996 to estimate the costs of unbundled network elements. It was submitted to the Federal Communications Commission ("FCC") in CC Docket No. 96-98 on May 16 and 30, 1996, accompanied by descriptive documentation.[2] On July 3, 1996, that model was also placed into the record of CC Docket No. 96-45 to assist the Commission in determining the forward-looking economic costs of universal service.[3]

Further enhancements to this model were contained in the Hatfield Model, Version 2.2, Release 2 ("HM 2.2.2"). This version of the model estimated the efficient, forward-looking economic cost of both unbundled network elements and basic local telephone service. HM 2.2.2 derived certain of its inputs and methods from the BCM-PLUS model, a derivative of BCM1 that was developed and copyrighted by MCI Telecommunications Corporation.

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[1] The Benchmark Cost Model is a model of basic local telephone service that was developed by MCI, NYNEX, Sprint, and U S WEST.

[2] See Appendix E of the *Comments* of AT&T in CC Docket No. 96-98, In the Matter of Implementation of the Local Competition Provisions in the Telecommunications Act of 1996, and Appendix D of AT&T's *Reply Comments*. In the same proceeding, MCI submitted results based on an earlier "greenfield" version of the Model as Attachment 1 to its C*omments*.

[3] See FCC Public Notice, DA-96-1078, Released July 3, 1996 and DA 1094, Released July 10, 1996 ("Cost Model Public Notice").

On August 8, 1996, the FCC released its First Report and Order in CC Docket No. 96-98, Implementation of the Local Competition Provisions in the Telecommunications Act of 1996, and CC Docket No. 95-185, Interconnection Between Local Exchange Carriers and Commercial Mobile Radio Service Providers ("Interconnection Order"). The Interconnection Order provided a comprehensive set of criteria for the arrangements through which the incumbent Local Exchange Carriers (ILECs) would offer unbundled network elements to competitive local exchange carriers (CLECs). The criteria included a definition of a cost-based methodology that should be used in setting the price of unbundled network elements. The methodology was termed the "Total Element Long Run Incremental Cost," or TELRIC. The methodology of the Hatfield Model is fully consistent with the TELRIC principles set forth in the Interconnection Order for calculating the cost of UNEs, and with TSLRIC principles for calculating the cost of Basic Local Service.

AT&T and MCI used HM 2.2.2 as the basis for their recommended prices for unbundled network elements in a large number of state jurisdictions during the latter part of 1996. Its results were adopted in whole or in part in several of these proceedings. In the process, the Model was subject to thorough examination by the ILECs, state commission staffs, and other parties. This scrutiny, along with ongoing intense internal reviews, provided valuable insights into further desirable enhancements to the Model.

On November 8, 1996, the Joint Board issued its Recommended Decision in CC Docket No. 96-45.[4] In addition to defining Universal Service, the Board also addressed the issue of determining the level of support required for universal service. In doing so, it found that:

> . . . a properly crafted proxy model can be used to calculate the forward-looking economic costs for specific geographic areas, and be used as the cost input in determining the level of support a carrier may need to serve a high cost area. The Joint Board therefore recommends that the Commission continue to work with the state commissions to develop an adequate proxy model that can be used to determine the cost of providing supported services in a particular geographic area . . .[5]

An in-depth review of these issues was also provided in the Competitive Pricing Division Staff Analysis of "The Use of Computer Models for Estimating Forward-Looking Economic Costs."[6] Further suggestions for the improvement of proxy models were advanced at workshops conducted by the FCC in cooperation with the Joint Board staff on January 14 and 15, 1997. Although the FCC and state staffs declined at that time to

[4] Op. cit., Recommended Decision.

[5] Ibid., paragraph 268.

[6] Released January, 9, 1997.

recommend any particular proxy model, these workshops provided an extensive review of the existing models, and established a number of criteria these models should meet.[7]

On February 7, 1997, AT&T and MCI submitted to the Joint Board a preliminary version of a new release of the Hatfield Model, Release 3.0, with accompanying documentation. The submission included data and results for five states: California, Colorado, New Jersey, Texas, and Washington.[8] HM 3.0 addressed the concerns raised by the Joint Board in its consideration of proxy cost models and the FCC in its consideration of modeling the forward looking economic cost of interconnection. It was responsive to the principles established and concerns raised about existing models, in the Interconnection Order, the Joint Board Recommendation and in Staff Papers and Workshops.

Later the same month, on February 28, AT&T and MCI submitted Hatfield Model Release 3.1 (HM 3.1). It incorporated certain minor modifications to HM 3.0; further, it contained data for 49 states plus the District of Columbia.

In April, 1997, the state members of the Universal Service Joint Board issued several proxy cost modeling reports. Although these reports provided useful analyses of desired features within the models, they came to no clear final conclusion on the choice of a model.

[7] Ibid., paragraphs 273-277 and Appendix F.

[8] Results from Release 3.0 were submitted in three state proceedings: Kansas, Virginia, and Washington.

Appendix B – HAI Model Release 5.0a Inputs, Assumptions and Default Values

This appendix provides a list of the HAI Model Release 5.0a user inputs, as well as their definitions and the default values set in the model. The Appendix is organized based on the series of user input dialogue boxes that are used to set parameters in the HAI Model interface. This yields the following hierarchy:

Input Parameter Category (distribution, feeder, wire center, expense, and excavation)
    Category dialogue box (NID, drop, switching parameters, etc.)
        User Input field (fiber strands per remote terminal, etc.)

The appendix is organized into two sections. The first contains the index of dialogue boxes and specific user input fields. The second lists the inputs with their definitions and default values. These are numbered sequentially from B1 through B201. To facilitate cross-referencing between the two sections, each user-input field in the first section contains a numbered entry from the second section. Thus, for instance, the "B1" next to the Residential NID Materials, No Protector entry refers to the first item in the second section of the appendix.

With this organization, the appendix allows a user who is examining a given user input dialogue box and specific user input field to locate that box/field in the index in the first section, read the number of the corresponding input definition, and use that number to locate the input definition and default value in the second section.

Note that a few parameters are set in one module but used by several modules. In such cases, the parameter appears only once, but its use in other modules is noted at the end of each input parameter category in this index.

PART 1: INDEX OF DIALOGUE BOXES AND USER INPUT FIELDS

Distribution

B19	Pole Spacing

Geology and Clusters

B20	Difficult Terrain Distance Multiplier
B21	Rock Depth Threshold, inches
B22	Hard Rock Placement Multiplier
B23	Soft Rock Placement Multiplier
B24	Sidewalk / Street Fraction
B25	Maximum Analog Copper Total Distance
B26	Feeder Steering Enable
B27	Maximum Feeder Route/Air Multiplier
B27a	Require Serving Areas to be Square

Long Loop Investments

B28	T1 Repeater Investments, Installed
B29	CO Mux Capacity, Installed
B30	RT Cabinet & Common Equipment, Installed
B31	T1 Channel Unit Investment per Subscriber
B32	COT Investment per RT, Installed
B33	T1 Remote Terminal Fill Factor
B34	Maximum T1s per Cable
B35	T1 Repeater Spacing
B36	Aerial T1 Attenuation
B37	Buried T1 Attenuation

SAI Investment

B38	Cable Size
B38	Indoor SAI
B38	Outdoor SAI

Dedicated Circuit Inputs

B39	Percentage of Dedicated Circuits
B40	Pairs per Dedicated Circuit

Wireless Investment

B41	Wireless Investment Cap Enable
B42	Wireless Point to Point Investment Cap - Distribution
B43	Wireless Common Investment
B44	Wireless Per Line Investment
B45	Maximum Broadcast Lines per Common Investment

Feeder

Copper Placement

B46	Aerial Fraction
B46	Buried Fraction
B46	Underground Fraction
B47	Manhole Spacing, /ft.
B48	Pole Spacing, ft.
B49	Pole Materials
B49	Pole Labor
B50	Inner Duct Investment per Foot

Fiber Placement

B51	Aerial Fraction
B51	Buried Fraction
B51	Underground Fraction
B51	Buried Fraction Available for Shift
B52	Pullbox Spacing, ft.
B53	Buried Fiber Sheath Addition per Foot

Cable Sizing Factors

B54	Copper Feeder Cable Sizing Factors
B55	Fiber Feeder Cable Sizing Factor

Cable Costs

B56	Copper Investment per foot
B56	Copper Investment per Pair-foot
B57	Fiber Investment per foot
B57	Fiber Investment per Strand-foot

DLC Equipment

B58	High Density DLC Remote Terminal – Site and Power
B58	Low Density DLC Remote Terminal – Site and Power
B59	High Density DLC Remote Terminal – Maximum Lines
B59	Low Density DLC Remote Terminal – Maximum Lines
B60	High Density DLC Remote Terminal – RT Fill Factor
B60	Low Density DLC Remote Terminal – RT Fill Factor
B61	High Density DLC Remote Terminal – Common Equipment Investment
B61	Low Density DLC Remote Terminal – Common Equipment Investment
B62	High Density DLC Remote Terminal – POTS Channel Unit Investment
B62	Low Density DLC Remote Terminal – POTS Channel Unit Investment
B62	High Density DLC Remote Terminal – Coin Channel Unit Investment
B62	Low Density DLC Remote Terminal – Coin Channel Unit Investment
B63	High Density DLC Remote Terminal – POTS Lines per CU
B63	Low Density DLC Remote Terminal – POTS Lines per CU
B63	High Density DLC Remote Terminal – Coin Lines per CU
B63	Low Density DLC Remote Terminal – Coin Lines per CU
B64	LD Crossover Lines
B65	High Density DLC Remote Terminal – Fibers per RT
B65	Low Density DLC Remote Terminal – Fibers per RT
B66	High Density DLC Remote Terminal – Optical Patch Panel
B66	Low Density DLC Remote Terminal – Optical Patch Panel
B67	Copper Feeder Max Distance, ft
B68	High Density DLC Remote Terminal – Common Equipment Investment per 672 Lines
B68	Low Density DLC Remote Terminal – Common Equipment Investment per 120 Lines
B69	High Density DLC Remote Terminal – Number of Max Line Modules / RT
B69	Low Density DLC Remote Terminal – Number of Max Line Modules / RT

Copper Manhole Investment

B70	Materials

B70	Frame and Cover
B70	Site Delivery
B70	Excavate and Backfill
B71	Dewatering Factor for Manhole Placement
B72	Water Table Depth for Dewatering

Fiber Pullbox Investment

B73	Materials
B73	Installation

Note: The Feeder Module also uses inputs B13-B15.

Switching and Interoffice Transmission

End Office Switching

B74	Real time (BHCA)
B75	Traffic (BHCCS)
B76	Switch maximum line size
B77	Switch port administrative fill
B78	Switch maximum processor occupancy
B79	MDF/protector investment per line
B80	Analog line circuit offset of DLC per line
B81	Switch installation multiplier
B82	End Office Switching Investment Constant – BOC and Large ICO
B82	End Office Switching Investment Constant – Small ICO
B83	End Office Switching Investment Slope Term
B84	Processor Feature Loading Multiplier - Normal
B84	Processor Feature Loading Multiplier - Heavy business
B85	Processor Feature Loading Multiplier - Business penetration threshold

Wire Center

B86	Lot size, multiplier of switch room size
B87	Tandem/EO common factor
B88	Power
B89	Switch Room Size, square ft.
B90	Construction, square ft.
B91	Land, square ft.

Traffic Parameters

B92	Local Call Attempts
B93	Call Completion Factor
B94	IntraLATA Calls Completed
B95	InterLATA Intrastate Calls Completed
B96	InterLATA Interstate Calls Completed
B97	Local DEMs, thousands
B98	Intrastate DEMs, thousands
B99	Interstate DEMs, thousands
B100	Local Business/Residential DEMs
B101	Intrastate Business/Residential DEMs
B102	Interstate Business/Residential DEMs
B103	BH Fraction of Daily Usage
B104	Annual to Daily Usage Reduction Factor

B105	Residential Holding Time Multiplier
B105	Business Holding Time Multiplier
B106	Residential Call Attempts/BH
B106	Business Call Attempts/BH

Interoffice Investment

B107	OC-48 ADM, installed, 48 DS-3s
B107	OC-48 ADM, installed, 12 DS-3s
B107	OC-3/DS-1 Terminal Multiplexer, installed, 84 DS-1s
B107	Investment per 7 DS-1s
B108	Number of Fibers
B109	Pigtail Investment
B110	Optical Distribution Panel
B111	EF&I, per hour
B112	EF&I, hours
B113	Regenerator, installed
B114	Regenerator Spacing, miles
B115	Channel Bank Investment/24 lines
B116	Fraction of SA lines requiring multiplexing
B117	Digital Cross Connect System, installed per DS3
B118	Transmission Terminal Fill (DS-0 level)
B119	Fiber Cable
B120	Number of Strands per ADM
B121	Buried Fraction
B121	Aerial Fraction
B122	Buried Placement
B122	Conduit Placement
B123	Buried Sheath Addition
B124	Conduit
B125	Pullbox Spacing
B126	Spare Tubes per route
B126	Pullbox Investment
B127	Pole Spacing, ft.
B128	Pole Material
B128	Pole Labor
B129	Fraction of poles and buried/underground placement common with feeder
B130	Fraction of aerial structure assigned to telephone
B130	Fraction of buried structure assigned to telephone
B130	Fraction of underground structure assigned to telephone

Transmission Parameters

B131	Operator Traffic Fraction
B132	Total Interoffice Traffic Fraction
B133	Maximum Trunk Occupancy, CCS
B134	Trunk Port, per end
B135	Direct Routed fraction of local interoffice
B136	Tandem Routed fraction of intraLATA traffic
B137	Tandem Routed fraction of interLATA traffic
B138	POPs per Tandem Location
B139	Threshold Value for Off-Ring Wire Centers
B140	Remote – Host Fraction of Interoffice Traffic
B141	Host – Remote Fraction of Interoffice Traffic
B142	Maximum Nodes per Ring

B142a	Ring Transiting Traffic Factor
B142b	Intertandem Fraction of Tandem Trunks

Tandem Switching

B143	Real Time Limit, BHCA
B144	Port Limit, trunks
B145	Common Equipment Investment
B146	Maximum Trunk Fill
B147	Maximum Real Time Occupancy
B148	Common Equipment Intercept Factor
B149	Entrance Facility Distance from Serving Wire Center & IXC POP

Signaling

B150	STP Link Capacity
B151	STP Maximum Fill
B152	STP investment, per pair, maximum
B153	STP investment, per pair, minimum
B154	Link Termination, both ends
B155	Signaling Bit Rate
B156	Link Occupancy
B157	C Link Cross Section
B158	ISUP Messages per interoffice BHCA
B159	ISUP Messages length, bytes
B160	TCAP Messages per transaction
B161	TCAP Message Length, bytes
B162	Fraction of BHCA requiring TCAP
B163	SCP investment/transaction/second

OS and Public Telephone

B164	Investment per position
B165	Maximum Utilization per position, CCS
B166	Operator Intervention Factor
B167	Public Telephone Equipment Investment, per station

ICO Parameters

B168	ICO STP Investment per line, Equipment
B169	ICO Local Tandem Investment per line, Equipment
B170	ICO OS Tandem Investment per line, Equipment
B171	ICO SCP Investment per line, Equipment
B172	ICO STP/SCP Wire Center Investment per line
B173	ICO Local Tandem Wire Center Investment per line
B174	ICO OS Tandem Wire Center Investment per line
B175	ICO C-Link / Tandem A-Link Investment per line
B175a	Equivalent Facility Investment per DS0
B175b	Equivalent Terminal Investment per DS0

Host / Remote Assignment

B176	Host – Remote CLLI Assignments
B177	Host – Remote Assignment Flag

Host / Remote Investment

B177a	Line Size Designation
B177b	Fixed and per Line Investment

Expense

Cost of Capital

B178	Cost of Debt
B178	Debt Fraction
B178	Cost of Equity

Depreciation and Net Salvage

B179	Motor Vehicles
B179	Garage Work Equipment
B179	Other Work Equipment
B179	Buildings
B179	Furniture
B179	Office Support Equipment
B179	Company Comm. Equipment
B179	General Purpose Computer
B179	Digital Electronic Switching
B179	Operator Systems
B179	Digital Circuit Equipment
B179	Public Telephone Terminal Equipment
B179	Poles
B179	Aerial Cable – metallic
B179	Aerial Cable – non metallic
B179	Underground Cable – metallic
B179	Underground Cable – non metallic
B179	Buried Cable – metallic
B179	Buried Cable – non metallic
B179	Intrabuilding Cable – metallic
B179	Intrabuilding Cable – non metallic
B179	Conduit Systems

Expense Assignment

B179a	Furniture – Capital Costs
B179a	Furniture – Expenses
B179a	Office Equipment – Capital Costs
B179a	Office Equipment – Expenses
B179a	General Purpose Computer – Capital Costs
B179a	General Purpose Computer – Expenses
B179a	Motor Vehicles – Capital Costs
B179a	Motor Vehicles – Expenses
B179a	Buildings – Capital Costs
B179a	Buildings – Expenses
B179a	Garage Work Equipment – Capital Costs
B179a	Garage Work Equipment – Expenses
B179a	Other Work Equipment – Capital Costs
B179a	Other Work Equipment – Expenses
B179a	Network Operations
B179a	Other Taxes
B179a	Variable Overhead

Structure Fraction Assigned to Telephone

B180	Distribution Aerial

B180	Distribution Buried
B180	Distribution Underground
B180	Feeder Aerial
B180	Feeder Buried
B180	Feeder Underground

Other

B181	Income Tax Rate
B182	Corporate Overhead Factor
B183	Other Taxes Factor
B184	Billing/Bill Inquiry per line per month
B185	Directory Listing per line per month
B186	Forward-looking Network Operations Factor
B187	Alternative CO Switching Factor
B188	Alternative Circuit Equipment Factor
B189	EO Non Line-Port Cost Fraction
B190	Per line monthly LNP cost
B191	Carrier – Carrier Customer Service, per line per year
B192	NID Expense per line per year
B193	DS-0/DS-1 Terminal factor
B194	DS-1/DS-3 Terminal factor
B195	Average Lines per Business Location
B196	Average Trunk Utilization

Excavation and Restoration

Underground Excavation

B197	Trenching, per Foot
B197	Backhoe Fraction
B197	Backhoe Cost, per Foot
B197	Hand Trench Fraction
B197	Hand Trench Cost per Foot

Underground Restoration

B198	Cut/Restore Asphalt Fraction
B198	Cut/Restore Asphalt, per Foot
B198	Cut/Restore Concrete Fraction
B198	Cut/Restore Concrete, per Foot
B198	Cut/Restore Sod Fraction
B198	Cut/Restore Sod, per Foot
B198	Simple Backfill, per Foot
B198	Pavement, per Foot
B198	Dirt, per Foot

Buried Excavation

B199	Plow Fraction
B199	Plow per Foot
B199	Trench per Foot
B199	Backhoe Fraction
B199	Backhoe, per Foot
B199	Hand Trench Fraction
B199	Hand Trench, per Foot

B199	Bore Cable Fraction
B199	Bore Cable, per Foot

Buried Installation and Restoration

B200	Push Pipe/Pull Cable Fraction
B200	Push Pipe/Pull Cable per Foot
B200	Cut/Restore Asphalt Fraction
B200	Cut/Restore Asphalt, per Foot
B200	Cut/Restore Concrete Fraction
B200	Cut/Restore Concrete, per Foot
B200	Cut/Restore Sod Fraction
B200	Cut/Restore Sod, per Foot
B200	Restoral Not Required
B200	Simple Backfill

Surface Texture

B201	Percent of cluster Likely Affected and Effect of Texture Code

Labor Adjustment Factors

Labor Adjustment Factor

B16	Regional Labor Factor

Labor Adjustment Factor Weightings

B16a	Contractor Excavation and Restoration
B16a	Telco Construction – Copper
B16a	Telco Construction – Fiber
B16a	Telco Drop/NID Installation and Maintenance
B16a	Contractor Pole Setting

PART 2: INPUT PARAMETER DEFINITIONS AND DEFAULT VALUES

DISTRIBUTION INPUT PARAMETERS

NETWORK INTERFACE DEVICE

B1. NID Investment per line

Definition

The investment in the components of the network interface device (NID), the device at the customers' premises within which the drop wire terminates, and which is the point of subscriber demarcation. The NID investment is calculated as the cost of the NID case plus the product of the protection block cost per line and the number of lines terminated.

Default Values

NID Materials and Installation	
	Costs
Residential NID case, no protector	$10.00
Residential NID basic labor	$15.00
Installed NID case	*$25.00*
Protection block, per line	$4.00
Business NID case, no protector	$25.00
Business NID basic labor	$15.00
Installed NID case	*$40.00*
Protection block, per line	$4.00
Indoor NID Case	$5.00

DROP

B2. Drop Distance

Definition

The average length of a drop cable in each of nine density zones. The drop extends from the NID at the customer's premises to the block terminal at the distribution cable that runs along the street or the lot line.

Default Values

Drop Distance by Density	
Density Zone	Drop Distance, feet
0-5	150
5-100	150
100-200	100
200-650	100
650-850	50
850-2,550	50
2,550-5,000	50
5,000-10,000	50
10,000+	50

B3. Drop Placement, Aerial and Buried

Definition

The total placement cost by density zone of an aerial drop wire, and the cost per foot for buried distribution cable placement, respectively.

Default Values

Drop Placement, Aerial & Buried		
Density Zone	Aerial, total	Buried, per foot
0-5	$23.33	$0.60
5-100	$23.33	$0.60
100-200	$17.50	$0.60
200-650	$17.50	$0.60
650-850	$11.67	$0.60
850-2,550	$11.67	$0.60
2,550-5,000	$11.67	$0.75
5,000-10,000	$11.67	$1.50
10,000+	$11.67	$5.00

B4. Buried Drop Sharing Fraction

Definition

The fraction of buried drop cost that is assigned to the telephone company. The other portion of the cost is borne by other utilities.

Default Value

Buried Drop Sharing Fraction	
Density Zone	Fraction
0-5	.50
5-100	.50
100-200	.50
200-650	.50
650-850	.50
850-2,550	.50
2,550-5,000	.50
5,000-10,000	.50
10,000+	.50

B5. Drop Structure Fractions

Definition

The percentage of drops that are aerial and buried, respectively, as a function of density zone.

Default values

Drop Structure Fractions		
Density Zone	Aerial	Buried
0-5	.25	.75
5-100	.25	.75
100-200	.25	.75
200-650	.30	.70
650-850	.30	.70
850-2,550	.30	.70
2,550-5,000	.30	.70
5,000-10,000	.60	.40
10,000+	.85	.15

B6. Number of Lines per Business Location

Definition

The average number of business lines per business location, used to calculate NID and drop cost. This parameter should be set the same as Parameter B195.

Default Value

4

B7. Terminal and Splice Investment per line

Definition

The installed cost per line for the terminal and splice that connect the drop to the distribution cable.

Default Value

Terminal and Splice Investment per Line	
Buried	Aerial
$42.50	$32.00

B8. Drop Cable Investment, per foot and Pairs per Wire

Definition

The investment per foot required for aerial and buried drop wire, and the number of pairs in each type of drop wire.

Default Values

Drop Cable Investment, per foot		
	Material Cost Per foot	Pairs
Buried	$0.140	3
Aerial	$0.095	2

CABLE AND RISER INVESTMENT

B9. Distribution Cable Sizes

Definition

Cable sizes used for distribution cable variables (in pairs).

Default Values

Cable Sizes
2400
1800
1200
900
600
400
200
100
50
25
12
6

B10. Copper Distribution Cable, $/foot

Definition

The cost per foot of copper distribution cable, as a function of cable size, including the costs of engineering, installation, and delivery, as well as the cable material itself.

Default Values

Copper Distribution Cable, $/foot	
Cable Size	Cost/foot (including engineering, installation, delivery and material)
2400	$20.00
1800	$16.00
1200	$12.00
900	$10.00
600	$7.75
400	$6.00
200	$4.25
100	$2.50
50	$1.63
25	$1.19
12	$0.76
6	$0.63

B11. Riser Cable, $/foot

Definition

The cost per foot of copper riser cable (cable inside high-rise buildings), as a function of cable size, including the costs of engineering, installation, and delivery, as well as the cable material itself.

Default Values

Riser Cable, $/foot	
Cable Size	Cost/foot (including engineering, installation, delivery and material)
2400	$25.00
1800	$20.00
1200	$15.00
900	$12.50
600	$10.00
400	$7.50
200	$5.30
100	$3.15
50	$2.05
25	$1.50
12	$0.95
6	$0.80

POLES AND CONDUIT

B12. Pole Investment

Definition

The installed cost of a 40-foot Class 4 treated southern pine utility pole

Default Value

Pole Investment	
Materials	$201
Labor	$216
Total	*$417*

B13. Buried Copper Cable Sheath Multiplier (feeder and distribution)

Definition

The additional cost of the filling compound used in buried cable to protect the cable from moisture expressed as a multiplier of the cost of non-filled cable.

Default value

1.04

B14. Conduit Material Investment per foot

Definition

Material cost per foot for 4" PVC.

Default Value

$0.60

B15. Spare Tubes per Route (distribution)

Definition

The number of spare tubes (i.e., conduit) placed per route.

Default Value

1

B16. Regional Labor Adjustment Factor (moved to the end of this document)

Note: This parameter is moved to the end of the document, page 77.

PLACEMENT FRACTION

B17. Distribution Structure Fractions

Definition

The distribution cable structure fractions are the relative amounts of different structure types supporting distribution cable in each density zone. Aerial distribution cable is attached to telephone poles or buildings, buried cable is laid directly in the earth, and underground cable runs through underground conduit. In the highest two density zones, aerial structure includes riser and block cable.

The buried fraction available for shift parameter is defined as the fraction of buried cable input value that is available to be shifted to aerial or the fraction of the input value by which the amount of buried cable can increase. If, for example, the user has entered an initial value of 0.5 for the buried cable fraction in a given density zone and then enters 0.6 as the buried fraction available for shift, the model can allow the computed buried fraction (according to local surface and bedrock conditions) to vary up or down by 0.3 (60% of 0.5), and thus lie between 0.2 and 0.8. Separate values must be entered for each density range, and the computed fraction of buried cable is not allowed by the model to exceed 1.0. Note that the parameter and associated process are applied to both distribution and feeder cable.

Defaults

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

CABLE SIZING FACTORS AND POLE SPACING

B18. Distribution Cable Sizing Factors

Definition

The factor by which distribution cable is increased above the size needed to serve a given quantity of demand in order to provide spare pairs for breakage, line administration, and some amount of growth. HM 5.0a divides the number of pairs needed in a distribution cable to meet existing demand by this factor to determine the minimum number of pairs required, then uses the next larger available size cable.

Default Values

Distribution Cable Sizing Factors	
Density Zone	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

B19. Distribution Pole Spacing

Definition

Spacing between poles supporting aerial distribution cable. HM 5.0a assumes Aerial Cable in the two densest zones is Block and Building Cable, not support on poles.

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	N/A
10,000+	N/A

GEOLOGY AND CLUSTERS

B20. Distribution 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

1.0

B21. Rock Depth Threshold, inches

Definition

The depth of bedrock, above which (that is, closer to the surface) additional costs are incurred for placing distribution or feeder cable.

Default

24 inches

B22. 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

3.5

B23. 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

2.0

B24. Sidewalk / Street Fraction

Definition

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

Default

0.20

B25. Maximum Analog Copper Total Distance

Definition

The maximum total copper cable length that is allowed to carry voiceband analog signals. When the potential copper cable length exceeds this threshold, it triggers long loop treatment and/or the deeper penetration of fiber based DLC.

Default

18,000 ft.

B26. Feeder steering enable

Definition

An option that, if enabled, instructs the model to adjust each main feeder route direction toward the preponderance of clusters in a quadrant. In the default state, feeder route directions from the wire center are North, East, South, and West.

Default

The default setting is disabled.

B27. Main feeder route/air multiplier

Definition

Route-to-air multiplier applied to main feeder distance when feeder steering is enabled to account for routing main feeder cable around obstacles.

Default

1.27

B27a. Require serving areas to be square

Definition

An option that, if enabled, instructs the model to treat all main clusters as square. In the default state, main clusters are computed as rectangular, with the height to width ratio determined by the process that produces the cluster input data.

Default

The default setting is disabled.

LONG LOOP INVESTMENTS

B28. T1 Repeater Investment, Installed

Definition

The investment per T1 repeater, including electronics, housing, and installation, used for T1 carrier long loop extensions.

Default

$527.00

B29. CO Mux Capacity, installed

Definition

The installed central office multiplexer investment required per road cable used for T1 carrier long loop extensions.

Default

$420.00

B30. Remote Terminal Cabinet and Common Equipment, Installed

Definition

The installed investment per T1 RT used for T1 carrier long loop extensions.

Default

$8,200.00

B31. T1 Channel Unit Investment per Subscriber

Definition

The investment per line in POTS channel units installed in T1 RT used for T1 carrier long loop extensions.

Default

$125.00

B32. Transceiver Investment per RT, Installed

Definition

The installed investment for the transceiver plug-in per T1 RT used to interface with the T1 carrier and to power the repeaters.

Default

$1,170.00

B33. T1 Remote terminal fill factor

Definition

The line unit fill factor in a T1 remote terminal; that is, the ratio of lines served by a T1 remote terminal to the number of line units equipped in the remote terminal.

Default

0.90

B34. Maximum T1s per cable

Definition

Maximum number of T1s that can share a cable without binder group separation or internal shielding.

Default

8

B35. T1 repeater spacing

Definition

Minimum design separation, measured in decibels, on copper cable as a function of the maximum loss between adjacent repeaters at 772 kHz, and the loss of the copper cable on which the repeaters are installed. Used for T1 carrier long loop extensions.

Default

32.0 dB

B36. Aerial T1 Attenuation

Definition

The copper cable attenuation for the design of T1 circuits at an operational frequency of 772 kHz and a maximum temperature of 140 degrees Fahrenheit. Based on air core PIC (Plastic Insulated Conductor) cable.

Default

6.3 dB/kft.

B37. Buried T1 Attenuation

Definition

The copper cable attenuation for the design of T1 circuits at an operational frequency of 772 kHz and at normal operating temperature. Based on water blocking compound filled cables, using solid PIC insulation.

Default

5.0 dB/kft.

SERVING AREA INTERFACE INVESTMENT

B38. Serving Area Interface (SAI) Investment

Definition

The installed investment in the SAI that acts as the physical interface point between distribution and feeder cable.

Default Values

SAI Investment		
SAI Size	Indoor SAI	Outdoor SAI
7200	$9,656	$10,000
5400	$7,392	$8,200
3600	$4,928	$6,000
2400	$3,352	$4,300
1800	$2,464	$3,400
1200	$1,776	$2,400
900	$1,232	$1,900
600	$888	$1,400
400	$592	$1,000
200	$296	$600
100	$148	$350
50	$98	$250

DEDICATED CIRCUIT INPUTS

B39. 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 - fraction DS0 - fraction DS1). The equivalence between the three circuit types -- that is, DS-0, DS-1, and DS-3 -- and wire pairs is expressed by Parameter B36. Note that the model assumes the circuit counts are expressed in terms of the number of DS-0, DS-1, and DS-3, circuits, respectively, not voice grade circuits or DS-0 equivalents. Thus if the data source expresses all circuit counts as DS-0 equivalents, as is the case with the existing ARMIS 43-08 report used as the source of special access line counts, the values for this parameter should be set to 100% DS-0 and 0% DS-1.

Default

Percentage of Dedicated Circuits	
DS-0	DS-1
100%	0%

B40. Pairs per Dedicated Circuit

Definition

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

Default

Pairs per Dedicated Circuit		
DS-0	DS-1	DS-3
1	2	56

WIRELESS INVESTMENT

B41. Wireless Investment Cap Enable

Definition

When enabled, invokes wireless investment cap for distribution plant investment calculations. In the default mode, the model does not impose the wireless cap.

Default

The default setting is disabled.

B42. Wireless Point to Point Investment Cap – Distribution

Definition

Per-subscriber investment for hypothetical point to point subscriber radio equipment.

Default

$7,500

B43. Wireless Common Investment

Definition

Base Station Equipment investment for hypothetical broadcast wireless loop system.

Default

$112,500

B44. Wireless Per Line Investment

Definition

Per-subscriber investment for hypothetical broadcast wireless loop systems, including customer premises equipment and per subscriber share of base station radios.

Default

$500

B45. Maximum Broadcast Lines per Common Investment

Definition

Capacity of hypothetical base station common equipment, in lines.

Default

30

FEEDER INPUT PARAMETERS

COPPER PLACEMENT

B46. Copper Feeder Structure Fractions

Definition

The relative amounts of different structure types supporting sheath feet of 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

Copper Feeder Structure Fractions			
Density Zone	Aerial/Block Cable	Buried Cable	Underground Cable (calculated)
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*

**Note: Buried Fraction Available for Shift for Copper Feeder Structure Fractions is taken from the Buried Fraction Available for Shift for Fiber Feeder Structure Fractions.*

B47. Copper Feeder Manhole Spacing, feet

Definition

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

Default Values

Copper Feeder Manhole Spacing, feet

Density Zone	Distance between manholes, ft.
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

B48. Copper Feeder Pole Spacing, feet

Definition

Spacing between poles supporting aerial copper feeder cable.

Default Values

Copper Feeder Pole Spacing	
Density Zone	Spacing, ft.
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

B49. Copper Feeder Pole Investment

Definition

The installed cost of a 40’ Class 4 treated southern pine pole.

Default Value

Pole Investment	
Materials	$201
Labor	$216
Total	*$417*

B50. Inner Duct Material Investment per foot

Definition

Material cost per foot of inner duct.

Default Value

$0.30

FIBER PLACEMENT

B51. 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

Fiber Feeder Structure Fractions				
Density Zone	Aerial/Block Cable	Buried Cable	Underground Cable (calculated)	Fraction of Buried Available for Shift
0-5	.35	.60	*.05*	*.75*
5-100	.35	.60	*.05*	*.75*
100-200	.35	.60	*.05*	*.75*
200-650	.30	.60	*.10*	*.75*
650-850	.30	.30	*.40*	*.75*
850-2,550	.20	.20	*.60*	*.75*
2,550-5,000	.15	.10	*.75*	*.75*
5,000-10,000	.10	.05	*.85*	*.75*
10,000+	.05	.05	*.90*	*.75*

B52. Fiber Feeder Pullbox Spacing, feet

Definition

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

Default Values

Fiber Feeder Pullbox Spacing, feet	
Density Zone	Distance between pullboxes, ft.
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

B53. Buried Fiber Sheath Addition, per foot

Definition

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

Default Value

$0.20/foot

SIZING FACTORS

B54. Copper Feeder Cable Sizing Factors

Definition

The factor by which copper feeder cable capacity is increased above the size needed to serve a given quantity of demand in order to provide spare pairs for breakage, line administration, and some amount of growth. Calculated as the ratio of the number of assigned pairs to the total number of available pairs in the cable.

Default Values

Copper Feeder Cable Sizing Factors	
Density Zone	Factors
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

B55. Fiber Feeder Cable Sizing Factor

Definition

Percentage of fiber strands in a cable that is available to be utilized.

Default

Fiber Feeder Cable Sizing Factor	
Density Zone	Factor
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

CABLE COSTS

B56. Copper Feeder Cable; $/ foot, per pair-foot

Definition

The cost per foot ($/foot) and per pair-foot of copper feeder cable, as a function of cable size, including the costs of engineering, installation, and delivery, as well as the cable material itself. The copper investment per pair-foot is used in estimating comparative life-cycle costs for copper feeder.

Default Value

Copper Feeder Investment	
Cable Size	$/foot (u/g & aerial)
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
Copper Investment per Pair – foot	
$ 0.0075 / pair-ft.	

B57. Fiber Feeder Cable; $/foot, per strand-foot

Definition

The cost per foot ($/foot) and per strand-foot of fiber feeder cable, as a function of cable size, including the costs of engineering, installation, and delivery, as well as the cable material itself. The fiber investment per strand-foot is used in estimating comparative life-cycle costs for copper and fiber feeder.

Default Value

Fiber Feeder Investment	
Cable Size	$/foot (u/g & aerial)
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
Fiber Investment per Strand – foot	
$ 0.10 / fiber-ft.	

DIGITAL LOOP CARRIER EQUIPMENT

B58. DLC site and power per remote terminal

Definition

The investment associated with site and power for the remote terminal of a Digital Loop Carrier (DLC) system.

Default Value

Remote Terminal Site and Power	
High Density DLC	Low Density DLC
$3,000	$1,300

B59. Maximum Line Size per Remote Terminal

Definition

The maximum number of lines supported by the initial line module of a remote terminal.

Default

Maximum Line Increment per Remote Terminal	
High Density DLC	Low Density DLC
672	120

B60. Remote terminal sizing factor

Definition

The line unit sizing factor in a DLC remote terminal, that is, the; the ratio of lines served by a DLC remote terminal to the number of line units equipped in the remote terminal.

Default Value

Remote Terminal Sizing Factors	
High Density DLC	Low Density DLC
0.90	0.90

B61. DLC initial common equipment investment

Definition

The cost of all common equipment and housing in the remote terminal, as well as the fiber optics multiplexer required at the CO end for the initial line module of the DLC system (assumes integrated digital loop carrier (IDLC) with a GR-303 interface to the local digital switch).

Default Value

Remote Terminal Initial Common Equipment Investment	
High Density DLC	Low Density DLC
$66,000	$16,000

B62. DLC channel unit investment

Definition

The investment in channel units required in the remote terminal of the DLC system.

Default Value

DLC Type	DLC channel unit investment per unit	
	POTS Channel Unit	Coin Channel Unit
High Density	$310	$250
Low Density	$600	$600

B63. DLC Lines per CU

Definition

The number of lines that can be supported on a single DLC channel unit.

Default Value

DLC Type	DLC Lines per channel unit	
	POTS	Coin
High Density	4	2
Low Density	6	6

B64. Low Density DLC to High Density DLC Cutover

Definition

The threshold number of lines served, above which the High Density DLC will be utilized.

Default

480

B65. Fibers per remote terminal

Definition

The number of fibers connected to each DLC remote terminal.

Default Value

Fibers per Remote Terminal	
High Density DLC	Low density DLC
4	4

B66. Optical Patch Panel

Definition

The investment required for each optical patch panel associated with a DLC remote terminal.

Default

Optical Patch Panel	
High Density DLC	Low density DLC
$1000	$1000

B67. Copper Feeder Maximum Distance, feet

Definition

The feeder length above which fiber feeder cable is used in lieu of copper cable. The value must be less than 18,000 feet.

Default Value

9,000 feet

B68. Common Equipment Investment per Additional Line Increment

Definition

The cost of the common equipment required for each additional line module in a remote terminal.

Default

Common Equipment Investment per Additional Line Increment	
High Density	Low Density
672 Lines	120 Lines
$18,500	$9,400

B69. Maximum Number of Additional Line Modules per Remote Terminal

Definition

The number of line modules (in increments of 672 or 120 lines) that can be added to a remote terminal.

Default

Max. # Add. Line Modules/RT	
High Density DLC	Low density DLC
2	1

COPPER MANHOLE INVESTMENT

B70. Manhole Investment, materials and labor

Definition

The installed cost of a prefabricated concrete manhole, including backfill and restoration. All the non-italicized costs in the following table are separately adjustable.

Default Value

Copper Cable Manhole Investment						
Density Zone	Materials	Frame & Cover	Site Delivery	Total Material	Excavation & Backfill	Total Installed Manhole
0-5	$1,865	$350	$125	*$2,340*	$2,800	*$5,140*
5-100	$1,865	$350	$125	*$2,340*	$2,800	*$5,140*
100-200	$1,865	$350	$125	*$2,340*	$2,800	*$5,140*
200-650	$1,865	$350	$125	*$2,340*	$2,800	*$5,140*
650-850	$1,865	$350	$125	*$2,340*	$3,200	*$5,540*
850-2,550	$1,865	$350	$125	*$2,340*	$3,500	*$5,840*
2,550-5,000	$1,865	$350	$125	*$2,340*	$3,500	*$5,840*
5,000-10,000	$1,865	$350	$125	*$2,340*	$5,000	*$7,340*
10,000+	$1,865	$350	$125	*$2,340*	$5,000	*$7,340*

B71. Dewatering factor for manhole placement

Definition

Fractional increase in manhole placement to reflect additional cost required to install manholes in presence of shallow water table.

Default

0.20

B72. Water table depth for dewatering

Definition

Water table depth at which dewatering factor is invoked.

Default

5.00 feet

FIBER PULLBOX INVESTMENT

B73. Fiber Feeder Pullbox Investment

Definition

The investment per fiber pullbox in the feeder portion of the network.

Default Values

Fiber Pullbox Investment		
Density Zone	Pullbox Materials	Pullbox Installation
0-5	$280	$220
5-100	$280	$220
100-200	$280	$220
200-650	$280	$220
650-850	$280	$220
850-2,550	$280	$220
2,550-5,000	$280	$220
5,000-10,000	$280	$220
10,000+	$280	$220

SWITCHING AND INTEROFFICE TRANSMISSION PARAMETERS

END OFFICE SWITCHING

B74. Switch real-time limit, busy hour call attempts

Definition

The maximum number of busy hour call attempts (BHCA) a switch can handle. If the model determines that the load on a processor, calculated as the number of busy hour call attempts times the processor feature load multiplier, would exceed the switch real time limit multiplied by the switch maximum processor occupancy, it will add a switch to the wire center.

Default Values

Switch Real-time limit, BHCA	
Lines Served	BHCA
1-1,000	10,000
1,000-10,000	50,000
10,000-40,000	200,000
40,000+	600,000

B75. Switch traffic limit, BHCCS

Definition

The maximum amount of traffic, measured in hundreds of call seconds (CCS), the switch can carry in the busy hour (BH). If the model determines that the offered traffic load on an end office switching network exceeds the traffic limit, it will add a switch.

Default Value

Lines	Busy Hour CCS
1-1,000	30,000
1,000-10,000	150,000
10,000-40,000	600,000
40,000+	1,800,000

B76. Switch maximum equipped line size

Definition

The maximum number of lines plus trunk ports that a typical digital switching machine can support.

Default Value

80,000

B77. Switch port administrative fill

Definition

The percent of lines in a switch that are assigned to subscribers compared to the total equipped lines in a switch.

Default Value

0.98

B78. Switch maximum processor occupancy

Definition

The fraction of total capacity (measured in busy hour call attempts, BHCA) an end office switch is allowed to carry before the model adds another switch.

Default Value

0.90

B79. MDF/Protector Investment per Line

Definition

The Main Distribution Frame investment, including protector, required to terminate one line.

Default Value

$12.00

B80. Analog Line Circuit Offset for DLC lines, per line

Definition

The reduction in per line switch investment resulting from the fact that line cards are not required in both the switch and remote terminal for DLC-served lines.

Default Value

$5.00

B81. Switch installation multiplier

Definition

Definition: The telephone company investment in switch engineering and installation activities, expressed as a multiplier of the switch investment.

Default Value

1.10

B82. End Office Switching Investment Constant Term

Definition

The value of the constant ("B") appearing in the function that calculates the per line switching investment as a function of switch line size for an amalgam of host-remote and stand alone switches, expressed separately for BOCs and large independents (ICOs), on the one hand, and for small ICOs, on the other hand. The function is cost per line = A *ln* X + B, where X is the number of lines.

Default Values

BOC and Large ICO	Small ICO
$242.73	$416.11

B83. End Office Switching Investment Slope Term

Definition

The constant multiplying the log function appearing in the EO switching investment function ("A" in the function shown in parameter 4.1.9.) that calculates the per line switching investment as a function of switch line size for an amalgam of host-remote and stand alone switches. This term is the same for BOCs, large independents, and small independents.

Default Value

-14.922

B84. Processor feature loading multiplier

Definition

The amount by which the load on a processor exceeds the load associated with ordinary telephone calls, due to the presence of vertical features, Centrex, etc., expressed as a multiplier of nominal load.

Default Value

The default value is 1.20 for business line percentage up to the variable business penetration rate, increasing linearly above that rate to a final value of 2.00 for 100% business lines.

B85. Business Penetration Ratio

Definition

The percentage of business lines to total line at which the processor feature loading multiplier is assumed to reach the “heavy business” value of 2.

Default Value

0.30

WIRE CENTER

B86. Lot size, multiplier of switch room size

Definition

The multiplier of switch room size to arrive at total lot size to accommodate building and parking requirements.

Default Value

2

B87. Tandem/EO wire center common factor

Definition

The percentage of tandem switches that are also end office switches or are collocated in wire centers with end office switches. This accounts for the fact that tandems and end offices are often located together, and is employed to avoid double counting of land and other wire center investment in these instances.

Default Value

0.4

B88. Power investment

Definition

The wire center investment required for rectifiers, battery strings, back-up generators and various distributing frames, as a function of switch line size.

Default Value

Lines	Investment Required
0	$5,000
1000	$10,000
5000	$20,000
25,000	$50,000
50,000	$250,000

B89. Switch room size

Definition

The area in square feet required to house a switch and its related equipment.

Default Value

Switch Room Size	
Lines	Sq. Feet of Floor Space Required
0	500
1,000	1,000
5,000	2,000
25,000	5,000
50,000	10,000

B90. Construction costs, per sq. ft.

Definition

The costs of construction of a wire center building.

Default Value

Construction Costs per sq. ft.	
Lines	Cost/sq. ft.
0	$75
1,000	$85
5,000	$100
25,000	$125
50,000	$150

B91. Land price, per sq. ft.

Definition

The land price associated with a wire center.

Default Value

Lines	Price/sq. ft.
0	$5.00
1,000	$7.50
5,000	$10.00
25,000	$15.00
50,000	$20.00

TRAFFIC PARAMETERS

B92. Local Call Attempts

Definition

The number of yearly local call attempts, as reported to the FCC.

Default Value

Taken from ARMIS reports for the LEC being studied.

B93. Call Completion Fraction

Definition

The percentage of call attempts that result in a completed call. Calls that result in a busy signal, no answer, or network blockage are all considered incomplete.

Default Value

0.7

B94. IntraLATA Calls Completed

Definition

The number of yearly intraLATA call attempts, as reported by the FCC.

Default Value

Taken from ARMIS reports for the LEC being studied.

B95. InterLATA Intrastate Calls Completed

Definition

The number of yearly interLATA intrastate call attempts, as reported to the FCC.

Default Value

Taken from ARMIS reports for the LEC being studied.

B96. InterLATA Interstate Calls Completed

Definition

The number of yearly interLATA interstate call attempts, as reported to the FCC.

Default Value

Taken from ARMIS reports for the LEC being studied.

B97. Local DEMs, thousands

Definition

The number of yearly local DEMs, as reported to the FCC.

Default Value

Taken from ARMIS reports for the LEC being studied.

B98. Intrastate DEMs, thousands

Definition

The number of yearly intrastate DEMs, as reported to the FCC.

Default Value

Taken from ARMIS reports for the LEC being studied.

B99. Interstate DEMs, thousands

Definition

The number of yearly interstate DEMs, as reported to the FCC.

Default Value

Taken from ARMIS reports for the LEC being studied.

B100. Local bus/res DEMs ratio

Definition

The ratio of local Business DEMs per line to local Residential DEMs per line.

Default Value

1.1

B101. Intrastate bus/res DEMs

Definition

The ratio of intrastate Business DEMs per line to intrastate Residential DEMs per line.

Default Value

2

B102. Interstate bus/res DEMs

Definition

The ratio of interstate Business DEMs per line to interstate Residential DEMs per line.

Default Value

3

B103. Busy hour fraction of daily usage

Definition

The percentage of daily usage that occurs during the busy hour.

Default Value

0.10

B104. Annual to daily usage reduction factor

Definition

The effective number of business days in a year, used to concentrate annual usage into a fewer number of days as a step in determining busy hour usage.

Default Value

270

B105. Holding time multipliers, residential/business

Definition

The potential modification to the average call "holding time" (i.e., duration) to reflect Internet use or other causes, expressed as a multiplier of the holding time associated with ordinary residential or business telephone calls.

Default Value

Holding time multipliers	
Residential	Business
1.0	1.0

B106. Call attempts, Busy Hour (BHCA), residential/business

Definition

The number of call attempts originated per residential and business subscriber during the busy hour.

Default Value

Busy Hour Call Attempts	
Residential	Business
1.3	3.5

INTEROFFICE INVESTMENT

B107. Transmission Terminal Investment

Definition

The investment in 1) the fully-equipped add-drop multiplexer (ADM) that extracts/inserts signals into OC-48 or OC-3 fiber rings, and are needed in each wire center to connect the wire center to the interoffice fiber ring; and 2) the fully-equipped OC-3/DS-1 terminal multiplexers required to interface to the OC-48 ADM and to provide point to point circuits between on-ring wire centers and end offices not connected directly to a fiber ring. The "Investment per 7 DS-1" figure is the amount by which the investment in OC-3s is reduced for each unit of 7 DS-1s below full capacity of the OC-3.

Default Value

Transmission Terminal Investment			
OC-48 ADM, Installed		OC-3/DS-1 ADM/Terminal Multiplexer, Installed	Investment per 7 DS-1s
48 DS-3s	12 DS-3s	84 DS-1s	7 DS-1s
$50,000	$40,000	$26,000	$500

B108. Number of fibers

Definition

The assumed fiber cross-section, or number of fibers in a cable, in an interoffice fiber ring and point to point connection.

Default Value

24

B109. Pigtail Investment

Definition

The cost of the short fiber connectors that attach the interoffice ring fibers to the wire center transmission equipment via a patch panel.

Default Value

$60.00 per pigtail

B110. Optical Distribution Panel

Definition

The cost of the physical fiber patch panel used to connect 24 fibers to the transmission equipment.

Default Value

$1,000.00

B111. EF&I, per hour

Definition

The per-hour cost for the "engineered, furnished, and installed" activities for equipment in each wire center associated with the interoffice fiber ring, such as the "pigtails" and patch panels to which the transmission equipment is connected.

Default Value

$55.00

B112. EF&I, units

Definition

The number of hours required to install the equipment associated with the interoffice transmission system (see EF&I, per hour, above).

Default Value

32 hours

B113. Regenerator investment, installed

Definition

The installed cost of an OC-48 optical regenerator.

Default Value

$15,000

B114. Regenerator spacing, miles

Definition

The distance between digital signal regenerators in the interoffice fiber optics transmission system.

Default Value

40 miles

B115. Channel Bank Investment, per 24 lines

Definition

The investment in voice grade to DS-1 multiplexers in wire centers required for some special access circuits.

Default Value

$5,000

B116. Fraction of SA Lines Requiring Multiplexing

Definition

The percentage of special access circuits that require DS-0 to DS-1 multiplexing in the wire center in order to be carried on the interoffice transmission system. This parameter is for use in conjunction with a study of the cost of special access circuits.

Default Value

0.0

B117. Digital Cross Connect System, Installed, per DS-3

Definition

The investment required for a digital cross connect system that interfaces DS-1 signals between switches and OC-3 multiplexers, expressed on a per DS-3 basis (672 DS-0).

Default Value

$30,000

B118. Transmission Terminal Fill (DS-0 level)

Definition

The fraction of maximum DS-0 circuit capacity that can actually be utilized in ADMs, DS-1 to OC-3 multiplexers, and channel banks.

Default Value

0.90

B119. Interoffice Fiber Cable investment per foot, installed

Definition

The installed cost per foot of interoffice fiber cable, assuming a 24-fiber cable.

Default Value

$3.50 installed and buried

B120. Number of Strands per ADM

Definition

The number of interoffice fiber strands connected to the ADM in each wire center. At least four strands per ADM are required around the ring.

Default Value

4

B121. Interoffice Structure Percentages

Definition

The relative amounts of different structure types supporting interoffice transmission facilities. Aerial cable is attached to telephone poles or buildings, buried cable is laid directly in the earth, and underground cable runs through underground conduit. Aerial and buried percentages are entered by the user; the underground fraction is then computed.

Default Values

Structure Percentages		
Aerial	Buried	Underground
20%	60%	*20%*

B122. Transport Placement

Definition

The cost of placement of fiber cable used in the interoffice transmission system.

Default Values

Transport Placement, per foot	
Buried	Conduit
$1.77	$16.40

B123. Buried Sheath Addition

Definition

The cost of dual sheathing for additional mechanical protection of fiber interoffice transport cable.

Default Value

$0.20/foot

B124. Interoffice conduit, cost and number of tubes

Definition

The cost per foot for interoffice fiber cable conduit, and the number of spare tubes (conduit) placed per route.

Default Values

Cost per foot	Spare tubes per route
$0.60	1

B125. Pullbox Spacing

Definition

Spacing between pullboxes in the interoffice portion of the network.

Default Value

2,000 feet

B126. Pullbox Investment

Definition

Investment per fiber pullbox in the interoffice portion of the network.

Default Value

$500

B127. Pole Spacing, Interoffice

Definition

Spacing between poles supporting aerial interoffice fiber cable.

Default Value

150 feet

B128. Interoffice pole material and labor

Definition

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

Default Value

Pole Investment	
Materials	$201
Labor	$216
Total	*$417*

B129. Fraction Interoffice Structure Common With Feeder

Definition

The percentage of structure supporting interoffice transport facilities that is also shared by feeder facilities, expressed as a fraction of the smaller of the interoffice and feeder investment for each of the three types of facilities (i.e., aerial, buried and underground are considered separately in calculating the amount of sharing).

Default

0.75

B130. Fraction of interoffice structure assigned to telephone

Definition

The fraction of investment in interoffice poles and trenching that is assigned to LECs. The remainder is attributed to other utilities/carriers

Default Value

Fraction of Interoffice Structure Assigned to Telephone		
Aerial	Buried	Underground
0.33	0.33	0.33

TRANSMISSION PARAMETERS

B131. Operator traffic fraction

Definition

Fraction of traffic that requires operator assistance. This assistance can be automated or manual (see Operator Intervention Fraction in the Operator Systems section below)

Default

0.02

B132. Total interoffice traffic fraction

Definition

The fraction of all calls that are completed on a switch other than the originating switch, as opposed to calls completed within a single switch.

Default

0.65

B133. Maximum trunk occupancy, CCS

Definition

The maximum utilization of a trunk during the busy hour.

Default

27.5

B134. Trunk port investment, per end

Definition

Per-trunk equivalent investment in switch trunk port at each end of a trunk.

Default

$100

B135. Direct-routed fraction of local inter-office

Definition

The amount of local interoffice traffic that is directly routed between originating and terminating end offices as opposed to being routed via a tandem switch.

Default

0.98

B136. Tandem routed fraction of total intraLATA traffic

Definition

Fraction of intraLATA calls that are routed through a tandem.

Default

0.2

B137. Tandem routed fraction of total interLATA traffic

Definition

Fraction of interLATA (IXC access) calls that are routed through a tandem instead of directly to the IXC.

Default

0.2

B138. POPs per Tandem Location

Definition

The number of IXC points of presence requiring an entrance facility, per LEC tandem.

Default

5

B139. Threshold value for off-ring wire centers

Definition

The treshold value, in lines, that determines whether a wire center should be included in ring calculations and therefore be a candidate to appear on (that is, be directly connected to) a ring. Wire centers whose size falls below the threshold will not be appear on a ring, but will be connected via a point-point link to the tandem switch or via a “spur” to the nearest wire center that is on a ring. Transmission equipment in such cases consists of terminal multiplexers and not ADMs. This parameter only applies to companies that own and operate a local tandem switch.

Default

1 line

B140. Remote - host fraction of interoffice traffic

Definition

Fraction of local direct traffic assumed to flow from a remote to its host switch.

Default

0.10

B141. Host - remote fraction of interoffice traffic

Definition

Fraction of local direct traffic assumed to flow from a host to its remotes.

Default

0.05

B142. Maximum nodes per ring

Definition

Maximum number of ADMs that are permitted on a single ring.

Default

16

B142a. Ring transiting traffic factor

Definition

An estimated factor, representing the fraction of traffic that flows from one ring to another by way of a third, or "transit," ring.

Default

0.40

B142b. Intertandem fraction of tandem trunks

Definition

A factor used to estimate the number of additional trunks required to carry intertandem traffic.

Default

0.10

TANDEM SWITCHING

B143. Real time limit, BHCA

Definition

The maximum number of BHCA a tandem switch can process.

Default

750,000

B144. Port limit, trunks

Definition

The maximum number of trunks that can be terminated on a tandem switch.

Default

100,000

B145. Tandem common equipment investment

Definition

The amount of investment in tandem switch common equipment, which is the hardware and software that is present in the tandem in addition to the trunk terminations themselves. The cost of a tandem is estimated by the HM as the cost of common equipment plus an investment per trunk terminated on the tandem.

Default

$1,000,000

B146. Maximum trunk fill (port occupancy)

Definition

The fraction of the maximum number of trunk ports on a tandem switch that can be utilized.

Default

0.90

B147. Maximum real time tandem occupancy

Definition

The fraction of the total capacity (expresses as the real time limit, BHCA) a tandem switch is allowed to carry before an additional switch is provided.

Default

0.90

B148. Tandem common equipment intercept factor

Definition

The multiplier of the common equipment investment input that gives the common equipment cost for the smallest tandem switch, allowing scaling of tandem switching investment according to trunk requirements.
.

Default

0.50

B149. Entrance Facility Distance from Serving Wire Center & IXC POP

Definition

Average length of trunks connecting an IXC with the wire center that serves it.

Default

0.5 miles

SIGNALING

B150. STP link capacity

Definition

The maximum number of signaling links that can be terminated on a given STP pair.

Default Value

720

B151. STP maximum fill

Definition

The fraction of maximum links, as stated by the STP link capacity input, that the model assumes can be utilized before it adds another STP pair.

Default Value

0.80

B152. STP maximum common equipment investment, per pair

Definition

The cost to purchase and install an STP pair, fully equipped for the maximum number of links.

Default Value

Maximum investment: $5,000,000

B153. STP minimum common equipment investment, per pair

Definition

The minimum investment for a minimum-capacity STP, i.e.: the fixed investment for an STP pair that serves a minimum number of links.

Default Value

$1,000,000

B154. Link termination, both ends

Definition

The investment required for the transmission equipment that terminates both ends of an SS7 signaling link.

Default Value

$900.00

B155. Signaling link bit rate

Definition

The rate at which bits are transmitted over an SS7 signaling link.

Default Value

56,000 bits per second

B156. Link occupancy

Definition

The fraction of the maximum bit rate that can be sustained on an SS7 signaling link.

Default Value

0.40

B157. C link cross-section

Definition

The number of C-links in each segment connecting a mated STP pair.

Default Value

24

B158. ISUP messages per interoffice BHCA

Definition

The number of Integrated Services Digital Network User Part (ISUP) messages associated with each interoffice telephone call attempt, i.e. the messages switches send to each other over the SS7 network to negotiate establishing a voice path.

Default Value

6

B159. ISUP message length, bytes

Definition

The average number of bytes in each ISUP (ISDN User Part) message.

Default Value

25 bytes

B160. TCAP messages per transaction

Definition

The number of Transaction Capabilities Application Part (TCAP) messages required per SCP database query. A TCAP message is a message from a switch to a database or another switch that provides the switch with additional information prior to setting up a call or completing a call.

Default Value

2

B161. TCAP message length, bytes

Definition

The average length of a TCAP message.

Default Value

100 bytes

B162. Fraction of BHCA requiring TCAP

Definition

The percentage of BHCAs that require a database query, and thus generate TCAP messages.

Default Value

0.10

B163. SCP investment per transaction per second

Definition

The investment in the Service Control Point (SCP) associated with database queries, or transactions, stated as the investment required per transaction per second. For example, an SCP required to handle 100 transactions per second would require a 2 million dollar investment, if the default of $20,000 is assumed.

Default Value

$20,000

OS AND PUBLIC TELEPHONE

B164. Investment per operator position

Definition

The investment per computer required for each operator position.

Default Value

$6,400

B165. Maximum utilization per position, CCS

Definition

The estimated maximum number of CCS that one operator position can handle during the busy hour.

Default Value

32

B166. Operator intervention factor

Definition

The percentage of all operator-assisted calls that require operator intervention, expressed as 1 out of every N calls, where N is the value of the input.

Default Value

10

B167. Public Telephone equipment investment per station

Definition

The weighted average cost of a public telephone and pedestal (coin/non-coin and indoor/outdoor).

Default Value

$760

ICO PARAMETERS

B168. ICO STP Investment per Line

Definition

The surrogate value for the per line investment in a signal transfer point by an independent telephone company (ICO), in lieu of calculating it directly in the model.

Default Value

$5.50

B169. Per Line ICO Local Tandem Investment

Definition

The surrogate value for the per line investment in a local tandem switch by an independent telephone company (ICO), in lieu of calculating it directly in the model.

Default Value

$1.90

B170. Per Line ICO OS Tandem Investment

Definition

The surrogate value for the per line investment in an Operator Services tandem switch by an independent telephone company (ICO), in lieu of calculating it directly in the model.

Default Value

$0.80

B171. Per Line ICO SCP Investment

Definition

The surrogate value for the per line investment in a SCP by an independent telephone company (ICO), in lieu of calculating it directly in the model.

Default Value

$2.50

B172. Per Line ICO STP/SCP Wire Center Investment

Definition

The surrogate value for the per line investment in an STP/SCP wire center by an independent telephone company (ICO), in lieu of calculating it directly in the model.

Default Value

$0.40

B173. Per Line ICO Local Tandem Wire Center Investment

Definition

The surrogate value for the per line investment in a local tandem wire center by an independent telephone company (ICO), in lieu of calculating it directly in the model.

Default Value

$2.50

B174. Per Line ICO OS Tandem Wire Center Investment

Definition

The surrogate value for the per line investment in a operator services tandem wire center by an independent telephone company (ICO), in lieu of calculating it directly in the model.

Default Value

$1.00

B175. Per Line ICO C-Link / Tandem A-Link Investment

Definition

The surrogate value for the per line investment in a C-link / tandem A-link by an independent telephone company (ICO), in lieu of calculating it directly in the model.

Default Value

$0.30

B175a. Equivalent Facility Investment per DS0

Definition

The per-DS0 surrogate facilities investment by a small ICO for dedicated circuits between an end office and tandem switch belonging to the BOC (or other large LEC) on which the ICO relies for interoffice connectivity.

Default Value

$138.08

B175b. Equivalent Terminal Investment per DS0

Definition

The per-DS0 surrogate investment by a small ICO for terminal equipment used on dedicated circuits between an end office and tandem switch belonging to the BOC (or other large LEC) on which the ICO relies for interoffice connectivity.

Default Value

$111.62

HOST / REMOTE ASSIGNMENT

B176. Host / remote CLLI assignments

Definition

An input form consisting of parameters that allow the user to specify the set of host and remote wire centers, and establish the relationships between remotes and their serving host, using the CLLI codes of the respective switches. In the default mode, HM 5.0a assumes all switches operate independently, and thus does not include host/remote designations or relationships.

Default Value

Default settings do not define hosts or remotes.

B177. Host / remote assignment enable

Definition

An option that, if enabled, instructs the model to perform switching calculations based on the host-remote relationships defined by Parameter 4.10.1.

Default Value

Default setting is disabled.

HOST / REMOTE INVESTMENT

B177a. Line Size Designation

Definition

The line size designation of fixed and per line investments for standalone, host, and remote switches.

Default Value

Line Size
0
640
5,000
10,000

B177b. Fixed and per Line Investments

Definition

The fixed and per line investments included in the function that calculates the per line switching investment as a function of switch line size for host, remote, and stand alone switches, expressed separately for BOCs and large independents and for small independents. The cost function for each type of switch and each type of telephone company is assumed to have the form A + B * x, where A is the fixed investment, B is the per-line investment, and x is the number of lines.

Default Value

Fixed and per Line Investments for Standalone, Host and Remote Switches						
BOCs and Large ICOs						
Line Size	Standalone fixed investment	Host fixed investment	Remote fixed investment	Standalone per line investment	Host per line investment	Remote per line investment
0	$175,000	$183,750	$10,000	$75	$75	$85
640	$175,000	$183,750	$55,000	$75	$75	$83
5,000	$175,000	$183,750	$70,000	$75	$75	$85
10,000	$475,000	$498,750	$225,000	$73	$73	$70
Small ICOs						
Line Size	Standalone fixed investment	Host fixed investment	Remote fixed investment	Standalone per line investment	Host per line investment	Remote per line investment
0	$300,001	$315,001	$17,143	$129	$129	$146
640	$300,001	$315,001	$94,286	$129	$129	$141
5,000	$300,001	$315,001	$120,000	$129	$129	$146
10,000	$814,289	$855,003	$385,716	$124	$124	$120

EXPENSE

COST OF CAPITAL

B178. Cost of capital

Definition

The capital cost structure, including the debt/equity ratio, cost of debt, and return on equity, that makes up the overall cost of capital.

Default Values

Debt percent	0.450
Cost of debt	0.077
Cost of equity	0.119
Weighted average cost of capital	*0.1001*

DEPRECIATION AND NET SALVAGE

B179. Depreciation Lives and Net Salvage Percentages

Definition

The economic life and net salvage value of various network plant categories.

Default Value

Plant Type	Economic Life	Net Salvage %
motor vehicles	8.24	11.21
garage work equipment	12.22	-10.71
other work equipment	13.04	3.21
buildings	46.93	1.87
furniture	15.92	6.88
office support equipment	10.78	6.91
company comm. Equipment	7.40	3.76
general purpose computers	6.12	3.73
digital electronic switching	16.17	2.97
operator systems	9.41	-0.82
digital circuit equipment	10.24	-1.69
public telephone term. Equipment	7.60	7.97
Poles	30.25	-89.98
aerial cable, metallic	20.61	-23.03
aerial cable, non metallic	26.14	-17.53
underground cable, metallic	25.00	-18.26
underground cable, non metallic	26.45	-14.58
buried cable, metallic	21.57	-8.39
buried cable, non metallic	25.91	-8.58
intrabuilding cable, metallic	18.18	-15.74
intrabuilding cable, non metallic	26.11	-10.52
conduit systems	56.19	-10.34

EXPENSE ASIGNMENT

B179a. Expense Assignment

Definition

The fraction of certain categories of indirect expenses, including the loop component of general support, as well as network operations, other taxes, and variable overhead, that are assigned to loop UNEs (distribution, concentrator, feeder and NID), and thus to universal service, on a per-line basis, rather than the default assignment based on the relative proportions of the direct costs associated with these UNEs.

Default Value

Expense Assignment	Percent to be assigned per line
General Support Loops	
Furniture – Capital Costs	0 %
Furniture – Expenses	0 %
Office Equipment – Capital Costs	0 %
Office Equipment – Expenses	0 %
General Purpose Computer – Capital Costs	0 %
General Purpose Computer – Expenses	0 %
Motor Vehicles – Capital Costs	0 %
Motor Vehicles – Expenses	0 %
Buildings – Capital Costs	0 %
Buildings – Expenses	0 %
Garage Work Equipment – Capital Costs	0 %
Garage Work Equipment – Expenses	0 %
Other Work Equipment – Capital Costs	0 %
Other Work Equipment – Expenses	0 %
Network Operations	0 %
Other Taxes	0 %
Variable Overhead	0 %

STRUCTURE FRACTION ASSIGNED TO TELEPHONE

B180. Structure Percentage Assigned to Telephone Company

Definition

The fraction of investment in distribution and feeder poles and trenching that is assigned to LECs. The remainder is attributed to other utilities/carriers.

Default Values

Structure Percent Assigned to Telephone Company						
	Distribution			Feeder		
Density Zone	Aerial	Buried	Underground	Aerial	Buried	Underground
0-5	.50	.33	1.00	.50	.40	.50
5-100	.33	.33	.50	.33	.40	.50
100-200	.25	.33	.50	.25	.40	.40
200-650	.25	.33	.50	.25	.40	.33
650-850	.25	.33	.40	.25	.40	.33
850-2,550	.25	.33	.33	.25	.40	.33
2,550-5,000	.25	.33	.33	.25	.40	.33
5,000-10,000	.25	.33	.33	.25	.40	.33
10,000+	.25	.33	.33	.25	.40	.33

OTHER

B181. Income tax rate

Definition

The combined federal and state income tax rate on earnings paid by a telephone company.

Default Value

39.25%

B182. Variable overhead factor

Definition

Forward-looking corporate overhead costs, expressed as a fraction of the sum of all capital costs and operations expenses calculated by the model.

Default Value

10.4%

B183. Other taxes factor

Definition

Operating taxes (primarily gross receipts and property taxes) paid by a telephone company in addition to federal and state income taxes.

Default Value

5%

B184. Billing/bill inquiry per line per month

Definition

The cost of bill generation and billing inquiries for end users, expressed as an amount per line per month.

Default Value

$1.22

B185. Directory listing per line per month

Definition

The monthly cost of creating and maintaining white pages listings on a per line, per month basis that is to be eligible for universal service support.

Default Value

$0.00

B186. Forward-looking network operations factor

Definition

The forward-looking factor applied to a specific category of expenses reported in ARMIS called Network Operations. The factor is expressed as the percentage of current ARMIS-reported Network Operations.

Default Value

50%

B187. Alternative Central office switching expense factor

Definition

The expense to investment ratio for digital switching equipment, used as an alternative to the ARMIS expense ratio, reflecting forward looking rather than embedded costs. Thus, this factor multiplies the calculated investment in digital switching in order to determine the monthly expense associated with digital switching. This factor is not intended to capture the cost of software upgrades to the switch, as all switching software is part of the capital value inputs to HM 5.0a.

Default Value

2.69%

B188. Alternative circuit equipment factor

Definition

The expense to investment ratio for all circuit equipment (as categorized by LECs in their ARMIS reports), used as an alternative to the ARMIS expense ratio to reflect forward looking rather than embedded costs.

Default Value

0.0153

B189. End office non line-port cost fraction

Definition

The fraction of the total investment in digital switching that is assumed to be not related to the connection of lines to the switch.

Default Value

70%

B190. Per-line monthly LNP cost

Definition

The estimated cost of permanent Local Number Portability (LNP), expressed on a per-line, per-month basis, including the costs of implementing and maintaining the service. This is included in the USF calculations only, not the UNE rates, because it will be included in the definition of universal service once the service is implemented.

Default Value

$0.25

B191. Carrier-carrier customer service per line

Definition

The yearly amount of customer operations expense associated with the provision of unbundled network elements by the LECs to carriers who purchase those elements.

Default Value

$1.69

B192. NID expense per line per year

Definition

The estimated annual NID expense on a per line basis, based on an analysis of ARMIS data modified to reflect forward looking costs. This is for the NID only, not the drop wire, which is included in the ARMIS cable and wire account.

Default Value

$1.00/line/year

B193. DS-0/DS-1 Terminal Factor

Definition

The relative terminal investment per DS-0, between the DS-1 and DS-0 levels.

Default Value

12.4

B194. DS-1/DS-3 Terminal Factor

Definition

The relative investment per DS-0, between the DS-3 and DS-1 levels.

Default

9.9

B195. Average Lines per Business Location

Definition

The average number of business lines per business location, used to calculate NID and drop cost. This parameter should be set the same as B6.

Default

4

B196. Average trunk utilization

Definition

The 24 hour average utilization of an interoffice trunk.

Default Value

0.30

EXCAVATION AND RESTORATION PARAMETERS

B197. Underground Excavation, Cost per Foot

Definition

The cost per foot to dig a trench in connection with building an underground conduit system to facilitate the placement of underground cables. Cutting the surface, placing the 4" PVC conduit pipes, backfilling the trench with appropriately screened fill, and restoring surface conditions is covered in the following section titled, "Underground Restoration Cost per Foot." These two sections do not include the material cost of the PVC conduit pipe, which is covered under "Conduit Material Investment per foot."

Default Value

Underground Excavation Costs per Foot						
Density	Normal Trenching		Backhoe		Hand Trench	
Range	Fraction	Per Foot	Fraction	Per Foot	Fraction	Per Foot
0-5	*54%*	$1.90	45%	$3.00	1%	$5.00
5-100	*54%*	$1.90	45%	$3.00	1%	$5.00
100-200	*54%*	$1.90	45%	$3.00	1%	$5.00
200-650	*52%*	$1.90	45%	$3.00	3%	$5.00
650-850	*52%*	$1.95	45%	$3.00	3%	$5.00
850-2,550	*50%*	$2.15	45%	$3.00	5%	$5.00
2,550-5,000	*35%*	$2.15	55%	$3.00	10%	$5.00
5,000-10,000	*23%*	$6.00	67%	$20.00	10%	$10.00
10,000+	*16%*	$6.00	72%	$30.00	12%	$18.00

Note: Fraction % for Trenching is the fraction remaining after subtracting Backhoe % & Trench %.

B198. Underground Restoration, Cost per Foot

Definition

The cost per foot to cut the surface, place the 4” PVC conduit pipes, backfill the trench with appropriately screened fill, and restore surface conditions. Digging a trench in connection with building an underground conduit system to facilitate the placement of underground cables is covered in the preceding section titled, "Distribution Underground Excavation Cost per Foot." These two sections do not include the material cost of the PVC conduit pipe, which is covered under “Conduit Material Investment per foot.”

Default Value

Underground Restoration Costs per Foot												
	Cut/Restore Asphalt		Cut/Restore Concrete		Cut/Restore Sod		Simple Backfill		Conduit Placement & Stabilization			
Density Range	Frac-tion	Per Foot	Frac-tion	Per Foot	Frac-tion	Per Foot	Frac-tion	Per Foot	Frac-tion	Pave-ment/ft	Frac-tion	Dirt/ft
0-5	55%	$6.00	10%	$9.00	1%	$1.00	*34%*	$0.15	*65%*	$5.00	*35%*	$1.00
5-100	55%	$6.00	10%	$9.00	1%	$1.00	*34%*	$0.15	*65%*	$5.00	*35%*	$1.00
100-200	55%	$6.00	10%	$9.00	1%	$1.00	*34%*	$0.15	*65%*	$5.00	*35%*	$1.00
200-650	65%	$6.00	10%	$9.00	3%	$1.00	*22%*	$0.15	*75%*	$5.00	*25%*	$1.00
650-850	70%	$6.00	10%	$9.00	4%	$1.00	*16%*	$0.15	*80%*	$5.00	*20%*	$1.00
850-2,550	75%	$6.00	10%	$9.00	6%	$1.00	*9%*	$0.15	*85%*	$9.00	*15%*	$4.00
2,550-5,000	75%	$6.00	15%	$9.00	4%	$1.00	*6%*	$0.15	*90%*	$13.00	*10%*	$11.00
5,000-10,000	80%	$18.00	15%	$21.00	2%	$1.00	*3%*	$0.15	*95%*	$17.00	*5%*	$12.00
10,000+	82%	$30.00	16%	$36.00	0%	$1.00	*2%*	$0.15	*98%*	$20.00	*2%*	$16.00

Note: Fraction % for Simple Backfill is the fraction remaining after subtracting Asphalt % & Concrete % & Sod %. Fraction % for Conduit Placement & Stabilization for Pavement is Asphalt % + Concrete %. Dirt is Sod % + Simple Backfill %

B199. Buried Excavation, Cost per Foot

Definition

The cost per foot to dig a trench to allow buried placement of cables, or the plowing of one or more cables into the earth using a single or multiple sheath plow.

Default Value

Buried Excavation Costs per Foot												
	Plow		Normal Trench		Backhoe		Hand Trench		Bore Cable		Push Pipe/Pull Cbl	
Density Range	Frac-tion	Per Foot	Frac-tion	Per Foot	Frac-tion	Per Foot	Frac-tion	Per Foot	Frac-tion	Per Foot	Frac-tion	Per Foot
0-5	60%	$0.80	*28%*	$1.90	10%	$3.00	0%	$5.00	0%	$11.00	2 %	$6.00
5-100	60%	$0.80	*28%*	$1.90	10%	$3.00	0%	$5.00	0%	$11.00	2%	$6.00
100-200	60%	$0.80	*28%*	$1.90	10%	$3.00	0%	$5.00	0%	$11.00	2%	$6.00
200-650	50%	$0.80	*37%*	$1.90	10%	$3.00	1%	$5.00	0%	$11.00	2%	$6.00
650-850	35%	$0.80	*51%*	$1.95	10%	$3.00	2%	$5.00	0%	$11.00	2%	$6.00
850-2,550	20%	$1.20	*59%*	$2.15	10%	$3.00	4%	$5.00	3%	$11.00	4%	$6.00
2,550-5,000	0%	$1.20	*76%*	$2.15	10%	$3.00	5%	$5.00	4%	$11.00	5%	$6.00
5,000-10,000	0%	$1.20	*73%*	$6.00	10%	$20.00	6%	$10.00	5%	$11.00	6%	$6.00
10,000+	0%	$1.20	*54%*	$15.00	25%	$30.00	10%	$18.00	5%	$18.00	6%	$24.00

Note: Fraction % for Normal Trenching is the fraction remaining after subtracting Plow %, Backhoe %, Hand Trench %, Bore Cable % and Push Pipe / Pull Cable %.

B200. Buried Installation and Restoration, Cost per Foot

Definition

The cost per foot to push pipe under pavement , or the costs per foot to cut the surface, place cable in a trench, backfill the trench with appropriately screened fill, and restore surface conditions. Digging a trench in connection with placing buried cable is covered in the preceding section titled, "Distribution Buried Excavation Cost per Foot".

Default Value

Buried Installation and Restoration Costs per Foot										
	Cut/Restore Asphalt		Cut/Restore Concrete		Cut/Restore Sod		Simple Backfill		Restoral Not Req'd
Density Range	Frac-tion	Per Foot	Frac-tion	Per Foot	Frac-tion	Per Foot	Frac-tion	Per Foot	Fraction
0-5	3%	$6.00	1%	$9.00	2%	$1.00	32%	$0.15	62%
5-100	3%	$6.00	1%	$9.00	2%	$1.00	32%	$0.15	62%
100-200	3%	$6.00	1%	$9.00	2%	$1.00	32%	$0.15	62%
200-650	3%	$6.00	1%	$9.00	2%	$1.00	42%	$0.15	52%
650-850	3%	$6.00	1%	$9.00	2%	$1.00	57%	$0.15	37%
850-2,550	5%	$6.00	3%	$9.00	35%	$1.00	30%	$0.15	27%
2,550-5,000	8%	$6.00	5%	$9.00	35%	$1.00	43%	$0.15	9%
5,000-10,000	18%	$18.00	8%	$21.00	11%	$1.00	52%	$0.15	11%
10,000+	60%	$30.00	20%	$36.00	5%	$1.00	4%	$0.15	11%

Note: Restoral is not required for plowing, boring, or pushing pipe & pulling cable. Fraction for Simple Backfill is the fraction remaining after subtracting Restoral Not Required fraction and the cut/restore activities fractions.

B201. Surface Texture Effect

Definition

The increase in placement cost attributable to the soil condition in a main cluster and its associated outlier clusters, expressed as a multiplier of a fraction of all buried or underground structure excavation components in the clusters. The multiplier appears in the "Effect" column, and the fraction appears in the "Fraction of Cluster Affected" column. The surface conditions are determined from the CBG to which the clusters belong.

Default Value

Fraction Clus-ter Affected	Effect	Texture	Description of Texture
1.00	1.00		Blank
1.00	1.00	BY	Bouldery
1.00	1.00	BY-COS	Bouldery Coarse Sand
1.00	1.00	BY-FSL	Bouldery & Fine Sandy Loam
1.00	1.00	BY-L	Bouldery & Loam
1.00	1.00	BY-LS	Bouldery & Sandy Loam
1.00	1.00	BY-SICL	Bouldery & Silty Clay Loam
1.00	1.00	BY-SL	Bouldery & Sandy Loam
1.00	1.10	BYV	Very Bouldery
1.00	1.10	BYV-FSL	Very Bouldery & Fine Sandy Loam
1.00	1.10	BYV-L	Very bouldery & Loamy
1.00	1.10	BYV-LS	Very Bouldery & Loamy Sand
1.00	1.10	BYV-SIL	Very Bouldery & Silt
1.00	1.10	BYV-SL	Very Bouldery & Sandy Loam
1.00	1.30	BYX	Extremely Bouldery

Fraction Cluster Affected	Effect	Texture	Description of Texture
1.00	1.30	BYX-FSL	Extremely Bouldery & Fine Sandy Loam
1.00	1.30	BYX-L	Extremely Bouldery & Loamy
1.00	1.30	BYX-SIL	Extremely Bouldery & Silt Loam
1.00	1.30	BYX-SL	Extremely Bouldery & Sandy Loam
1.00	1.00	C	Clay
1.00	1.00	CB	Cobbly
1.00	1.00	CB-C	Cobbly & Clay
1.00	1.00	CB-CL	Cobbly & Clay Loam
1.00	1.00	CB-COSL	Cobbly & Coarse Sandy Loam
1.00	1.10	CB-FS	Cobbly & Fine Sand
1.00	1.10	CB-FSL	Cobbly & Fine Sandy Loam
1.00	1.00	CB-L	Cobbly & Loamy
1.00	1.00	CB-LCOS	Cobbly & Loamy coarseSand
1.00	1.00	CB-LS	Cobbly & Loamy Sand
1.00	1.10	CB-S	Cobbly & Sand
1.00	1.00	CB-SCL	Cobbly & Sandy Clay Loam
1.00	1.00	CB-SICL	Cobbly & Silty Clay Loam
1.00	1.00	CB-SIL	Cobbly & Silt Loam
1.00	1.10	CB-SL	Cobbly & Sandy Loam
1.00	1.00	CBA	Angular Cobbly
1.00	1.10	CBA-FSL	Angular Cobbly & Fine Sandy Loam
1.00	1.20	CBV	Very Cobbly
1.00	1.20	CBV-C	Very Cobbly & Clay
1.00	1.20	CBV-CL	Very Cobbly & Clay Loam
1.00	1.20	CBV-FSL	Very Cobbly & Fine Sandy Loam
1.00	1.20	CBV-L	Very Cobbly & Loamy
1.00	1.20	CBV-LFS	Very Cobbly & Fine Loamy Sand
1.00	1.20	CBV-LS	Very Cobbly & Loamy Sand
1.00	1.20	CBV-MUCK	Very Cobbly & Muck
1.00	1.20	CBV-SCL	Very Cobbly & Sandy Clay Loam
1.00	1.20	CBV-SIL	Very Cobbly & Silt
1.00	1.20	CBV-SL	Very Cobbly & Sandy Loam
1.00	1.20	CBV-VFS	Very Cobbly & Very Fine Sand
1.00	1.20	CBX	Extremely Cobbly
1.00	1.20	CBX-CL	Extremely Cobbly & Clay
1.00	1.20	CBX-L	Extremely Cobbly Loam
1.00	1.20	CBX-SIL	Extremely Cobbly & Silt
1.00	1.20	CBX-SL	Extremely Cobbly &Sandy Loam
1.00	1.30	CBX-VFSL	Extremely Cobbly Very Fine Sandy Loam
1.00	1.00	CE	Coprogenous Earth
1.00	1.00	CIND	Cinders
1.00	1.00	CL	Clay Loam
1.00	1.30	CM	Cemented
1.00	1.00	CN	Channery

Fraction Cluster Affected	Effect	Texture	Description of Texture
1.00	1.00	CN-CL	Channery & Clay Loam
1.00	1.10	CN-FSL	Channery & Fine Sandy Loam
1.00	1.00	CN-L	Channery & Loam
1.00	1.00	CN-SICL	Channery & Silty Clay Loam
1.00	1.00	CN-SIL	Channery & Silty Loam
1.00	1.00	CN-SL	Channery & Sandy Loam
1.00	1.00	CNV	Very Channery
1.00	1.00	CNV-CL	Very Channery & Clay
1.00	1.00	CNV-L	Very Channery & Loam
1.00	1.00	CNV-SCL	Channery & Sandy Clay Loam
1.00	1.00	CNV-SIL	Very Channery & Silty Loam
1.00	1.00	CNV-SL	Very Channery & Sandy Loam
1.00	1.00	CNX	Extremely Channery
1.00	1.00	CNX-SL	Extremely Channery & Sandy Loam
1.00	1.00	COS	Coarse Sand
1.00	1.00	COSL	Coarse Sandy Loam
1.00	1.20	CR	Cherty
1.00	1.20	CR-L	Cherty & Loam
1.00	1.20	CR-SICL	Cherty & Silty Clay Loam
1.00	1.20	CR-SIL	Cherty & Silty Loam
1.00	1.20	CR-SL	Cherty & Sandy Loam
1.00	1.20	CRC	Coarse Cherty
1.00	1.20	CRV	Very Cherty
1.00	1.20	CRV-L	Very Cherty & Loam
1.00	1.20	CRV-SIL	Very Cherty & Silty Loam
1.00	1.30	CRX	Extremely Cherty
1.00	1.30	CRX-SIL	Extremely Cherty & Silty Loam
1.00	1.00	DE	Diatomaceous Earth
1.00	1.00	FB	Fibric Material
1.00	1.00	FINE	Fine
1.00	1.00	FL	Flaggy
1.00	1.10	FL-FSL	Flaggy & Fine Sandy Loam
1.00	1.00	FL-L	Flaggy & Loam
1.00	1.00	FL-SIC	Flaggy & Silty Clay
1.00	1.00	FL-SICL	Flaggy & Silty Clay Loam
1.00	1.00	FL-SIL	Flaggy & Silty Loam
1.00	1.00	FL-SL	Flaggy & Sandy Loam
1.00	1.10	FLV	Very Flaggy
1.00	1.10	FLV-COSL	Very Flaggy & Coarse Sandy Loam
1.00	1.10	FLV-L	Very Flaggy & Loam
1.00	1.10	FLV-SICL	Very Flaggy & Silty Clay Loam
1.00	1.10	FLV-SL	Very Flaggy & Sandy Loam
1.00	1.10	FLX	Extremely Flaggy
1.00	1.10	FLX-L	Extremely Flaggy & Loamy

Fraction Cluster Affected	Effect	Texture	Description of Texture
1.00	1.00	FRAG	Fragmental Material
1.00	1.10	FS	Fine Sand
1.00	1.10	FSL	Fine Sandy Loam
1.00	1.00	G	Gravel
1.00	1.00	GR	Gravelly
1.00	1.00	GR-C	Gravel & Clay
1.00	1.00	GR-CL	Gravel & Clay Loam
1.00	1.00	GR-COS	Gravel & Coarse Sand
1.00	1.00	GR-COSL	Gravel & Coarse Sandy Loam
1.00	1.00	GR-FS	Gravel & Fine Sand
1.00	1.00	GR-FSL	Gravel & Fine Sandy Loam
1.00	1.00	GR-L	Gravel & Loam
1.00	1.00	GR-LCOS	Gravel & Loamy Coarse Sand
1.00	1.10	GR-LFS	Gravel & Loamy Fine Sand
1.00	1.00	GR-LS	Gravel & Loamy Sand
1.00	1.00	GR-MUCK	Gravel & Muck
1.00	1.00	GR-S	Gravel & Sand
1.00	1.00	GR-SCL	Gravel & Sandy Clay Loam
1.00	1.00	GR-SIC	Gravel & Silty Clay
1.00	1.00	GR-SICL	Gravel & Silty Clay Loam
1.00	1.00	GR-SIL	Gravel & Silty Loam
1.00	1.00	GR-SL	Gravel & Sandy Loam
1.00	1.10	GR-VFSL	Gravel & Very Fine Sandy Loam
1.00	1.00	GRC	Coarse Gravelly
1.00	1.00	GRF	Fine Gravel
1.00	1.00	GRF-SIL	Fine Gravel Silty Loam
1.00	1.00	GRV	Very Gravelly
1.00	1.00	GRV-CL	Very gravelly & Clay Loam
1.00	1.00	GRV-COS	Very Gravelly & coarse Sand
1.00	1.00	GRV-COSL	Very Gravelly & coarse Sandy Loam
1.00	1.00	GRV-FSL	Very Gravelly & Fine Sandy Loam
1.00	1.00	GRV-L	Very Gravelly & Loam
1.00	1.00	GRV-LCOS	Very Gravelly & Loamy Coarse Sand
1.00	1.00	GRV-LS	Very Gravelly & Loamy Sand
1.00	1.00	GRV-S	Very Gravelly & Sand
1.00	1.00	GRV-SCL	Very Gravelly & Sandy Clay Loam
1.00	1.00	GRV-SICL	Very Gravelly & Silty Clay Loam
1.00	1.00	GRV-SIL	Very Gravelly & Silt
1.00	1.00	GRV-SL	Very Gravelly & Sandy Loam
1.00	1.00	GRV-VFS	Very Gravelly & Very Fine Sand
1.00	1.00	GRV-VFSL	Very Gravelly & Very Fine Sandy Loam
1.00	1.10	GRX	Extremely Gravelly
1.00	1.10	GRX-CL	Extremely Gravelly & Coarse Loam
1.00	1.10	GRX-COS	Extremely Gravelly & Coarse Sand

Fraction Cluster Affected	Effect	Texture	Description of Texture
1.00	1.10	GRX-COSL	Extremely Gravelly & Coarse Sandy Loam
1.00	1.10	GRX-FSL	Extremely Gravelly & Fine Sand Loam
1.00	1.10	GRX-L	Extremely Gravelly & Loam
1.00	1.10	GRX-LCOS	Extremely Gravelly & Loamy Coarse
1.00	1.10	GRX-LS	Extremely Gravelly & Loamy Sand
1.00	1.10	GRX-S	Extremely Gravelly & Sand
1.00	1.10	GRX-SIL	Extremely Gravelly & Silty Loam
1.00	1.10	GRX-SL	Extremely Gravelly & Sandy Loam
1.00	1.20	GYP	Gypsiferous Material
1.00	1.00	HM	Hemic Material
1.00	1.50	ICE	Ice or Frozen Soil
1.00	1.20	IND	Indurated
1.00	1.00	L	Loam
1.00	1.00	LCOS	Loamy Coarse Sand
1.00	1.10	LFS	Loamy Fine Sand
1.00	1.00	LS	Loamy Sand
1.00	1.00	LVFS	Loamy Very Fine Sand
1.00	1.00	MARL	Marl
1.00	1.00	MEDIUM coarse	Medium Coarse
1.00	1.00	MK	Mucky
1.00	1.00	MK-C	Mucky Clay
1.00	1.00	MK-CL	Mucky Clay Loam
1.00	1.00	MK-FS	Muck & Fine Sand
1.00	1.00	MK-FSL	Muck & Fine Sandy Loam
1.00	1.00	MK-L	Mucky Loam
1.00	1.00	MK-LFS	Mucky Loamy Fine Sand
1.00	1.00	MK-LS	Mucky Loamy Sand
1.00	1.00	MK-S	Muck & Sand
1.00	1.00	MK-SI	Mucky & Silty
1.00	1.00	MK-SICL	Mucky & Silty Clay Loam
1.00	1.00	MK-SIL	Mucky Silt
1.00	1.00	MK-SL	Mucky & Sandy Loam
1.00	1.00	MK-VFSL	Mucky & Very Fine Sandy Loam
1.00	1.00	MPT	Mucky Peat
1.00	1.00	MUCK	Muck
1.00	1.00	PEAT	Peat
1.00	1.00	PT	Peaty
1.00	1.50	RB	Rubbly
1.00	1.50	RB-FSL	Rubbly Fine Sandy Loam
1.00	1.00	S	Sand
1.00	1.00	SC	Sandy Clay
1.00	1.00	SCL	Sandy Clay Loam
1.00	1.00	SG	Sand & Gravel
1.00	1.00	SH	Shaly

Fraction Cluster Affected	Effect	Texture	Description of Texture
1.00	1.00	SH-CL	Shaly & Clay
1.00	1.00	SH-L	Shale & Loam
1.00	1.00	SH-SICL	Shaly & Silty Clay Loam
1.00	1.00	SH-SIL	Shaly & Silt Loam
1.00	1.50	SHV	Very Shaly
1.00	1.50	SHV-CL	Very Shaly & Clay Loam
1.00	2.00	SHX	Extremely Shaly
1.00	1.00	SI	Silt
1.00	1.00	SIC	Silty Clay
1.00	1.00	SICL	Silty Clay Loam
1.00	1.00	SIL	Silt Loam
1.00	1.00	SL	Sandy Loam
1.00	1.00	SP	Sapric Material
1.00	1.00	SR	Stratified
1.00	1.00	ST	Stony
1.00	1.00	ST-C	Stony & Clay
1.00	1.00	ST-CL	Stony & Clay Loam
1.00	1.00	ST-COSL	Stony & Coarse Sandy Loam
1.00	1.10	ST-FSL	Stony & Fine Sandy Loam
1.00	1.00	ST-L	Stony & Loamy
1.00	1.00	ST-LCOS	Stony & Loamy Coarse Sand
1.00	1.10	ST-LFS	Stony & Loamy Fine Sand
1.00	1.00	ST-LS	Stony & Loamy Sand
1.00	1.00	ST-SIC	Stony & Silty Clay
1.00	1.00	ST-SICL	Stony & Silty Clay Loam
1.00	1.00	ST-SIL	Stony & Silt Loam
1.00	1.00	ST-SL	Stony & Sandy Loam
1.00	1.10	ST-VFSL	Stony & Sandy Very Fine Silty Loam
1.00	1.20	STV	Very Stony
1.00	1.20	STV-C	Very Stony & Clay
1.00	1.20	STV-CL	Very Stony & Clay Loam
1.00	1.20	STV-FSL	Very Stony & Fine Sandy Loam
1.00	1.20	STV-L	Very Stony & Loamy
1.00	1.20	STV-LFS	Very Stony & Loamy Fine Sand
1.00	1.20	STV-LS	Very Stony & Loamy Sand
1.00	1.20	STV-MPT	Very Stony & Mucky Peat
1.00	1.20	STV-MUCK	Very Stony & Muck
1.00	1.20	STV-SICL	Very Stony & Silty Clay Loam
1.00	1.20	STV-SIL	Very Stony & Silty Loam
1.00	1.20	STV-SL	Very Stony & Sandy Loam
1.00	1.20	STV-VFSL	Very Stony & Very Fine Sandy Loam
1.00	1.30	STX	Extremely Stony
1.00	1.30	STX-C	Extremely Stony & Clay
1.00	1.30	STX-CL	Extremely Stony & Clay Loam

Fraction Cluster Affected	Effect	Texture	Description of Texture
1.00	1.30	STX-COS	Extremely Stony & Coarse Sand
1.00	1.30	STX-COSL	Extremely Stony & Coarse Sand Loam
1.00	1.30	STX-FSL	Extremely Stony & Fine Sandy Loam
1.00	1.30	STX-L	Extremely Stony & Loamy
1.00	1.30	STX-LCOS	Extremely Stony & Loamy Coarse Sand
1.00	1.30	STX-LS	Extremely Stony & Loamy Sand
1.00	1.30	STX-MUCK	Extremely Stony & Muck
1.00	1.30	STX-SIC	Extremely Stony & Silty Clay
1.00	1.30	STX-SICL	Extremely Stony & Silty Clay Loam
1.00	1.30	STX-SIL	Extremely Stony & Silty Loam
1.00	1.30	STX-SL	Extremely Stony & Sandy Loam
1.00	1.30	STX-VFSL	Extremely Stony & Very Fine Sandy Loam
1.00	3.00	SY	Slaty
1.00	3.00	SY-L	Slaty & Loam
1.00	3.00	SY-SIL	Slaty & Silty Loam
1.00	3.50	SYV	Very Slaty
1.00	4.00	SYX	Extremely Slaty
1.00	1.00	UNK	Unknown
1.00	2.00	UWB	Unweathered Bedrock
1.00	1.00	VAR	Variable
1.00	1.00	VFS	Very Fine Sand
1.00	1.00	VFSL	Very Fine Sandy loam
1.00	3.00	WB	Weathered Bedrock

LABOR ADJUSTMENT FACTOR

B16. Regional Labor Adjustment Factors

Definition

Factors that adjust a specific portion of certain investments by a labor factor adjustment that account for regional differences in the availability of trained labor, union contracts, and cost of living factors. Both the portions of different categories of investments that are affected and the size of adjustment are included as parameters.

Default Value

Regional Labor Adjustment Factor	
Factor	1.0

B16a. Labor Adjustment Factor Weightings

Definition

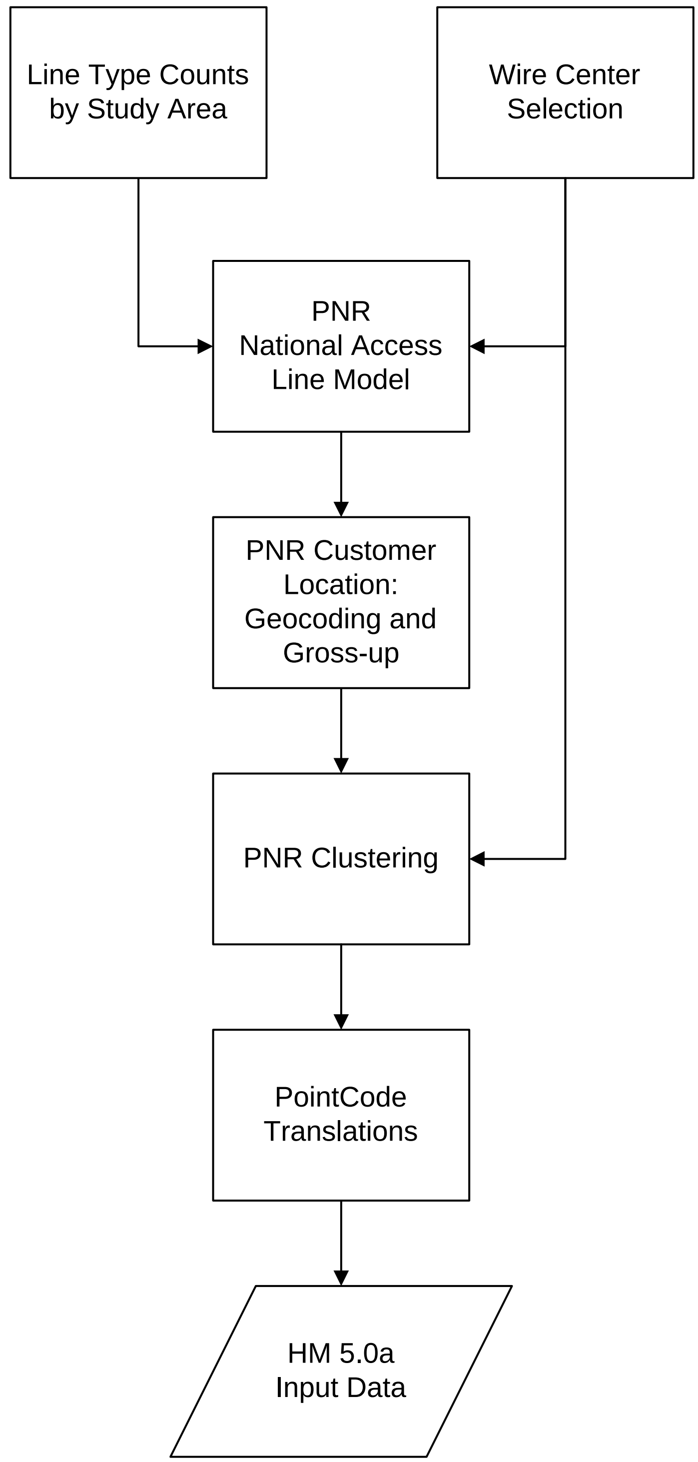
The fraction of the installed investment affected by the regional labor adjustment factor.

Default Value

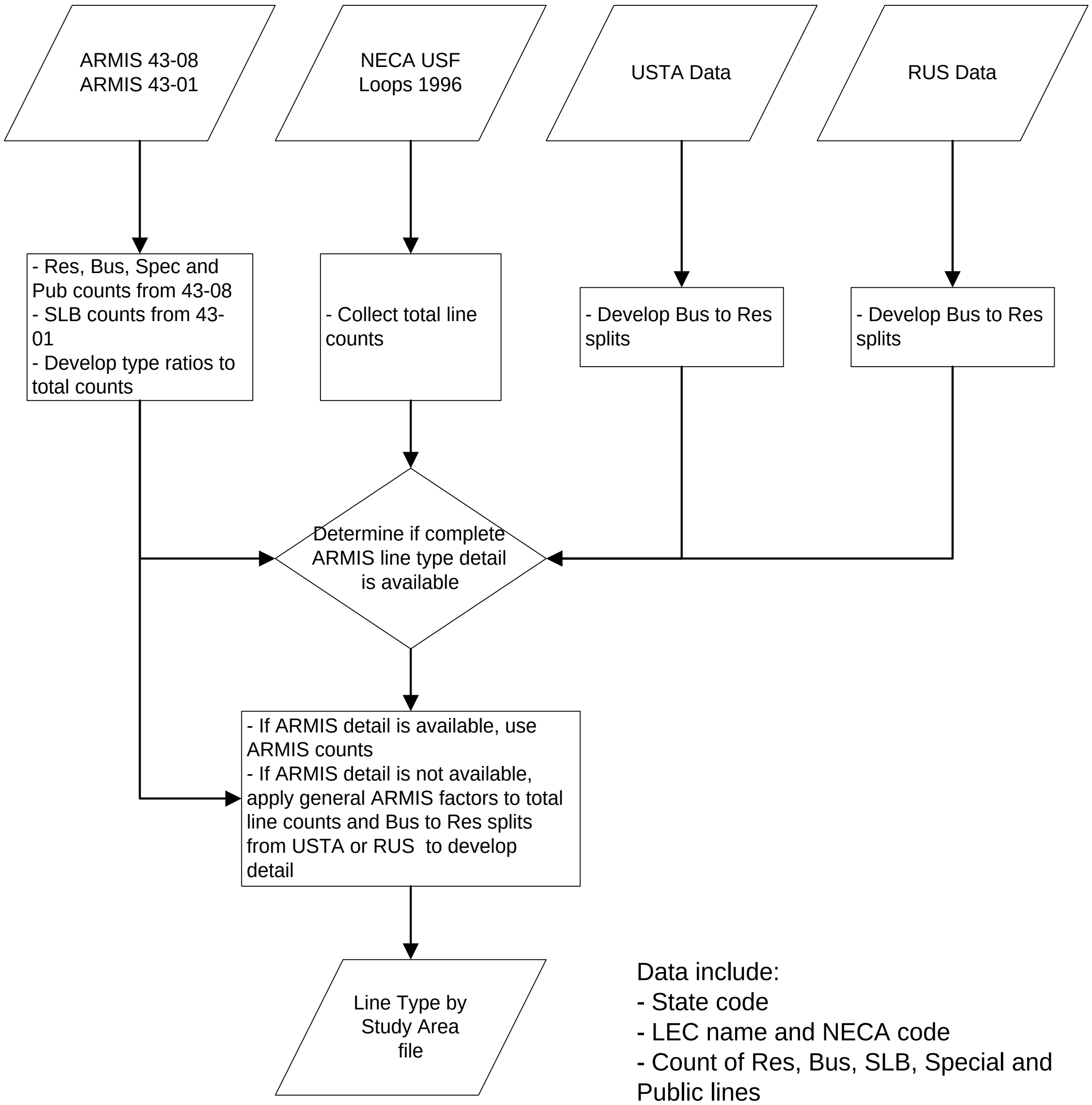
Regional Labor Adjustment Factor Fraction of Installed Investment Affected	
Contractor Trenching	.125
Telco Construction – Copper	.164
Telco Construction – Fiber	.364
Telco I&M – NID & Drop	.571
Pole Placing	.518

Index **Page #**

OVERALL INPUT DATA DEVELOPMENT PROCESS

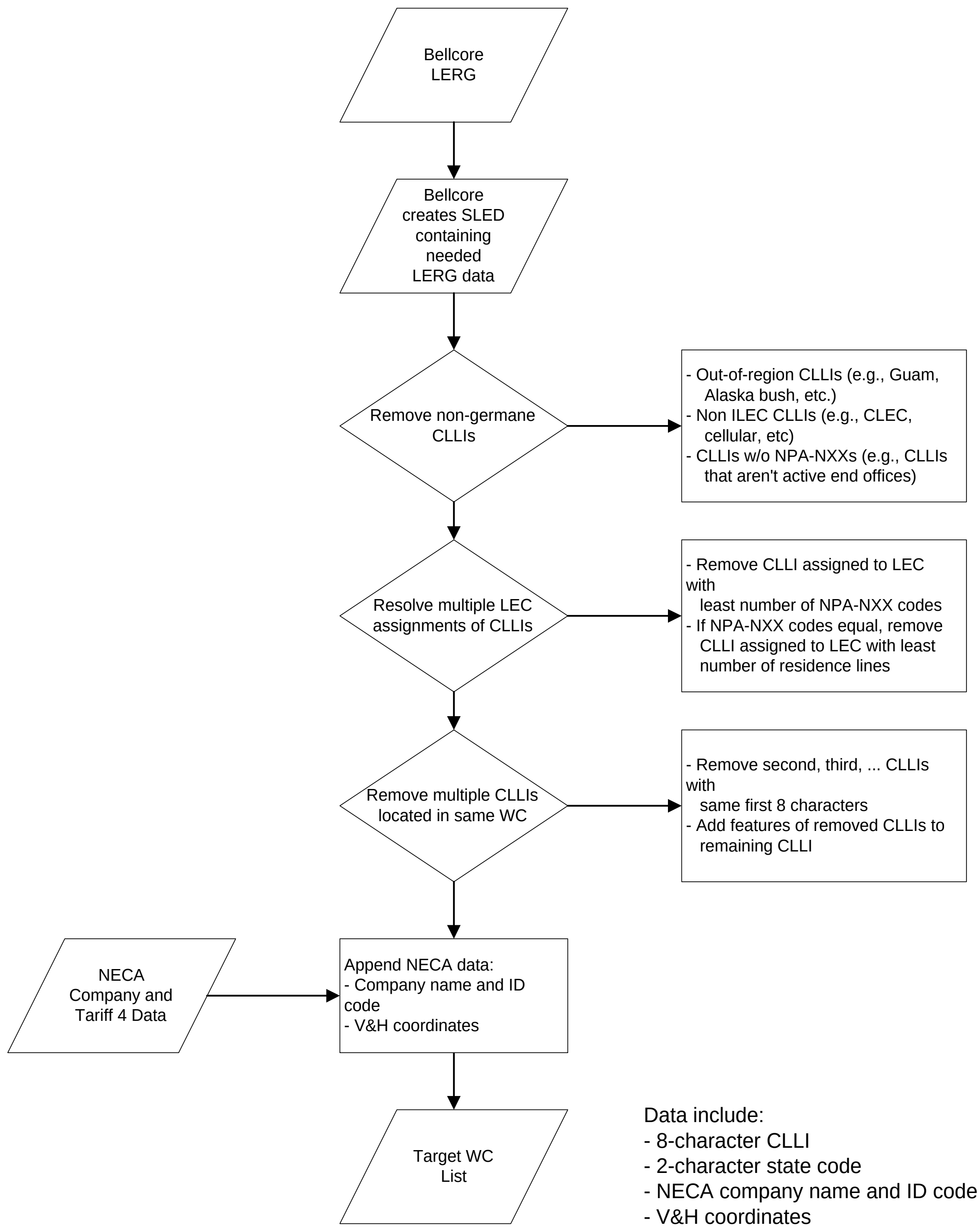


LINE TYPE COUNTS BY STUDY AREA

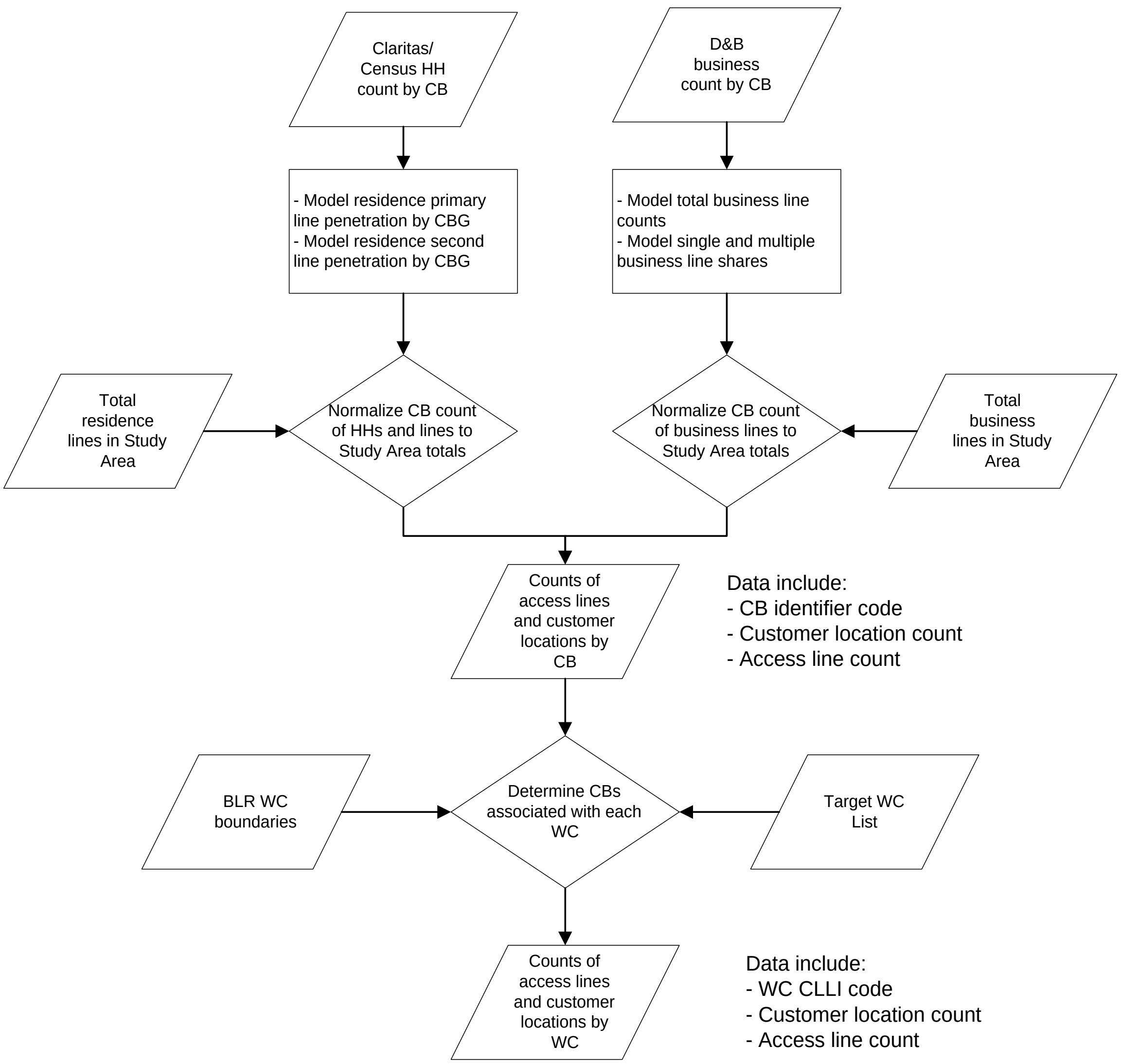


Data include:
- State code
- LEC name and NECA code
- Count of Res, Bus, SLB, Special and Public lines

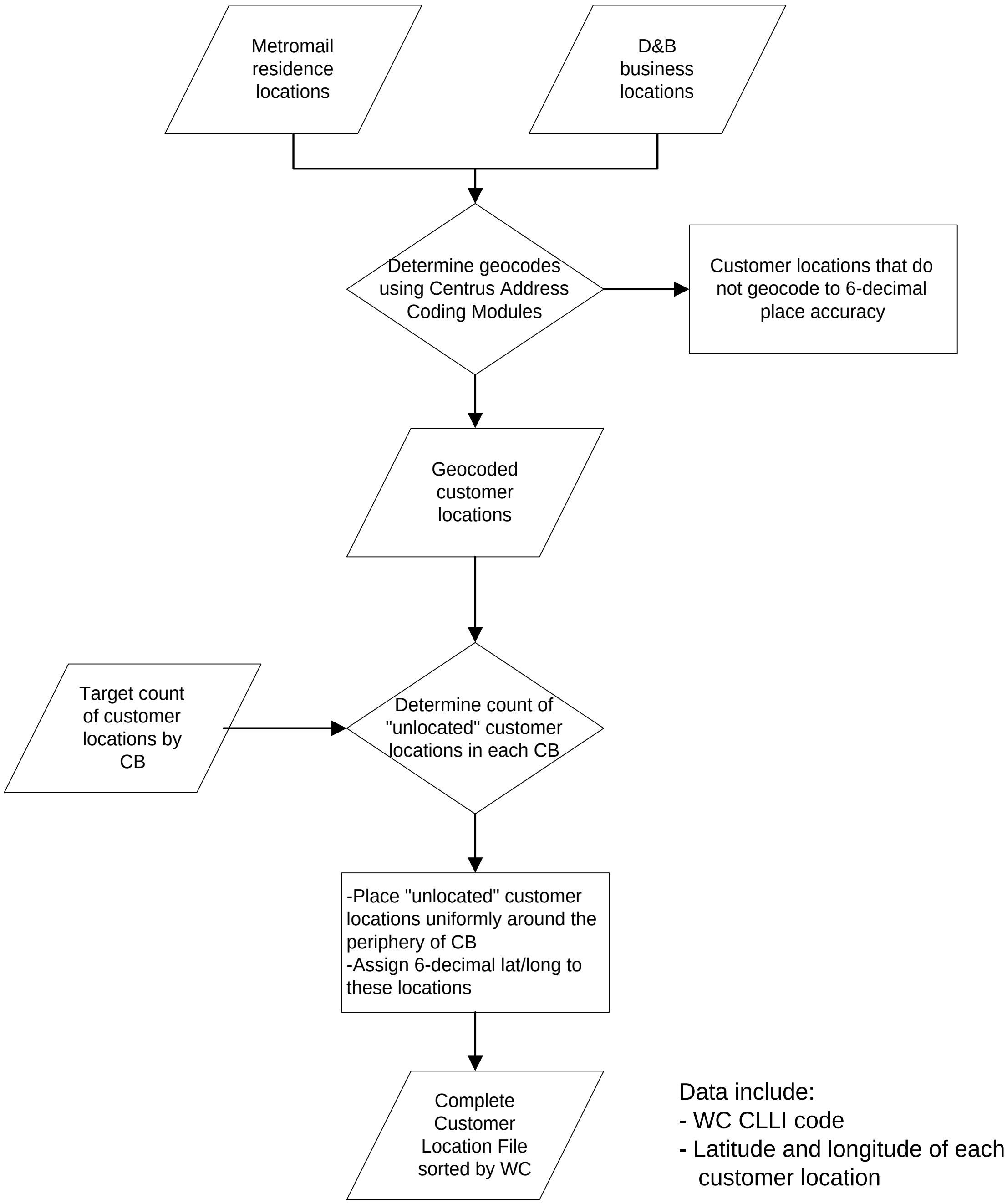
WIRE CENTER SELECTION PROCESS



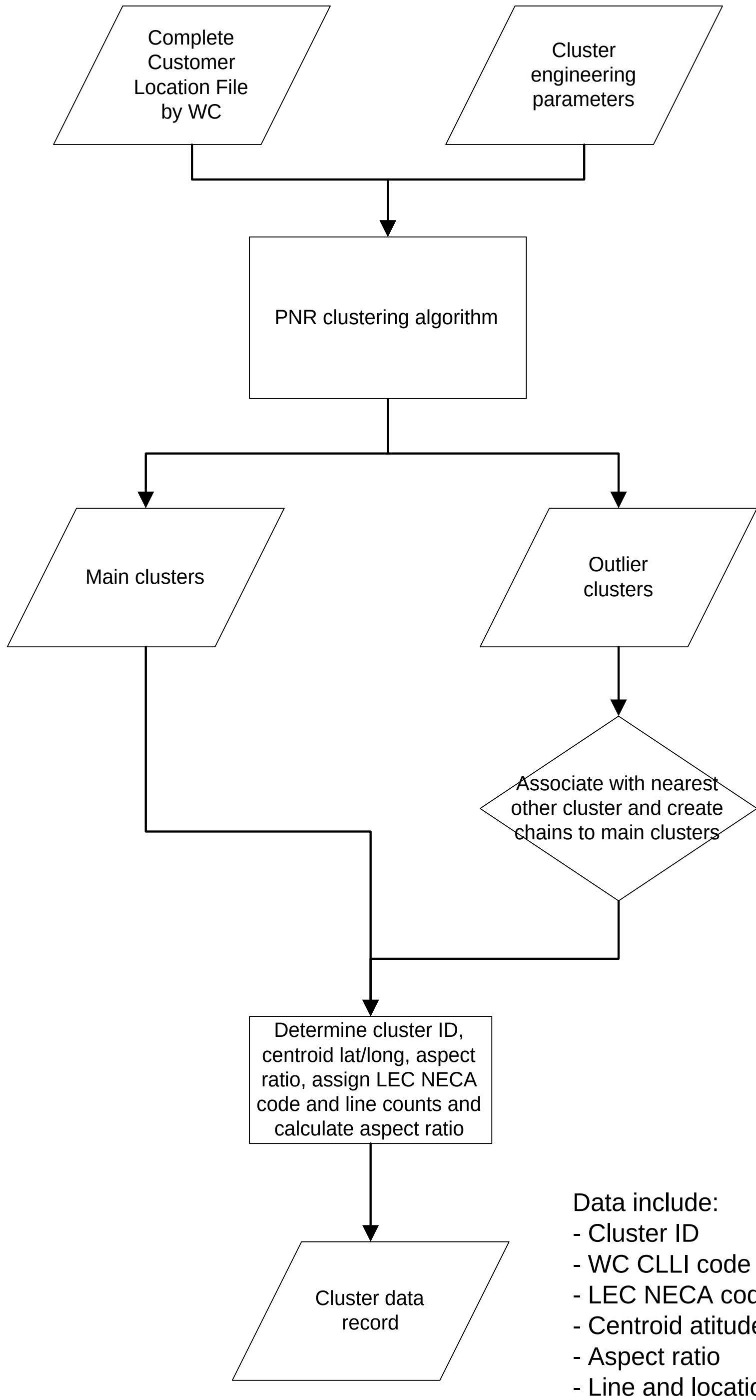
PNR NATIONAL ACCESS LINE MODEL DEVELOPMENT PROCESS



GEOCODE AND GROSS-UP PROCESS

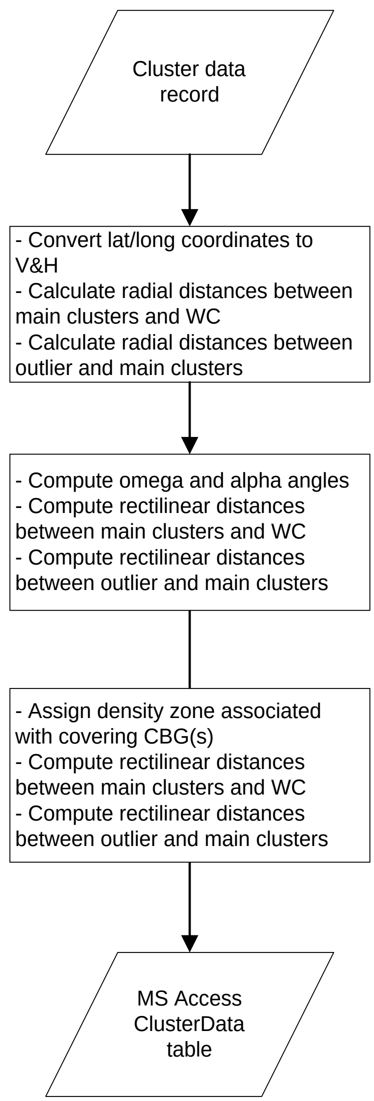


CLUSTERING PROCESS



Data include:
- Cluster ID
- WC CLLI code
- LEC NECA code
- Centroid atitude and longitude
- Aspect ratio
- Line and location counts
- Identity of nearest other cluster

"POINTCODE" PROCESSES



Data include:
- 2-character state code
- 8-character CLLI
- LEC name and NECA code
- Covering CBG ID
- Alpha, omega and radial distance
- Area, aspect ratio, lines density
- Terrain characteristics
- Line, household and housing unit counts
- Firm and employee counts

General Rules Governing the Creation of the HM 5.0a Distance Files

1) Three distances are computed for each wire center (WC). They include WC to tandem WC to OS tandem, and WC to STP locations.

2) The SLED is the official data source for computation of the distance files.

3) BOC WCs home on the nearest BOC tandems and BOC STPs in the same state and LATA. There are some cases where LATA boundaries cross state lines. In this case, BOC WCs will first attempt to home on a tandem or STP in the same state and LATA where the WC is physically located. However, if tandems or STPs do not exist in the same state as the WC, then the WC will home on the nearest BOC tandem and STP pair.

4) Independent WCs will home on the nearest independent tandems and independent STPs in the same state, when such tandem/STP facilities are available. When independent tandem/STP facilities are not available, independent WCs will home on the nearest BOC wire center. In cases where independent wire centers home on BOC wire centers (any of which always have tandem, OS tandem, and STP connectivity), the CLLI of the homed-on BOC wire center will be tracked. LATA boundaries are meaningless when making ICO distance computations.

5) The set of eligible BOC tandems will be the same set used to compute distances in HM 3.1, with the following adjustments: 1) non-ILEC tandems will be removed from the HM 3.1 list of tandems and STPs; and 2) in most cases, at least one BOC tandem/STP pair will be placed in each LATA (in HM 3.1 there were some LATAs without BOC tandems or STPs). The set of eligible independent tandems will consist of all existing independent tandems in the study state.

6) BOCs will be limited to one OS tandem per state in small states (determined by population) and two OS tandems in large states. The set of OS tandems will be hand-selected from the list of current OS tandem locations in the study state. Independent tandem distances will be computed based on the current locations of all independent OS tandems.

7) BOCs will be limited to a single STP pair per LATA. The set of independent STPs is the set of all independent STP pairs in the study state. Embedded STP *pairing* relationships will be maintained for BOCs and independent companies. Note that embedded STP *homing* relationships are not maintained. LATAs without any STP pairs will be assigned a hand-selected pair of wire centers to serve as the STPs. Hand-selection is rare and only occurs in a few areas (i.e., Alaska, Puerto Rico, etc.).

8) There are several cases that must be specifically addressed when creating the distance database. Although these cases are discussed in items 3 and 4 above, they are individually presented here for clarity. The same set of rules apply whether determining distances from WCs to tandems, OS tandems, or STPs. These cases are identified immediately below.

- Case 1: For BOC companies, WC is in the same LATA, same state, and has the same OCN as at least one tandem. The action in this case is to determine the path length to the nearest tandem in this state and LATA, with the same OCN.
- Case 2: For BOC companies, WC is in a different LATA than any BOC tandems in the state. In this case, determine the path length to the nearest BOC tandem in this state. If such a WC belongs to a different BOC than the predominant BOC in the state, the same rule applies.
- Case 3: For ICOs, the WC has a different OCN than any tandem in the state. The action in this case is to determine the path length to the nearest BOC wire center in this state and track the CLLI code of the homed-on BOC wire center.
- Case 4: For ICOs, the WC is in the same state and has the same OCN as at least one tandem. The action in this case is to determine the path length to the nearest tandem in this state with the same OCN.

9) Distances between facilities are computed as right angle runs.

10) WC to STP distances will be computed as the total distance from the WC to each STP in the pair.

11) In cases where one member of the STP pair lies outside of the study state, the distance to the one STP in the state will be doubled as a proxy for the out-of-state STP. Proxy STP pairs will only be used in cases where an actual STP pair is unavailable.

12) Tandem to tandem distances will be computed as a fully-interconnected mesh network of all tandems with the same OCN. BOC tandems will interconnect within LATA boundaries.

Distance File Contents

The following calculated and non-calculated information will be contained in the state-specific distance files:

<u>Calculated Information</u>

1) The WC to tandem homing arrangements that result from the application of the rules defined in this memo. This information is necessary when computing interoffice ring distances.
2) The WC to tandem distance.

3) The WC to STP (A-link) distance.
4) The WC to OS tandem distance.
5) The STP to STP (C-link) distance.
6) The number of tandems by company code.
7) The number of STP pairs by company code.
8) The tandem to tandem distance for a fully-interconnected mesh of tandems by company code.
9) The total tandem to STP (A-link) distance by company code.

Non-Calculated Information

Non calculated information include the NECA data that is necessary for interoffice ring calculations. These data are included for each CLLI in the study state.

1) Vertical coordinate
2) Horizontal Coordinate
3) NECA Company code

Additional Information

The distance file calculations require the following database fields, which are taken from the indicated source.

	Field	Source
-	LATA	SLED
-	OCN	SLED
-	CLLI	SLED
-	STATE	SLED
-	VERTICAL COORDS	SLED
-	HORIZONTAL COORDS	SLED
-	STP PAIRS	LERG
-	OS TANDEM INDICATOR	SLED
-	LOCAL TANDEM INDICATOR	SLED
-	STUDY STATE	USER INPUT
-	BOC OCN	USER INPUT

Workbook: **R50A_distribution.xls**
Worksheet: **cluster input data**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
A	wire center	The data for this sheet is taken from the ClusterData table in the access database.	
B	company		
C	operating company type		
D	CBG geocode		
E	cluster		
F	overall quadrant		
G	overall omega		
H	overall alpha		
I	overall radial dist ft		
J	outlier indicator		
K	cluster quadrant		
L	cluster omega		
M	cluster alpha		
N	outlier radius, ft		
O	area, sq mi		
P	aspect ratio		
Q	spare		
R	density, lines/sq mi		
S	Rock Depth		
T	Rock Hrdns		
U	Surf Tex		
V	Wtr Tbl Dpth		
W	tot lines		
X	total business lines		
Y	residential lines		
Z	special access		
AA	public		
AB	single-line business		
AC	households		
AD	1-hu detach		
AE	1-hu attach		

Workbook: **R50A_distribution.xls**
Worksheet: **cluster input data**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
AF	hu-2		
AG	hu-4		
AH	hu-5-9		
AI	hu 10-19		
AJ	hu-20-49		
AK	hu-50+		
AL	mobile		
AM	other		
AN	businesses		
AO	employees		
AP	cluster fraction of wire center lines		
AQ	average outlier loop length		
AR	total outlier lines		

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
A	CBG	='cluster input data'!D2	repeats principal CBG for cluster
B	cluster	='cluster input data'!E2	repeats cluster or outlier ID from cluster input data
C	Main feeder distance (ft)	=IF(P2=0,'cluster input data'!I2*COS(PI()/180*DM2)*IF(diff_sfc>1,dstnc_mult,1),0)*IF(fdr_steer_enable,fdr_rte_air,1)	Distance along main feeder route from wire center to point at which subfeeder cable departs to connect with cluster; includes adjustments for difficult surface routing increase, if selected, and for route/air ratio, if feeder steering enabled
D	Basic subfeeder distance (ft)	=IF(P2=0,'cluster input data'!I2*SIN(PI()/180*DM2)*IF(diff_sfc>1,dstnc_mult,1),0)	perpendicular distance from main feeder route to center of cluster, adjusted for difficult surface rerouting, if selected
E	Total feeder distance (ft)	=C2+D2	Calculates sum of main and subfeeder distance for cluster
F	Fiber Indicator	=IF(OR(E2>fiber_dist,E2+T2+W2+0.5*AX2+0.5*AW2/U2>max_cu_dstnc,CK2=1,DN2+DP2<DO2),1,0)	Computed value of 1 indicates fiber feeder required for this cluster; fiber required if feeder distance > fiber feeder crossover distance, max distance from wire center to extremity of cluster > maximum allowed copper distance, outliers present, or fiber+DLC costs less than estimated copper feeder life cycle costs
G	aspect ratio	=IF(AND(NOT(rect_clustr_switch),'cluster input data'!P2>0),'cluster input data'!P2,1)	selects input aspect ratio if rectangular cluster calculations are enabled; otherwise, makes clusters square
H	Rock placement multiplier	=IF(rock_hrdns="HARD",hard_plc_mult,soft_plc_mult)	Selects hard rock factor when shown in cluster input data, otherwise inserts soft rock factor for use in calculation of rock multiplier
I	Rock multiplier adjusted for depth	=IF(OR(ISBLANK(rock_depth),rock_depth>bdrock_thresh),1,H2-(H2-1)/bdrock_thresh*rock_depth)	Adjusts rock multiplier linearly with bedrock depth; if bedrock is below placement depth, the factor is unity; at zero depth, the factor is the basic placement factor in column H
J	Difficult surface multiplier	=IF(ISBLANK('cluster input data'!U2),1,IF(ISNA(VLOOKUP('cluster input data'!U2,surf_text,2,FALSE)),1,VLOOKUP('cluster input data'!U2,surf_text,2,FALSE)))	Obtains difficult surface condition placement factor from inputs sheet.
K	Lot frontage, ft	=IF(P2=0,MAX(66,SQRT(0.5*O2)),0)	Computes lot frontage in feet from average lot size using assumption that depth is twice the frontage. Minimum value is 66 feet
L	lot depth, ft	=2*K2	computes lot depth as twice the frontage

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
M	Households	='cluster input data'!AC2	repeats household count from cluster input data
N	Businesses	='cluster input data'!AN2	Repeats total business line count from cluster input data
O	Average cluster lot size, sq ft	='cluster input data'!O2/Q2*5280^2	Computes average lot size from cluster area in cluster input data and computed estimate of subscriber locations within cluster
P	outlier indicator	=IF('cluster input data'!J2=1,1,0)	indicates whether record pertains to cluster or outlier
Q	Total locations	=hh_det+0.5*(hh_att+hh_2+hh_4+hh_59+hh_1019+hh_2049+hh_mob+hh_other+firms)+hh_50/4	Estimates effective number of subscriber locations by weighting different housing types
R	Lines	=lines_adj	total lines, including special access, in cluster or outlier
S	backbone length divisor/RT multiplier	=MAX(1,CEILING((MAX(0,2640*SQRT(clustr_area*aspect)-depth)/(max_cu_dstnc/(1+1/aspect))),1))	backbone cable length divisor, normally unity, computed whenever backbone distance exceeds one-half the user-set maximum cable distance; used to ensure copper distances do not exceed maximum; application divides the length of each backbone cable and increases the number of cables (there are normally two)
T	Backbone cable length	=IF(AND(P2=0,V2>2),MAX(0,2640*SQRT(clustr_area*aspect)-depth)/S2,0)*IF(diff_sfc>1,dstnc_mult,1)	Computes backbone cable distance as distance from center of cluster to point one lot depth from cluster boundary; includes adjustment for aspect ratio if enabled, allowing rectangular clusters
U	branch length divisor/RT multiplier	=MAX(1,CEILING((MAX(0,2640*SQRT(clustr_area/aspect)-front_lot)/(max_cu_dstnc/(1+aspect))),1))	branch cable length divisor, normally unity, computed whenever branch distance exceeds one-half the user-set maximum cable distance; used to ensure copper distances do not exceed maximum; application of factor increases number of branch cables and corresponding shortens each
V	number of branches (per cluster)	=IF(P2=0,CEILING(5280*SQRT(clustr_area*aspect)/(2*depth),1),0)*U2*2	computes the number of branch cables in a cluster; branch cables extend from the backbone to either side to a point one lot width from edge of cluster
W	branch length	=IF(AND(Q2>2,P2=0),MAX(0,2640*SQRT(clustr_area/aspect)-front_lot)/U2,0)*IF(diff_sfc>1,dstnc_mult,1)	Distance from the backbone cable to the edge of the occupied cluster area, less one lot width; includes aspect ratio factor which allows computation of rectangular clusters

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
X	pairs required per branch cable	=IF(AND(P2=0,V2>0),(lines_adj/V2)/VLOOKUP('cluster input data'!$R2,density_inputs,2),0)	Pairs required per branch cable with cable sizing factor
Y	branch cable cross section	=IF(P2=0,INDEX(cable_range,MATCH($X2-Z2*max_cable,cable_range,-1),1),0)	assigned branch cable cross section; if maximum-sized cables are present, this value covers remaining lines not served by maximum cable
Z	number of maximum branch cables	=TRUNC(X2/max_cable)	calculates number of "overflow" branch cables required by cluster
AA	backbone cross section	=IF(P2=0,INDEX(cable_range,MATCH((1/(S2)*V2*0.5*(Y2+Z2*max_cable))-$AB2*max_cable,cable_range,-1),1),0)	assigned backbone cable size; computed from branch cable size and number of branch cables to ensure preservation of binder-group integrity
AB	number of max backbone cables	=TRUNC(1/(S2)*V2*0.5*(Y2+Z2*max_cable)/max_cable)	computes number of backbone "overflow" cables required
AC	Backbone Taper Factor	=IF(V2/(S2*U2)<=2,1,0.5)	factor accounting for tapering of backbone cable when more than two branch cables connect to each backbone cable
AD	effective subscriber road cable distance	=IF(OR(P2=0,Q2<2),0,5280*MAX(SQRT('cluster input data'!O2*aspect),SQRT('cluster input data'!O2/aspect))+MAX(0,5280*MIN(SQRT('cluster input data'!O2*aspect),SQRT('cluster input data'!O2/aspect))-2*VLOOKUP(density,density_inputs,9)))*IF(diff_sfc>1,dstnc_mult,1)	computes length of cable required to serve outlier locations; length computed as the major dimension of the outlier area plus the minor dimension less two drop lengths, adjusted for difficult surface routing if elected by user
AE	required subscriber road cable pairs	=IF(P2=1,(lines_adj)/MAX(1,BQ2)/VLOOKUP('cluster input data'!R2,density_inputs,2),0)	cable pairs, including sizing factor, required to serve subscribers centered on outlier position
AF	subscriber road cable cross section, per cable	=IF(P2=1,INDEX(cable_range,MATCH(AE2-AG2*max_cable,cable_range,-1),1),0)	assigned road cable cross section in addition to any necessary maximum-sized cables
AG	number of max road cables	=IF(P2=1,TRUNC(AE2/max_cable),0)	computes number of maximum-sized road cables
AH	unadjusted road subscriber cable investment	=IF(AND(P2=1,BH2=0),AD2*AG2*max_cable_inv+AD2*VLOOKUP(calculations!AF2,cable_inv,2,FALSE),0)	total road cable investment for outlier without adjustments for aerial, buried, or underground use
AI	effective road T1 cable distance	=IF(P2=1,'cluster input data'!N2*(SIN(PI()/180*'cluster input data'!M2)+COS(PI()/180*'cluster input data'!M2)),0)*IF(diff_sfc>1,dstnc_mult,1)	T1 road cable distance assuming rectangular routing between end points, with difficult surface routing adjustment if elected by user
AJ	required road T1 cable pairs, per cable	=IF(OR(P2=0,AK2=0,BH2=1),0,2*total_T1s/AK2/VLOOKUP('cluster input data'!R2,density_inputs,2))	required cable pairs, including two pairs per T1 on cable and cable sizing factor
AK	number of road T1 cables	=IF(OR(P2=0,BH2=1),0,CEILING(total_T1s/max_T1s_cable,1))	number of T1 cables required; controlled by maximum allowable T1 pairs in cable

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
AL	road T1 cable cross section	=IF(P2=1,INDEX(cable_range,MATCH(AJ2,cable_range,-1),1),0)	assigned T1 cable cross section
AM	unadjusted road T1 cable investment	=IF(AND(P2=1,BH2=0),AI2*AK2*VLOOKUP(AL2,cable_inv,2,FALSE),0)	total T1 cable investment for this outlier, unadjusted for aerial, buried, or underground structure
AN	total unadjusted cable investment	=IF(BH2=1,0,((IF(P2=0,VLOOKUP(Y2,cable_inv,2,FALSE)*W2*V2+AC2*2*S2*U2*T2*VLOOKUP(calculations!AA2,cable_inv,2,FALSE),0)+AH2+AM2+(AC2*2*S2*U2*T2*AB2+Z2*W2*V2)*max_cable_inv)))	total cable investment for cluster or outlier, including branch, backbone (for clusters) and T1 road, and customer road cables (for outliers); connecting cable investment, if any, is computed by feeder module
AO	underground cable inv	=($AN2)*CF2	computes underground fraction of total cable investment using input underground structure fraction
AP	buried cable inv	=($AN2)*CD2*inputs!$C$19	computes buried cable investment, including additional cable investment for filled cable, using computed buried structure fraction
AQ	aerial cable investment	=($AN2)*CE2+BM2	total aerial cable investment computed with calculated aerial structure fraction
AR	total structure distance	=IF(BH2=1,0,IF(P2=1,AI2+IF(CI3<=CI2,0.5*AD2,0)+IF(Q2<2,0,0.5*(5280*MAX(SQRT('cluster input data'!O2*aspect),SQRT('cluster input data'!O2/aspect))+MAX(0,5280*MIN(SQRT('cluster input data'!O2*aspect),SQRT('cluster input data'!O2/aspect))-2*VLOOKUP(density,density_inputs,9)))),2*S2*U2*T2+V2*W2))	computes total structure distance for cluster; for outliers, includes total distance for T1 cables plus one-half the sum of the major outlier dimension and the minor outlier dimension less two drop lengths; for terminal outliers, total also includes one-half the suuscriber road cable distance
AS	pole investment	=IF(OR(BH2=1,'cluster input data'!R2>=inputs!$B$12),0,((1+CEILING(AR2*CE2/VLOOKUP('cluster input data'!R2,density_inputs,8),1))*(pole_inv+pole_labor*((1-wtg_pole_set)+wtg_pole_set*labor_adj)*(rock_mult+diff_sfc-1))))	computes total pole investment, including pole setting, with adjustments for local surface and rock conditions and labor rates
AT	buried placement	=IF($BH2=1,0,AR2*CD2*VLOOKUP('cluster input data'!$R2,density_inputs,7)*(rock_mult+diff_sfc-1)*((1-wtg_excav)+wtg_excav*labor_adj))	computes total buried placement investment, with adjustments for local surface and rock conditions and labor rates
AU	conduit investment	=IF($BH2=1,0,IF(P2=0,(2*S2*U2*$T2*(1+sp_tubes+$AB2)+$V2*$W2*(1+sp_tubes+$Z2)),(AI2+IF(CI3<=CI2,0.5*AD2,0))*(1+sp_tubes+AG2))*CF2*conduit_inv)	computes total conduit investment, including spare tubes
AV	conduit placement	=IF($BH2=1,0,AR2*CF2*VLOOKUP('cluster input data'!$R2,density_inputs,6)*(rock_mult+diff_sfc-1)*((1-wtg_excav)+wtg_excav*labor_adj))	computes total underground placement investment, with adjustments for local surface and rock conditions and labor rates

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
AW	vertical connecting cable length, ft	=IF($P2=1,0,2*U2*(S2-1)*(T2+depth))	optical connecting cable (feeder) used in subdivided backbone cables to connect subfeeder to RTs; investment computed in feeder module
AX	horizontal connecting cable length, ft	=IF(P2=1,0,2*(U2-1)*(W2+front_lot))	connecting cable horizontal optical connecting cable used to connect subfeeder to RTs when branch cables are subdivided; investment computed in feeder module
AY	vertical structure distance, ft	=IF(P2=1,0,2*U2*(S2-1)*(depth))	structure required to support vertical connecting cable; may be shared with backbone structure in certain cases
AZ	horizontal structure distance, ft	=IF(P2=1,0,IF(EVEN(V2)/4<>TRUNC(EVEN(V2)/4),2*(U2-1)*front_lot,AX2))	structure required to support horizontal connecting cable; may be shared with branch structure in certain cases
BA	total required SAI capacity, per SAI	=(3.5*'cluster input data'!AC2+2*('cluster input data'!X2+SA_loops+'cluster input data'!AA2))/(S2*U2)	computes SAI capacity as the sum of the feeder and distribution connections
BB	max SAIs	=IF(BH2=1,0,TRUNC(SAI_cap/max_SAI))	computes number of maximum-sized SAIs required for cluster
BC	SAI size	=IF(OR(P2=1,BH2=1),0,INDEX(SAI_range,MATCH(SAI_cap-BB2*max_SAI,SAI_range,-1),1))	assigns SAI size for determination of investment
BD	SAI investment	=IF(OR(P2=1,BH2=1),0,BB2*max_SAI_inv+VLOOKUP(BC2,SAI_inv,3,FALSE))*S2*U2	computes total SAI investment
BE	max SAIs, high-rise	=IF(BH2=1,TRUNC((SAI_cap)/max_SAI),0)	computes number of maximum-sized indoor SAIs required
BF	SAI size, high-rise	=IF(BH2=1,INDEX(SAI_range,MATCH(SAI_cap-BE2*max_SAI,SAI_range,-1),1),0)	assigns indoor SAI size for determination of investment
BG	SAI investment, high-rise	=IF(BH2=1,BE2*max_SAI_inv+VLOOKUP(BF2,SAI_inv,2,FALSE),0)*S2*U2	computes total indoor SAI investment
BH	high-rise indicator	=IF(AND(P2=0,clustr_area<0.03,'cluster input data'!R2>30000),1,0)	indicates whether high-rise calculations are to be invoked; requires line density > 30,000 lines/sq mi and cluster area < 0.03 sq mi
BI	high-rise factor	=IF(BH2=0,0,('cluster input data'!AC2*1500+'cluster input data'!AO2*200)/((1-inputs!$F$30)*'cluster input data'!O2*5280^2))	estimates number of "floors" using assumed floor areas per household and employees
BJ	number of riser pairs required per cable	=(2*'cluster input data'!AC2+'cluster input data'!AA2+SA_loops+'cluster input data'!X2)/2	computes required cable pairs, including cable sizing factor; two equally-sized cables assumed
BK	number of maximum riser cables	=TRUNC(BJ2/max_riser)*2	computes number of maximum-sized riser cables
BL	riser cable cross section	=INDEX(riser_range,MATCH(BJ2-$BK2/2*max_riser,riser_range,-1),1)	assigns riser cable size

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
BM	riser cable investment	=IF(BH2=1,(BK2*max_riser_inv+2*VLOOKUP(BL2,riser_inv,2,FALSE))*15*CEILING(MIN(BI2,50),1),0)	computes total riser cable investment; limits building to fifty stories
BN	total T1s required per route	=IF(P2=1,CN2,0)	repeats count of T1s traversing or terminating at current outlier
BO	total repeaters required per cable	=IF(P2=1,CEILING(AI2/(1000*T1_rptr_spcng/(CE2*T1_atten_aerial+(1-CE2)*T1_atten_buried)),1)*BN2,0)	computes repeaters required for T1s in outlier segment by considering aerial and ug/buried structure fractions, number of T1, distance, and allowable cable loss between repeaters
BP	total installed repeater investment per cable	=BO2*repeater_inv	computes total investment in T1 repeaters per cable; multiplied by number of T1 cables in output sheet (AF2)
BQ	road RT indicator/copper distance multiplier	=IF(AND(P2=1,CR2=0),MAX(1,CEILING(AI2/max_cu_dstnc,1)),0)	computes factor to add RTs in outlier distribution if total outlier customer distance exceeds maximum copper distance
BR	total road RTs	=IF(AND(P2=1,BQ2>0),BQ2*CEILING(lines_adj/BQ2/RT_fill/24,1),0)	calculates number of small RTs to serve subscribers assigned to outliers
BS	total installed terminal investment per cable	=IF(AND(P2=1,BR2>0),BR2*(road_RT_inv+road_COT_per_RT_inv)+CU_inv_road*calculations!R2/RT_fill,0)	computes total RT investment, including common equipment and channel units, for outlier
BT	average loop length in cluster	=IF(P2=0,0.5*(T2+W2+AW2/U2+AX2)+E2,0)	estimates average loop length within cluster, including common feeder distance for all cluster lines; includes effects of connecting cable when present
BU	distribution route distance in cluster	=IF(P2=0,2*S2*U2*T2+V2*W2+CQ2,0)	calculates total route, or structure, distance for cluster
BV	maximum loop length in cluster	=IF(P2=0,E2+T2+W2+0.5*(AW2/U2+AX2),0)	calculates maximum loop length within cluster
BW	equivalent SA loops	=sa_lines*(DS0_frac*DS0_pair+DS1_frac*DS1_pair+DS3_frac*DS3_pair)	computes equivalent special access loops for users with access to precise input data concerning types and numbers of multiplexed special access lines in cluster
BX	adjusted total lines	=lines-sa_lines+SA_loops	adjusts input line total for re-computed special access loop total for users having access to precise special access facility data for cluster
BY	number of DLC LD terminals	=IF(OR(P2=1,(R2+CS2)/(S2*U2)>=inputs!$C$105),0,S2*U2*CEILING((R2+CS2)/(S2*U2)/(inputs!$D$96*inputs!$D$97*(1+inputs!$D$110)),1))	computes number of low-density remote terminals required for cluster; includes effects of branch and backbone subdivision, if required

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
BZ	LD terminal investment	=IF(OR(P2=1,(R2+CS2)/(S2*U2)>=inputs!$C$105),0,inputs!$D$95+inputs!$D$107+inputs!$D$98*BY2+IF((R2+CS2)/(S2*U2)/inputs!$D$97>inputs!$D$96,CEILING(((R2+CS2)/(S2*U2)/inputs!$D$97-inputs!$D$96)/inputs!$D$96,1)*inputs!$D$109,0)+(CEILING((output!$L2+output!$M2+CS2)/(S2*U2)/inputs!$D$97/inputs!$D$100,1)*inputs!$D$99+CEILING(output!$O2/(S2*U2)/inputs!$D$97/inputs!$D$102,1)*inputs!$D$101))	computes total investment in low-density remote terminals, including site, common equipment, and channel units
CA	number of HD RTs	=IF(OR(P2=1,(R2+CS2)/(S2*U2)<inputs!$C$105),0,S2*U2*CEILING((R2+CS2)/(S2*U2)/(inputs!$C$96*inputs!$C$97*(1+inputs!$C$110)),1))	calculates number of high-density remote terminals to serve cluster; this calculation and that in BY are mutually exclusive
CB	HD RT investment	=IF(OR(P2=1,(R2+CS2)/(S2*U2)<inputs!$C$105),0,inputs!$C$95+inputs!$C$107+inputs!$C$98*CA2+IF((R2+CS2)/(S2*U2)/inputs!$C$97>inputs!$C$96,CEILING(((R2+CS2)/(S2*U2)/inputs!$C$97-inputs!$C$96)/inputs!$C$96,1)*inputs!$C$109,0)+(CEILING((output!$L2+output!$M2+CS2)/(S2*U2)/inputs!$C$97/inputs!$C$100,1)*inputs!$C$99+CEILING(output!$O2/(S2*U2)/inputs!$C$97/inputs!$C$102,1)*inputs!$C$101))	calculates total investment in high-density remote terminal, including site, common equipment, and channel units, as well as CO multiplexing equipment
CC	fiber strands required	=BY2*inputs!$D$106+CA2*inputs!$C$106	calculates number of fiber strands required to serve cluster according to computed RT totals and user-set number of strands per RT
CD	effective buried fraction distribution	=VLOOKUP('cluster input data'!R2,density_inputs,5)+DC2	computes effective buried structure fraction according to local surface and rock conditions
CE	effective aerial fraction distribution	=MAX(0,1-CD2-CF2)	computes effective aerial structure fraction according to local surface and rock conditions
CF	effective u/g fraction distribution	=VLOOKUP('cluster input data'!R2,density_inputs,3)	repeats input underground structure fraction set by user
CG	cluster serial number	=RIGHT(LEFT(B2,SEARCH(".",B2)-1),SEARCH(".",B2)-2)	extracts basic cluster serial number from cluster or outlier ID in cluster input data
CH	outlier number	=RIGHT(B2,LEN(B2)-SEARCH(".",B2))	Extracts outlier extension from cluster ID
CI	outlier order	=IF(P2=1,LEN(CH2)/3,0)	Computes outlier level from outlier number
CJ	outlier root ID	=IF(ISBLANK(CH2),0,LEFT(CH2,3))	extracts number of outlier on which current outlier chain homes
CK	cluster -- attached outlier indicator	=IF(AND(P2=0,P3=1),1,0)	indicates for clusters whether any outliers are attached; used in specifying whether fiber feeder is required
CL	cumulative lines in chain	=IF(ISBLANK(CH2),0,IF(AND(CJ3=CJ2,CG3=CG2),CL3+CU2,CU2))	accumulates line count within outlier chain
CM	number of T1s req'd -- terminal outlier	=IF(P2=0,0,IF(CI3>CI2,0,CEILING(CU2/RT_fill/24,1)))	calculates number of T1s required to serve last outlier in chain

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
CN	number of T1s reqd -- "through" clusters	=IF(CI3<=CI2,CM2,CEILING((CL2-IF(AND(CI2=1,AI2<max_cu_dstnc),CU2,0))/RT_fill/24,1))	computes total of number of T1s required to serve current and subsequent outliers in chain
CO	total T1s in chain	=IF(CI2=1,CN2,0)	
CP	cumulative T1s in cluster	=IF(CG3=CG2,CP3+CO2,CO2)	accumulates number of T1s required to serve all outliers in cluster
CQ	cumulative outlier road distance in cluster	=IF(CG3=CG2,CQ3+AI2,AI2)	accumulates outlier road distance for cluster
CR	first-order outlier lines not on T1	=IF(AND(CI2=1,AI2+0.5*AD2<max_cu_dstnc),CU2,0)	calculates number of lines in first-order outliers (those connected directly to clusters) that lie within maximum copper distance
CS	cumulative first-order outlier lines not on T1	=IF(CG3=CG2,CS3+CR2,CR2)	accumulates non-T1-served first-order outlier lines for cluster
CT	terminal outlier indicator	=IF(AND(P2=1,CI3<=CI2),1,0)	indicates whether outlier is last in chain
CU	outlier lines	=IF(P2=1,R2,0)	repeats total line count for outlier
CV	distribution buried investment/foot, cable + placement, with sharing	=VLOOKUP(IF(P2=0,$Y2,AF2),cable_inv,2,FALSE)*inputs!$C$19+VLOOKUP(density,density_inputs,7)*VLOOKUP(density,density_inputs,19)	calculates buried cable and placement investment per foot, with effect of structure sharing
CW	distribution aerial investment/foot, cable	=VLOOKUP(IF(P2=0,$Y2,AF2),cable_inv,2,FALSE)	calculates aerial cable investment per foot
CX	distribution aerial investment/foot, pole, with sharing	=(inputs!$C$16+inputs!$C$17*inputs!$C$25)/VLOOKUP(density,density_inputs,8)*VLOOKUP(density,density_inputs,18)	calculates aerial structure investment per foot, with effects of structure sharing
CY	std buried LC cost/ft, with sharing	=CV2*(LCFactors!$D$3+LCFactors!$C$3)	calculates life cycle cost per foot of buried cable and structure without effects of local rock and surface conditions
CZ	std aerial LC cost/ft, with sharing	=CW2*(LCFactors!$D$5+LCFactors!$C$5)+CX2*(LCFactors!$D$9+LCFactors!$C$9)	calculates life cycle cost per foot of aerial cable and structure without effects of local rock and surface conditions
DA	local buried LC cost/ft, w/sharing	=(VLOOKUP(IF(P2=0,$Y2,AF2),cable_inv,2,FALSE)*inputs!$C$19+(I2+J2-1)*VLOOKUP(density,density_inputs,7)*VLOOKUP(density,density_inputs,19))*(LCFactors!$D$3+LCFactors!$C$3)	calculates life cycle cost of buried cable and structure, with effects of local rock and surface conditions
DB	local aerial LC cost/ft, w/sharing	=CW2*(LCFactors!$D$5+LCFactors!$C$5)+(inputs!$C$16+(I2+J2-1)*inputs!$C$17*inputs!$C$25)/VLOOKUP(density,density_inputs,8)*VLOOKUP(density,density_inputs,18)*(LCFactors!$D$9+LCFactors!$C$9)	calculates life cycle cost of aerial cable and structure, with effects of local rock and surface conditions

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
DC	buried adjustment	=(0.5-1/(1+(CY2/CZ2)/((DA2/DB2)^inputs!$G$82)))*VLOOKUP(density,density_inputs,21)	calculates adjustment to buried fraction using standard and local costs in logistic function
DD	wire center	='cluster input data'!A2	repeats wire center location ID from cluster input data
DE	quadrant	='cluster input data'!F2	repeats quadrant number from cluster input data
DF	sign	=VLOOKUP('cluster input data'!G2,inputs!$X$5:$Y$8,2)	determines sign of cluster angular coordinate
DG	angle	=DF2*'cluster input data'!H2	attaches sign to cluster angular coordinate
DH	maincluster angle x radius	=IF(P2=0,DG2*'cluster input data'!I2,0)	calculates distance weighting for angular coordinate of cluster
DI	cumulative product	=IF(AND(DD3=DD2,DE3=DE2),DI3+DH2,DH2)	accumulates weighted angle for feeder route (quadrant)
DJ	main cluster cumulative radius	=IF(AND(DD3=DD2,DE3=DE2),DJ3+IF(P2=0,'cluster input data'!I2,0),IF(P2=0,'cluster input data'!I2,0))	accumulates distance for clusters along feeder route
DK	wtd avg feeder offset angle (no limit)	=IF(OR(DD1<>DD2,DE1<>DE2),DI2/DJ2,0)	calculates feeder steering angle offset to be applied to angular coodinate for each cluster when feeder steering enabled
DL	repeated offset	=IF(fdr_steer_enable,IF(AND(DD1=DD2,DE1=DE2),DL1,DK2),0)	repeats offset angle for each cluster in feeder route (quadrant)
DM	resultant	=ABS(DG2-DL2)	applies offset to angle when feeder steering enable
DN	RT est. annual cost, w/per-line EO adjustments	=IF(P2=0,(BZ2+CB2-BX2*(inputs!$G$101+inputs!$G$102))*(LCFactors!$C$10+LCFactors!$D$10),0)	estimates annual life-cycle cost for remote terminals, including end-office adjustments for DLC per-line investment and MDF savings
DO	copper cable est. annual cost	=IF(P2=0,lines_adj*E2*inputs!$G$100/VLOOKUP(density,inputs!$F$89:$G$97,2)*(CE2*(LCFactors!$C$5+LCFactors!$D$5)+CD2*(LCFactors!$C$3+LCFactors!$D$3)+CF2*(LCFactors!$C$7+LCFactors!$D$7)),0)	estimates annual life-cycle cost for copper feeder cable to serve cluster
DP	fiber cable est. annual cost	=IF(P2=0,E2*CC2*inputs!$G$99*(CD2*(LCFactors!$C$4+LCFactors!$D$4)+CE2*(LCFactors!$C$6+LCFactors!$D$6)+CF2*(LCFactors!$C$8+LCFactors!$D$8)),0)	estimates annual life-cycle cost for fiber feeder cable to serve cluster
DQ	cumulative cable and structure investment	=IF(CG3=CG2,DQ3+AO2+AP2+AQ2+AS2+AT2+AU2+AV2,AO2+AP2+AQ2+AS2+AT2+AU2+AV2)	accumulates cable and structure investment for cluster and outliers to determine total per-line investment for cluster/outlier system
DR	cumulative DLC and T1 investment	=IF(CG3=CG2,DR3+BZ2+CB2+BP2+BS2,BZ2+CB2+BP2+BS2)	accumulates T1 investment for outliers to determine total per-line investment for cluster/outlier system

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
DS	cumulative SAI investment	=IF(CG3=CG2,DS3+BD2+BG2,BD2+BG2)	accumulates SAI investment for cluster and outliers to determine total per-line investment for cluster/outlier system
DT	terminal investment	=IF(calculations!BH2=0,lines_adj*VLOOKUP(density,density_inputs,16),0)	calculates terminal investment for cluster or outlier
DU	cumulative terminal investment	=IF(CG3=CG2,DU3+DT2,DT2)	accumulates terminal investment for cluster and outliers to determine total per-line investment for cluster/outlier system
DV	drop investment	=IF(calculations!BH2=1,0,VLOOKUP(density,density_inputs,17)*('cluster input data'!AB2+'cluster input data'!AD2+'cluster input data'!AE2+'cluster input data'!AF2+'cluster input data'!AG2+'cluster input data'!AL2+'cluster input data'!AM2)+VLOOKUP(density,density_inputs,15)*('cluster input data'!X2-'cluster input data'!AB2+'cluster input data'!AA2+SA_loops+IF('cluster input data'!AC2=0,0,('cluster input data'!AH2+'cluster input data'!AI2+'cluster input data'!AJ2+'cluster input data'!AK2)/'cluster input data'!AC2*'cluster input data'!Y2)))	computes drop investment for cluster or outlier
DW	cumulative drop investment	=IF(CG3=CG2,DW3+DV2,DV2)	accumulates drop investment for cluster/outlier system
DX	NID investment	=IF(calculations!BH2=0,hh_tot*inputs!$C$30+'cluster input data'!Y2*inputs!$C$32+('cluster input data'!X2+SA_loops)*(inputs!$C$35/inputs!$C$38+inputs!$C$36)+(inputs!$C$35+inputs!$C$36)*'cluster input data'!AA2,NID_indoor*lines_adj)	computes NID investment for cluster or outlier
DY	cumulative NID investment	=IF(CG3=CG2,DY3+DX2,DX2)	accumulates NID investment for cluster/outlier system
DZ	cumulative lines	=IF(CG3=CG2,DZ3+lines_adj,lines_adj)	accumulates total line count for cluster/outlier system
EA	total distribution investment per line	=IF(AND(P2=0,DZ2>0),(DQ2+DR2+DS2+DU2+DW2+DY2)/DZ2,0)	computes total per-line investment for distribution plant and equipment
EB	wireless cap indicator	=IF(AND(wireless_cap_enable,P2=0,clustr_tot_lines<=brdcast_lines_max),IF(EA2>IF(clustr_tot_lines<=brdcast_thresh,wireless_cap,brdcast_common_inv*CEILING(clustr_tot_lines/brdcast_lines_max,1)/clustr_tot_lines+brdcast_var_inv),1,0),0)	when wireless cap enabled, compares total per-line distribution investment to estimated wireless technology investment and indicates when wireless estimate is less than wireline
EC	repeated wireless cap indicator	=IF(CG1=CG2,EC1,EB2)	repeats wireless cap indicator for all outliers in cluster/outlier system
ED	maximum outlier dimension, ft	=IF(P2=1,5280*MAX(SQRT('cluster input data'!O2*aspect),SQRT('cluster input data'!O2/aspect)),0)	computes maximum outlier dimension in feet using input outlier area and aspect ratio

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
EE	outlier subscriber road cable adjustment to average loop length wtd by lines	=IF(P2=1,IF(CU2<=1,0,IF(CU2<=2,0.5*ED2,IF(CU2<=3,5*ED2/12,1.5*ED2)))*CU2,0)	computes average distance from outlier center to subscribers served by subscriber road cable, wtd by lines in outlier
EF	cumulative weighted outlier adjustment	=IF(CG3=CG2,EF3+EE2,EE2)	accumulates weighted outlier adjust across all outliers in cluster
EG	weighted average outlier subscriber road cable adjustment	=IF(OR(P2=1,'cluster input data'!AR2=0),0,EF2/'cluster input data'!AR2)	computes wtd average adjustment for cluster

Workbook: **R50A_distribution.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
A	company	='cluster input data'!B2	reports operating company name
B	operating company indicator	='cluster input data'!C2	reports operating company type indicator from 'cluster input data'
C	wire center	='cluster input data'!A2	reports 8-character location identifier (specifies wire center)
D	CBG number	=IF(calculations!P2=0,'cluster input data'!D2,0)	reports principal CBG identifier for cluster
E	quadrant	=IF(calculations!P2=0,'cluster input data'!F2,0)	reports which wire center quadrant the cluster falls in
F	main feeder distance, ft	=calculations!C2	reports main feeder distance, modified by difficult terrain or route/air multiplier as required
G	subfeeder cable distance, ft	=calculations!D2	reports subfeeder cable distance, modified by difficult terrain distance multiplier if required
H	total distribution route distance in cluster, ft	=calculations!BU2	reports total structure distance for distribution plnnt
I	total lines	=lines_adj	reports total line count, including adjusted special access lines, public lines, business and residential lines
J	density -- lines/sq mi	=IF(calculations!P2=0,'cluster input data'!R2,0)	reports density expressed as total lines per sq mi of cluster or outlier area
K	area, sq mi	='cluster input data'!O2	reports cluster or outlier area in sq mi
L	business lines	='cluster input data'!X2	reports total business lines, including single- and multi-line service
M	residential lines	='cluster input data'!Y2	reports total residential lines, including first and multiple lines
N	individual SA lines -- VG/DS-0 equiv	=SA_loops	reports special access total voice grade/DS0 equivalents
O	public lines	='cluster input data'!AA2	reports total public lines
P	households	='cluster input data'!AC2	reports total households in cluster or outlier
Q	single-line business lines	='cluster input data'!AB2	reports total single-line business lines; total included in business line count
R	distribution cable inv, underground	=IF(wireless_cap_ind=0,calculations!AO2,0)	reports total investment in underground distribution cable
S	distribution cable inv, buried	=IF(wireless_cap_ind=0,calculations!AP2,0)	reports total investment in buried distribution cable
T	distribution cable inv, aerial	=IF(wireless_cap_ind=0,calculations!AQ2,0)	reports total investment in aerial distribution cable

Workbook: **R50A_distribution.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
U	distribution conduit inv	=IF(wireless_cap_ind=0,calculations!AU2,0)	reports total investment in distribution conduit materials
V	distribution conduit placement inv	=IF(wireless_cap_ind=0,calculations!AV2,0)	reports total investment in distribution conduit placement
W	distribution poles inv	=IF(wireless_cap_ind=0,calculations!AS2,0)	reports total investment in distribution poles and pole setting
X	distribution buried placement inv	=IF(wireless_cap_ind=0,calculations!AT2,0)	reports total investment in distribution buried cable placement
Y	rock plcmt mult	=IF(calculations!P2=0,rock_mult,0)	reports rock placement multiplier to be used by feeder module in modifying placement investment as may be required by shallow bedrock conditions
Z	difficult surface mult	=IF(calculations!P2=0,diff_sfc,0)	reports difficult surface placement multiplier to be used by feeder module in modifying placement investment as may be required by difficult surface conditions
AA	water table depth, ft	=IF(calculations!P2=0,'cluster input data'!V2,0)	reports water table depth for use by feeder module in modifying manhole investment in presence of high water table
AB	effective distribution fill	=IF(AND(wireless_cap_ind=0,calculations!P2=0),(0.5*calculations!R2/(calculations!S2*calculations!U2)/(calculations!AA2+calculations!AB2*max_cable)),0)	reports achieved distribution cable fill factor as computed at distribution side of SAI
AC	number of high-density RTs	=IF(wireless_cap_ind=0,IF(calculations!F2=1,calculations!CA2,0),0)	reports total high-density remote terminals required in cluster; includes effects of branch or backbone subdivision, if required
AD	high-density RT investment	=IF(wireless_cap_ind=0,IF(calculations!F2=1,calculations!CB2,0),IF(calculations!P2=0,IF(clustr_tot_lines<=brdcast_thresh,clustr_tot_lines*wireless_cap,brdcast_common_inv*CEILING(clustr_tot_lines/brdcast_lines_max,1)+brdcast_var_inv*clustr_tot_lines),0))	reports total investment in high-density DLC remote terminals for cluster; computes representative wireless investment totals if wireless "cap" calculations are enabled and local distribution investment exceeds either point-to-point or broadcast "cap"
AE	number of low-density DLC RTs	=IF(wireless_cap_ind=0,IF(calculations!F2=1,calculations!BY2,0),0)	reports total low-density remote terminals required in cluster; includes effects of branch or backbone subdivision, if required
AF	low-density DLC and T1 road terminal and repeater investment	=IF(wireless_cap_ind=0,IF(calculations!F2=1,calculations!BZ2,0)+calculations!BP2*calculations!AK2+calculations!BS2,0)	reports investment in low-density DLC remote terminals and in T1 equipment for outliers

Workbook: **R50A_distribution.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
AG	fiber strands required	=IF(wireless_cap_ind=0,IF(calculations!F2=1,calculations!CC2,0),IF(calculations!P2=0,4,0))	reports total fiber strands needed by RTs in cluster; if wireless cap exceeded, reports four fibers for radio equipment
AH	SAI investment	=IF(wireless_cap_ind=0,calculations!BD2+calculations!BG2,0)	reports total SAI investment for cluster, including indoor SAI totals when high-rise calculations are invoked
AI	terminal investment	=IF(wireless_cap_ind=0,calculations!DT2,0)	reports total investment in terminals (interface between drops and distribution cable)
AJ	drop investment	=IF(wireless_cap_ind=0,calculations!DV2,0)	reports total investment in installed subscriber drops
AK	NID investment	=IF(wireless_cap_ind=0,calculations!DX2,0)	reports total investment in network interface devices
AL	number of DLC lines	=IF(AG2=0,0,calculations!DZ2)	reports total number of lines served by DLC in cluster and outliers
AM	vertical connecting cable length, ft	=IF(wireless_cap_ind=0,calculations!AW2,0)	reports vertical (optical fiber) connecting cable to feeder module for sizing and investment computation when backbone cable is subdivided
AN	horizontal connecting cable length, ft	=IF(wireless_cap_ind=0,calculations!AX2,0)	reports horizontal (optical fiber) connecting cable to feeder module for sizing and investment computation when branch cables are subdivided
AO	vertical connecting structure distance, ft	=IF(wireless_cap_ind=0,calculations!AY2,0)	reports structure distance for vertical connecting cable, when present
AP	horizontal connecting structure distance, ft	=IF(wireless_cap_ind=0,calculations!AZ2,0)	reports structure distance for horizontal connecting cable, when present
AQ	average loop length in cluster, ft	=IF(wireless_cap_ind=0,calculations!BT2,0)	reports average loop length within cluster
AR	maximum loop length, ft	=IF(wireless_cap_ind=0,calculations!BV2,0)	reports maximum loop length in cluster
AS	cluster ID	='cluster input data'!E2	repeats cluster ID from cluster input sheet
AT	cluster serial number	=calculations!CG2	reports basic cluster serial number without outlier extensions for use by interface in totalling cluster investments
AU	wireless cap indicator	=IF(calculations!P2=0,wireless_cap_ind,0)	reports whether wireless cap is reached for cluster; saved in workfile
AV	lines affected by wireless cap	=IF(AND(AU2=1,calculations!P2=0),calculations!DZ2,0)	If wireless cap applies, records total lines in cluster and outliers; save in workfile
AW	cable+structure+DLC inv less wireless estimate	=IF(AND(AU2=1,calculations!P2=0),calculations!EA2-output!AD2,0)	calculates investment saved by employment of wireless assumptions

Workbook: **R50A_distribution.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
AX	calc buried fraction -- main cluster	=IF(AND($AU2=0,calculations!$P2=0),calculations!CD2,0)	reports calculated buried fraction
AY	calc aerial fraction -- main cluster	=IF(AND($AU2=0,calculations!$P2=0),calculations!CE2,0)	reports calculated aerial structure fraction
AZ	calc u/g fraction -- main cluster	=IF(AND($AU2=0,calculations!$P2=0),calculations!CF2,0)	reports underground structure fraction
BA	overall wtd avg loop length	=IF(calculations!P2=0,(AQ2*lines_adj+('cluster input data'!AQ2*IF(diff_sfc>1,dstnc_mult,1)+calculations!EG2+F2+G2)*'cluster input data'!AR2)/('cluster input data'!AR2+lines_adj),0)	computes overall weighted average loop length, using average loop length in cluster and input average outlier length, weighted by lines
BB	cluster fraction of wire center lines	=IF(calculations!P2=0,'cluster input data'!AP2,0)	computes wtd average adjustment for cluster

Workbook: **R50A_feeder.xls**
Worksheet: **distribution input**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
A	Company	The data for this sheet is taken from output sheet of the distribution module.	
B	operating company indicator		
C	wire center		
D	CBG geocode		
E	quadrant		
F	main feeder distance		
G	subfeeder		
H	distribution distance		
I	total lines		
J	density, lines/sq mi		
K	area, sq mi		
L	business lines		
M	residential lines		
N	SA lines		
O	public lines		
P	households		
Q	single-line business lines		
R	distribution cable, underground		
S	distribution cable, buried		
T	distribution cable, aerial		
U	distribution conduit		
V	distribution conduit placement		
W	distribution poles		
X	distribution buried plcmt		
Y	rock plcmt mult		
Z	difficult surface mult		
AA	water table depth, ft		
AB	effective distribution cable fill		
AC	number of TR-303 RTs		
AD	TR-303 investment		

Workbook: **R50A_feeder.xls**
Worksheet: **distribution input**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
AE	number of low-density DLC RTs		
AF	low-density DLC investment		
AG	fiber strands required		
AH	SAI inv		
AI	terminal inv		
AJ	drop inv		
AK	NID inv		
AL	number of DLC lines		
AM	vertical connecting cable length, ft		
AN	horizontal connecting cable length, ft		
AO	vertical structure distance, ft		
AP	horizontal structure distance, ft		
AQ	average loop length, ft		
AR	maximum loop length, ft		
AS	cluster ID		
AT	cluster serial number		
AU	wireless cap indicator		
AV	lines affected by wireless cap		
AW	cable+structure+DLC inv less wireless estimate		
AX	calc buried fraction -- main cluster		
AY	calc aerial fraction -- main cluster		
AZ	calc u/g fraction -- main cluster		
BA	overall wtd avg loop length		
BB	cluster fraction of wire center lines		

Workbook: **R50A_feeder.xls**
Worksheet: **cable investment**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
A	wire center	='distribution input'!C2	Wire center serving this cluster
B	Quadrant	='distribution input'!E2	Quadrant where this cluster is located.
C	main feeder distance, ft	='distribution input'!F2	Main feeder distance from the wire center to the subfeeder splice for this cluster
D	subfeeder distance	='distribution input'!G2	Subfeeder distance from the main feeder splice to the center of this cluster
E	basic lines	='distribution input'!I2	Total lines in cluster
F	line density per sq mi	='distribution input'!J2	Repeats line density in lines/sq mi for cluster
G	strands required	='distribution input'!AG2	Number of fiber strands required to serve the DLC remote terminal(s)
H	copper subfeeder size	=IF(OR(subfeeder_dist=0,basic_segment_type="DLC"),"N/A",AJ2)	repeats assigned copper subfeeder cable cross section, if equipped
I	current segment inv	=IF(AG2=0,0,X2*(AH2*max_copper_inv+VLOOKUP(AG2,copper_inv,2,FALSE) *((1-wtg_copper_const)+wtg_copper_const*labor_adj)))	Investment in copper feeder cable required for feeder segment serving cluster
J	max copper cable inv (subfeeder)	=IF(basic_segment_type<>"Cable",0,max_copper_inv*(subfeeder_dist*AK2)*((1-wtg_copper_const)+wtg_copper_const*labor_adj))	calculates investment in maximum (overflow) copper subfeeder cables, if present
K	fiber subfeeder size	=IF(AND(subfeeder_dist<>0,basic_segment_type="DLC"),MAX(min_fiber_subfdr, INDEX(fiber_range,MATCH('distribution input'!$AG2/VLOOKUP(line_density,density_inputs,3),fiber_range,-1),1)),"N/A")	assigns cable size for fiber subfeeder cable
L	fiber subfeeder investment	=IF(K2="N/A",0,(subfeeder_dist+'distribution input'!AN2+'distribution input'!AM2)*VLOOKUP(K2,fiber_inv,2,FALSE))	calculates fiber subfeeder cable investment
M	fiber main segment investment	=IF(AC2=0,0,X2*VLOOKUP(AL2,fiber_inv,2,FALSE)+AM2*max_fiber_inv*X2)	calculates investment in fiber cable for feeder segment serving cluster, including investment in any overflow cables
N	fiber subfeeder segment investment	=IF(basic_segment_type="DLC",L2,0)	Repeats investment in fiber subfeeder cable
O	segment number	=IF(this_wire_cntr=0,0,IF(AND(this_wire_cntr=next_wire_cntr,this_quadrant=next_quadrant),O3+1,1))	Numbers clusters along feeder route beginning at 1 for cluster nearest wire center
P	segment investment per line	=IF(AD2=0,0,I2/AD2)	Divides segment investment for copper cable by number of lines in current cluster and sum of lines in all clusters served by copper more distant from the wire center
Q	cumulative investment per line	=IF(OR(O1=1,ISTEXT(Q1)),P2,P2+Q1)	Accumulates investment per line in copper cable from wire center end of feeder route

Workbook: **R50A_feeder.xls**
Worksheet: **cable investment**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
R	assigned copper cable investment	=IF(basic_segment_type="Cable",basic_lines*Q2,0)	assigns copper cable investment to cluster by multiplying segment investment per line by number of lines in cluster
S	segment investment per strand	=IF(AC2=0,0,M2/AC2)	calculates investment per strand of fiber cable for segment serving this cluster
T	cumulative investment per strand	=IF(OR(O1=1,ISTEXT(T1)),S2,S2+T1)	Accumulates investment per strand along feeder route, beginning at wire center end of route
U	assigned fiber investment	=G2*T2	Assigns share of fiber cable investment to cluster
V	max distance	=IF(OR(W3=1,ISBLANK(W3)),C2,V3)	Computes and repeats maximum distance along feeder route
W	cluster sequence number	=IF(OR(this_quadrant<>B1,this_wire_cntr<>A1),1,W1+1)	Numbers cluster appearance along feeder route, beginning at wire center
X	segment distance	=IF(AND(this_wire_cntr=A1,this_quadrant=B1),C2-C1,C2)	Computes length of main feeder segment connecting previous cluster to current cluster
Y	basic segment type	=IF(this_wire_cntr="","",IF(G2=0,"Cable","DLC"))	Indicates whether segment is served by fiber feeder ("DLC") or copper feeder ("Cable")
Z	secondary segment type	=IF(this_quadrant=0,"",IF(OR(W3=1,AND(this_wire_cntr=next_wire_cntr,this_quadrant=next_quadrant,basic_segment_type=Y3,ISBLANK(Z3))),"",IF(basic_segment_type<>Y3,Y3,Z3)))	Indicates whether clusters farther along feeder route from current cluster use feeder cable type different from that used by current cluster
AA	cumulative required copper pairs	=IF(basic_segment_type="Cable",IF(OR(W3=1,AND(W3<>1,basic_segment_type<>Y3,next_quadrant<>this_quadrant,Z2<>"Cable"),ISBLANK(AA3)),basic_lines/VLOOKUP(line_density,density_inputs,2),basic_lines/VLOOKUP(line_density,density_inputs,2)+AA3),IF(W3=1,0,AA3))	Accumulates required copper cable pair count, including cable sizing factor, from far end of cable toward wire center
AB	cumulative lines served by fiber	=IF(basic_segment_type="DLC",IF(OR(W3=1,AND(W3<>1,basic_segment_type<>Y3,Z2<>"DLC"),ISBLANK(AB3)),basic_lines,basic_lines+AB3),IF(Z2="DLC",AB3,0))	accumulates lines served by fiber from remote end of feeder route
AC	total number of fiber strands	=IF(AB2=0,0,IF(W3=1,G2,IF(AB2=AB3,AC3,G2+AC3)))	accumulates number of fiber strands required from remote end of feeder route
AD	cumulative copper lines	=IF(basic_segment_type="Cable",IF(OR(W3=1,AND(W3<>1,basic_segment_type<>Y3,next_quadrant<>this_quadrant,Z2<>"Cable"),ISBLANK(AA3)),basic_lines,basic_lines+AD3),IF(W3=1,0,AD3))	accumulates lines served by copper from remote end of feeder route
AE	cumulative fiber lines	=IF(basic_segment_type="DLC",IF(OR(W3=1,AND(W3<>1,basic_segment_type<>Y3,next_quadrant<>this_quadrant,Z2<>"DLC"),ISBLANK(AA3)),basic_lines,basic_lines+AE3),IF(W3=1,0,AE3))	Computes cumulative fiber line count from far end of feeder route for use in feeder conduit calculation
AF	calc copper feeder fill	=IF(OR(AG2=0,basic_segment_type="DLC"),0,AD2/(AG2+AH2*max_copper))	calculates achieved copper feeder fill factor for segment serving cluster

Workbook: **R50A_feeder.xls**
Worksheet: **cable investment**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
AG	equipped feeder cable	=IF(AA2<>0,INDEX(copper_range,MATCH(AA2-(max_copper*AH2),copper_range,-1),1),0)	determines feeder cable size in segment serving cluster
AH	number of maximum-sized main feeder cables	=TRUNC(IF(AA2>max_copper,AA2/max_copper,0))	computes number of "overflow," or maximum-sized, main feeder cables required, if any
AI	sub cable pairs	=IF(basic_segment_type="Cable",basic_lines/VLOOKUP(line_density,density_inputs,2),0)	determines number of copper pairs required in subfeeder cable to serve cluster; includes effect of cable sizing factor
AJ	sub cable size	=IF(AI2<>0,INDEX(copper_range,MATCH(AI2-(max_copper*AK2),copper_range,-1),1),0)	Assigns subfeeder cable size
AK	max sub cables	=TRUNC(IF(AI2>max_copper,AI2/max_copper,0))	Calculates number of overflow subfeeder copper cables, if any
AL	fiber cable size	=IF(AC2=0,0,INDEX(fiber_range,MATCH(AC2/VLOOKUP(line_density,density_inputs,3)-max_fiber*TRUNC(AC2/(max_fiber*VLOOKUP(line_density,density_inputs,3))),fiber_range,-1),1))	assigns fiber cable cross section for segment serving cluster.
AM	max fiber cables	=IF(AC2/VLOOKUP(line_density,density_inputs,3)>max_fiber,TRUNC(AC2/(max_fiber*VLOOKUP(line_density,density_inputs,3))),0)	calculates number of overflow fiber cables main feeder segment serving this cluster, if required
AN	fiber segment cumulative distance	=IF(AND(basic_segment_type<>"DLC",Z2<>"DLC"),0,IF(AND(this_wire_cntr=A1,this_quadrant=B1),X2+AN1,X2))	accumulates fiber segment distance beginning at wire center end of feeder route
AO	fiber segment total distance from end	=IF(OR(basic_segment_type="DLC",Z2="DLC"),IF(OR(W3=1,AND(Y3<>"DLC",Z3<>"DLC")),AN2,AO3),0)	Calculates distance from cluster to end of fiber route
AP	copper feeder conduit inv	=IF(OR(basic_segment_type="Cable",Z2="Cable"),(X2*(1+AH2+spare_tubes_sect))*BU2*conduit_mat_inv_ft,0)	Computes investment in conduit for copper feeder cable for segment, including spare tubes and tubes for overflow cables, if any
AQ	copper feeder manholes	=IF(OR(basic_segment_type="Cable",Z2="Cable"),X2*BU2/VLOOKUP(line_density,density_inputs,7)*(VLOOKUP(line_density,density_inputs,17)+IF('distribution input'!AA2<=water_thresh,(min_water_factor+(max_water_factor-min_water_factor)/water_thresh*(water_thresh-'distribution input'!AA2))*VLOOKUP(line_density,inputs!$B$16:$G$24,6),0)),0)	Computes investment in manholes for copper feeder cable; includes extra investment for dewatering, which varies linearly with water table depth
AR	copper feeder u/g trenching	=IF(basic_segment_type="Cable",X2*BU2*VLOOKUP(line_density,density_inputs,9)*((1-wtg_excav)+wtg_excav*labor_adj)*('distribution input'!Y2+'distribution input'!Z2-1),0)	Computes investment in underground placement for segment
AS	copper feeder buried placement	=IF(basic_segment_type="Cable",X2*BS2*VLOOKUP(line_density,density_inputs,8)*((1-wtg_excav)+wtg_excav*labor_adj)*('distribution input'!Y2+'distribution input'!Z2-1),0)	Calculates investment in buried feeder placement for segment

Workbook: **R50A_feeder.xls**
Worksheet: **cable investment**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
AT	copper feeder pole inv	=IF(basic_segment_type="Cable",(1+CEILING(X2*BT2/VLOOKUP(line_density,density_inputs,19),1))*(pole_materials+pole_labor*((1-wtg_pole_set)+wtg_pole_set*labor_adj))*('distribution input'!Y2+'distribution input'!Z2-1),0)	Computes investment in feeder poles for copper cable; poles carry both copper and optical fiber cable when required
AU	fiber feeder conduit inv	=IF(AND(basic_segment_type="Cable",Z2<>"DLC"),0,IF(AO2=0,0,1/AO2*V2*X2*BX2*((1+spare_tubes_sect)*(conduit_mat_inv_ft)+AM2*inner_duct_inv_ft)))	Computes investment in conduit for underground fiber feeder cable, including any required inner duct for overflow cable
AV	fiber fdr pullboxes	=IF(basic_segment_type<>"Cable",IF(AQ2<>0,0,X2*BX2/VLOOKUP(line_density,density_inputs,13)*VLOOKUP(line_density,density_inputs,18)),0)	Calculates investment for pullboxes for fiber feeder cable in segment
AW	fiber feeder u/g trenching	=IF(basic_segment_type<>"Cable",X2*BX2*VLOOKUP(line_density,density_inputs,15)*((1-wtg_excav)+wtg_excav*labor_adj)*('distribution input'!Y2+'distribution input'!Z2-1),0)	Computes investment in placement for underground fiber cable for segment
AX	fiber feeder buried placement	=IF(basic_segment_type<>"Cable",X2*BV2*VLOOKUP(line_density,density_inputs,14)*((1-wtg_excav)+wtg_excav*labor_adj)*('distribution input'!Y2+'distribution input'!Z2-1),0)	Calculates investment in buried placement for fiber feeder cable for this segment
AY	fiber feeder poles	=IF(basic_segment_type<>"Cable",(1+CEILING((X2)*BW2/VLOOKUP(line_density,density_inputs,19),1))*(pole_materials+pole_labor*((1-wtg_pole_set)+wtg_pole_set*labor_adj))*('distribution input'!Y2+'distribution input'!Z2-1),0)	Computes investment in feeder poles for fiber cable for this segment
AZ	cumulative number of lines	=IF(O2=1,basic_lines,basic_lines+AZ3)	Accumulates total lines from remote end of feeder route.
BA	copper feeder conduit segment inv per line	=IF(AD2=0,0,AP2/AD2)	Computes copper conduit investment for the current segment per line
BB	cumulative conduit inv per line	=IF(OR(O1=1,ISTEXT(BB1)),BA2,BA2+BB1)	accumulates per-line conduit investment from beginning of feeder route
BC	assigned copper feeder conduit inv	=IF(basic_segment_type="Cable",basic_lines*BB2+subfeeder_dist*(1+AK2+spare_tubes_sect)*BU2*conduit_mat_inv_ft,0)	Computes cluster's share of copper conduit investment plus conduit required for copper subfeeder. Note that connecting cable and structure distances do not affect this calculation because they are only used with fiber feeder
BD	total feeder manhole sgmt inv per line	=IF(AZ2=0,0,(AQ2+AV2)/AZ2)	computes manhole and pullbox investment per cumulative line
BE	cumulative inv per line	=IF(OR(O1=1,ISTEXT(BE1)),BD2,BD2+BE1)	accumulates per-line investment in manholes and pullboxes from beginning of route

Workbook: **R50A_feeder.xls**
Worksheet: **cable investment**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
BF	assigned total feeder manhole inv	=IF(basic_segment_type="Cable",subfeeder_dist*BU2/VLOOKUP(line_density,density_inputs,7)*VLOOKUP(line_density,density_inputs,17),(subfeeder_dist+'distribution input'!AO2+'distribution input'!AP2)*BX2/VLOOKUP(line_density,density_inputs,13)*VLOOKUP(line_density,density_inputs,18))+basic_lines*BE2	assigns manhole and pullbox investment to current cluster according to total lines in cluster; includes investment required for subfeeder (with connecting cables, if present)
BG	total feeder u/g placement segment inv per line	=IF(AZ2=0,0,(AR2+AW2)/AZ2)	calculates total underground (conduit) placement investment per line
BH	cumulative u/g placement investment per line	=IF(OR(O1=1,ISTEXT(BH1)),BG2,BG2+BH1)	accumulates feeder (conduit) underground placement investment per line
BI	assigned total feeder u/g placement inv	=IF(basic_segment_type="Cable",subfeeder_dist*BU2*VLOOKUP(line_density,density_inputs,9)*((1-wtg_excav)+wtg_excav*labor_adj),(subfeeder_dist+'distribution input'!AO2+'distribution input'!AP2)*BX2*VLOOKUP(line_density,density_inputs,15)*((1-wtg_excav)+wtg_excav*labor_adj))*('distribution input'!Y2+'distribution input'!Z2-1)+basic_lines*BH2	Assigns cluster share of main feeder underground placement investment according to lines in cluster; adds subfeeder placement
BJ	total feeder buried placement segment inv per line	=IF(AZ2=0,0,(AS2+AX2)/AZ2)	calculates buried placement investment for current segment expressed per line
BK	cumulative buried placement investment per line	=IF(OR(O1=1,ISTEXT(BK1)),BJ2,BJ2+BK1)	accumulates buried placement investment per line from beginning of feeder route
BL	assigned total feeder buried placement inv	=IF(basic_segment_type="Cable",subfeeder_dist*BS2*VLOOKUP(line_density,density_inputs,8)*((1-wtg_excav)+wtg_excav*labor_adj),(subfeeder_dist+'distribution input'!AO2+'distribution input'!AP2)*BV2*VLOOKUP(line_density,density_inputs,14)*((1-wtg_excav)+wtg_excav*labor_adj))*('distribution input'!Y2+'distribution input'!Z2-1)+basic_lines*BK2	computes cluster's share of total buried placement investment according to lines in cluster; includes subfeeder buried placement and connecting cables for fiber subfeeder, when present
BM	feeder pole segment inv per line	=IF(AZ2=0,0,(AT2+AY2)/AZ2)	calculates feeder pole investment for current segment per line
BN	cumulative inv per line	=IF(OR(O1=1,ISTEXT(BN1)),BM2,BM2+BN1)	Accumulates feeder pole investment per line from beginning of feeder route

Workbook: **R50A_feeder.xls**
Worksheet: **cable investment**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
BO	assigned feeder pole inv	=basic_lines*BN2+IF(basic_segment_type="Cable",(1+CEILING(subfeeder_dist*BT2/VLOOKUP(line_density,density_inputs,19),1))*(pole_materials+pole_labor*((1-wtg_pole_set)+wtg_pole_set*labor_adj)*('distribution input'!Y2+'distribution input'!Z2-1)),0)+IF(basic_segment_type<>"Cable",(1+CEILING((subfeeder_dist+'distribution input'!AO2+'distribution input'!AP2)*BW2/VLOOKUP(line_density,density_inputs,19),1))*(pole_materials+pole_labor*((1-wtg_pole_set)+wtg_pole_set*labor_adj))*('distribution input'!Y2+'distribution input'!Z2-1),0)	assigns feeder pole investment to cluster according to total lines in cluster; includes subfeeder poles
BP	fiber feeder conduit segment inv per line	=IF(AE2=0,0,AU2/AE2)	Computes per-line investment in conduit containing fiber feeder cable per line
BQ	cumulative inv per line	=IF(OR(O1=1,ISTEXT(BQ1)),BP2,BP2+BQ1)	accumulates fiber conduit investment per line from beginning of feeder route
BR	assigned fiber feeder conduit inv	=IF(basic_segment_type="DLC",basic_lines*BQ2,0)+IF(basic_segment_type="Cable",0,IF(AO2=0,"",(subfeeder_dist+'distribution input'!AO2+'distribution input'!AP2)*BU2*(conduit_mat_inv_ft*(1+spare_tubes_sect))))	Assigns fiber conduit investment to cluster according to total lines in cluster; includes subfeeder conduit
BS	effective copper buried fraction	=VLOOKUP(line_density,density_inputs,5)+CF2	Computes effective buried structure fraction according to local conditions and user-set input values
BT	effective copper aerial fraction	=MAX(0,1-BS2-BU2)	computes effective aerial structure fraction for copper cable from buried and underground fractions
BU	effective copper u/g fraction	=VLOOKUP(line_density,density_inputs,6)	Repeats user-selected copper cable underground fraction for cluster density range
BV	effective fiber buried fraction	=VLOOKUP(line_density,density_inputs,11)+CN2	Computes effective buried fiber cable structure fraction according to local conditions and user-set input values
BW	effective fiber aerial fraction	=MAX(0,1-BV2-BX2)	computes effective aerial structure fraction for fiber cable from buried and underground fractions
BX	effective fiber u/g fraction	=VLOOKUP(line_density,density_inputs,12)	Repeats user-selected fiber cable underground fraction for cluster density range
BY	copper buried investment/foot, cable + placement, with sharing	=IF(Y2="Cable",((AH2*max_copper_inv+VLOOKUP(AG2,copper_inv,2,FALSE))*inputs!$C$57+VLOOKUP(line_density,density_inputs,28))*((1-wtg_copper_const)+wtg_copper_const*labor_adj),0)	Computes total copper buried investment per foot, including placement and structure sharing
BZ	copper aerial investment/foot, cable	=IF(Y2="Cable",(AH2*max_copper_inv+VLOOKUP(AG2,copper_inv,2,FALSE)*((1-wtg_copper_const)+wtg_copper_const*labor_adj)),0)	Calculates aerial copper cable investment per foot

Workbook: **R50A_feeder.xls**
Worksheet: **cable investment**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
CA	copper aerial investment/foot, pole, with sharing	=IF(Y2="Cable",(pole_materials+pole_labor*((1-wtg_pole_set)+wtg_pole_set*labor_adj))/VLOOKUP(line_density,density_inputs,19)*VLOOKUP(line_density,density_inputs,20),0)	Calculates pole investment per foot for copper cables, including effects of pole sharing
CB	std copper buried LC cost/ft, with sharing	=BY2*(LCFactors!$C$3+LCFactors!$D$3)	Computes life cycle cost/ft of buried cable, including capital carrying costs, maintenance costs, and effects of structure sharing; result represents "standard" cost unaffected by local conditions
CC	std copper aerial LC cost/ft, with sharing	=BZ2*(LCFactors!$C$5+LCFactors!$D$5)+CA2*(LCFactors!$C$9+LCFactors!$D$9)	Computes life cycle cost/ft of aerial cable, including capital carrying costs, maintenance costs, and effects of structure sharing; result represents "standard" cost unaffected by local conditions
CD	local copper buried LC cost/ft, w/sharing	=IF(Y2="Cable",((AH2*max_copper_inv+VLOOKUP(AG2,copper_inv,2,FALSE))*inputs!$C$57+('distribution input'!Y2+'distribution input'!Z2-1)*VLOOKUP(line_density,density_inputs,28))*((1-wtg_copper_const)+wtg_copper_const*labor_adj),0)*(LCFactors!$C$3+LCFactors!$D$3)	Computes life cycle cost/ft of buried cable, including capital carrying costs, maintenance costs, and effects of structure sharing and local rock and difficult surface conditions; result represents local cost adjusted to local conditions
CE	local copper aerial LC cost/ft, w/sharing	=IF(Y2="Cable",BZ2*(LCFactors!$C$5+LCFactors!$D$5)+(pole_materials+('distribution input'!Y2+'distribution input'!Z2-1)*pole_labor*((1-wtg_pole_set)+wtg_pole_set*labor_adj))/VLOOKUP(line_density,density_inputs,19)*VLOOKUP(line_density,density_inputs,20)*(LCFactors!$C$9+LCFactors!$D$9),0)	Computes life cycle cost/ft of aerial cable, including capital carrying costs, maintenance costs, and effects of structure sharing and local rock and difficult surface conditions; result represents "local" cost adjusted for local conditions
CF	copper buried adjustment	=IF(Y2="Cable",(0.5-1/(1+(CB2/CC2)/((CD2/CE2)^inputs!$G$82)))*VLOOKUP(line_density,density_inputs,23),0)	Calculates adjustment to input buried structure fraction for local density range using user-specified buried "swing" factor and standard and local cost inputs to logistic function
CG	fiber buried investment/foot, cable + placement, with sharing	=IF(Y2="DLC",VLOOKUP(AL2,fiber_inv,2,FALSE)+inputs!$C$58+AM2*(max_fiber_inv+inputs!$C$58)+VLOOKUP(line_density,density_inputs,29),0)	Computes total fiber buried investment per foot, including placement and structure sharing
CH	fiber aerial investment/foot, cable	=IF(Y2="DLC",VLOOKUP(AL2,fiber_inv,2,FALSE)+AM2*(max_fiber_inv),0)	Calculates aerial fiber cable investment per foot
CI	fiber aerial investment/foot, pole, with sharing	=IF(Y2="DLC",(pole_materials+pole_labor*((1-wtg_pole_set)+wtg_pole_set*labor_adj))/VLOOKUP(line_density,density_inputs,19)*VLOOKUP(line_density,density_inputs,24),0)	Calculates pole investment per foot for fiber cables, including effects of pole sharing
CJ	std fiber buried LC cost/ft, with sharing	=CG2*(LCFactors!$C$4+LCFactors!$D$4)	Computes life cycle cost/ft of buried cable, including capital carrying costs, maintenance costs, and effects of structure sharing; result represents "standard" cost unaffected by local conditions

Workbook: **R50A_feeder.xls**
Worksheet: **cable investment**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
CK	std fiber aerial LC cost/ft, with sharing	=CH2*(LCFactors!$C$6+LCFactors!$D$6)+CI2*(LCFactors!$C$9+LCFactors!$D$9)	Computes life cycle cost/ft of aerial cable, including capital carrying costs, maintenance costs, and effects of structure sharing; result represents "standard" cost unaffected by local conditions
CL	local fiber buried LC cost/ft, w/sharing	=IF(Y2="DLC",VLOOKUP(AL2,fiber_inv,2,FALSE)+inputs!$C$58+AM2*(max_fiber_inv+inputs!$C$58)+('distribution input'!Y2+'distribution input'!Z2-1)*VLOOKUP(line_density,density_inputs,29),0)*(LCFactors!$C$4+LCFactors!$D$4)	Computes life cycle cost/ft of buried cable, including capital carrying costs, maintenance costs, and effects of structure sharing and local rock and difficult surface conditions; result represents local cost adjusted to local conditions
CM	local fiber aerial LC cost/ft, w/sharing	=IF(Y2="DLC",CH2*(LCFactors!$C$6+LCFactors!$D$6)+(pole_materials+('distribution input'!Y2+'distribution input'!Z2-1)*pole_labor*((1-wtg_pole_set)+wtg_pole_set*labor_adj))/VLOOKUP(line_density,density_inputs,19)*VLOOKUP(line_density,density_inputs,24)*(LCFactors!$C$9+LCFactors!$D$9),0)	Computes life cycle cost/ft of aerial cable, including capital carrying costs, maintenance costs, and effects of structure sharing and local rock and difficult surface conditions; result represents "local" cost adjusted for local conditions
CN	fiber buried adjustment	=IF(Y2="DLC",(0.5-1/(1+(CJ2/CK2)/((CL2/CM2)^inputs!$G$82)))*VLOOKUP(line_density,density_inputs,27),0)	Calculates adjustment to input fiber buried structure fraction for local density range using user-specified buried "swing" factor and standard and local cost inputs to logistic function

Workbook: **R50A_feeder.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
A	wire center	='distribution input'!C2	repeats wire center location ID from distribution input sheet
B	operating company	='distribution input'!A2	repeats company name from distribution input sheet
C	CBG	='distribution input'!D2	repeats CBG from distribution input sheet
D	operating company indicator	='distribution input'!B2	repeats operating company type indicator from distribution input sheet
E	total lines	='distribution input'!I2	repeats total lines from distribution input sheet
F	business lines	='distribution input'!L2	repeats business lines from distribution input sheet
G	res lines	='distribution input'!M2	repeats residential line total from distribution input sheet
H	SA lines	='distribution input'!N2	repeats special access line total from distribution input sheet
I	public lines	='distribution input'!O2	repeats public line total from distribution input sheet
J	households	='distribution input'!P2	repeats household total from distribution input sheet
K	single-line business lines	='distribution input'!Q2	repeats single-line business line total from distribution input sheet
L	area, sq mi	='distribution input'!K2	repeats area from distribution input sheet
M	density lines/sq mi	='distribution input'!J2	repeats line density from distribution input sheet
N	density range	=VLOOKUP(M2,density_inputs,16)	repeats density range from distribution input sheet
O	cpr fdr cbl inv, u/g	=('cable inv'!$R2+'cable inv'!J2)*'cable inv'!BU2+IF('cable inv'!H2="N/A",0,'cable inv'!D2*VLOOKUP('cable inv'!H2,copper_inv,2,FALSE)*'cable inv'!BU2)	computes overall feeder copper cable investment for underground placement, including effect of regional labor multiplier
P	cpr fdr cbl inv, buried	=('cable inv'!$R2+'cable inv'!J2)*'cable inv'!BS2*inputs!$C$57+IF('cable inv'!H2="N/A",0,'cable inv'!D2*VLOOKUP('cable inv'!H2,copper_inv,2,FALSE)*'cable inv'!BS2)*inputs!$C$57	computes overall feeder copper cable investment for buried placement, including effect of regional labor multiplier
Q	cpr fdr cbl inv, aerial	=('cable inv'!$R2+'cable inv'!J2)*'cable inv'!BT2+IF('cable inv'!H2="N/A",0,'cable inv'!D2*VLOOKUP('cable inv'!H2,copper_inv,2,FALSE)*'cable inv'!BT2)	computes overall feeder copper cable investment for aerial placement, including effect of regional labor multiplier
R	fiber fdr cbl inv, u/g	=('cable inv'!$U2+'cable inv'!N2)*'cable inv'!BX2	computes overall feeder fiber cable investment for underground placement
S	fiber fdr cbl inv, buried	=('cable inv'!$U2+'cable inv'!N2+IF('cable inv'!Y2<>"Cable",('cable inv'!D2+'cable inv'!X2+'distribution input'!AM2+'distribution input'!AN2)*inputs!$C$58,0))*'cable inv'!BV2	computes overall feeder fiber cable investment for buried placement,

Workbook: **R50A_feeder.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
T	fiber fdr cbl inv aerial	=('cable inv'!$U2+'cable inv'!N2)*'cable inv'!BW2	computes overall feeder fiber cable investment for aerial placement
U	fdr conduit inv	='cable inv'!BC2+'cable inv'!BR2	calculates total conduit investment as sum of copper and fiber investments
V	feeder manhole inv	='cable inv'!BF2	repeats feeder manhole investment (includes pullboxes for fiber)
W	feeder u/g copper plcmt inv	=IF('cable inv'!$Y2="Cable",'cable inv'!$BI2,0)	repeats underground copper placement investment
X	feeder u/g fiber plcmt inv	=IF('cable inv'!$Y2="DLC",'cable inv'!$BI2,0)	repeats feeder underground fiber placement investment
Y	feeder buried copper plcmt inv	=IF('cable inv'!$Y2="Cable",'cable inv'!$BL2,0)	repeats feeder buried copper placement investment
Z	feeder buried fiber plcmt inv	=IF('cable inv'!$Y2="DLC",'cable inv'!$BL2,0)	repeats feeder buried fiber placement investment
AA	feeder pole inv	='cable inv'!BO2	repeats feeder pole investment
AB	dist cable inv, underground	='distribution input'!R2	repeats distribution underground cable investment
AC	dist cable inv, buried	='distribution input'!S2	repeats buried distribution cable investment
AD	dist cable inv, aerial	='distribution input'!T2	repeats distribution aerial cable investment
AE	distribution conduit inv	='distribution input'!U2	repeats distribution conduit investment
AF	distribution conduit plcmt inv	='distribution input'!V2	repeats distribution underground conduit placement investment
AG	dist buried plcmt inv	='distribution input'!X2	repeats distribution buried placement investment
AH	dist pole inv	='distribution input'!W2	repeats distribution pole investment
AI	calc cpr fdr fill	='cable inv'!AF2	repeats calculated copper feeder achieved fill at cluster
AJ	calc dist fill	='distribution input'!AB2	repeats calculated distribution achieved fill
AK	calc "mainframe" fill	=IF(AND('cable inv'!W2=1,'cable inv'!Y2="Cable"),output!AI2,0)	selects achieved copper feeder fill at first cluster along copper feeder cable route; equivalent to fill at mainframe
AL	DLC inv w/site	='distribution input'!AD2+'distribution input'!AF2	repeats DLC investment
AM	SAI inv	='distribution input'!AH2	repeats SAI investment
AN	terminal inv	='distribution input'!AI2	repeats terminal investment
AO	drop inv	='distribution input'!AJ2	repeats drop investment
AP	NID inv	='distribution input'!AK2	repeats NID investment

Workbook: **R50A_feeder.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Feeder Module

Column	Name	Formula	Description
AQ	feeder distance	='cable inv'!X2+'cable inv'!D2	calculates incremental distance from previous cluster plus subfeeder distance
AR	total dist distance	='distribution input'!H2	repeats total distribution structure distance
AS	DLC lines	=IF('cable inv'!Y2="DLC",'cable inv'!E2,0)	repeats number of lines served by DLC
AT	wtd cluster average loop length	='distribution input'!BA2*'distribution input'!BB2	Calculates average loop length for cluster weighted by fraction of total wire center lines in cluster for use by interface in computing weighted average loop length for wire center
AU	cluster serial number	='distribution input'!AT2	repeats cluster serial number from distribution input sheet

Workbook: **R50A_switching_io.xls**
Worksheet: **host remote**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
A	Host		First three columns are populated by interface when host/remote calculations are enables and remote/host assignments made; these entries function as a lookup table for wire center investment sheet to obtain host and remote investments
B	Remote		
C	NECA Co Code		
D	total local switched lines per host	=IF($A1<>$A2,IF(ISNA(VLOOKUP($A2,inv_tbl,1,FALSE)),0,E2+F2),0)	calculates switched line total served from host wire center
E	total local residential lines per host	=IF($A1<>$A2,IF(ISNA(VLOOKUP($A2,inv_tbl,1,FALSE)),0,VLOOKUP($A2,inv_tbl,4,FALSE)/VLOOKUP($A2,inv_tbl,2,FALSE)),0)	calculates total residential lines served from host wire center
F	total local business + public lines per host	=IF($A1<>$A2,IF(ISNA(VLOOKUP($A2,inv_tbl,1,FALSE)),0,VLOOKUP($A2,inv_tbl,5,FALSE)/VLOOKUP($A2,inv_tbl,2,FALSE)),0)	calculates total business and public lines served from host wire center
G	total HR ring traffic per host, CCS	=IF(A1<>A2,(host_res*res_loc_dir+host_bus*bus_loc_dir)*hr_fraction,0)	calculates total traffic contributed to local host/remote ring by host
H	total BHCA per host	=IF($A1<>$A2,IF(ISNA(VLOOKUP($A2,inv_tbl,1,FALSE)),0,VLOOKUP($A2,inv_tbl,65,FALSE)/VLOOKUP($A2,inv_tbl,2,FALSE)),0)	calculates total interoffice BHCA generated by host alone
I	total interoffice traffic per host, CCS	=IF($A1<>$A2,IF(ISNA(VLOOKUP($A2,inv_tbl,1,FALSE)),0,VLOOKUP($A2,inv_tbl,66,FALSE)/VLOOKUP($A2,inv_tbl,2,FALSE)),0)*io_fraction	calculates total interoffice busy hour traffic generated by host alone
J	total switched lines per remote	=IF(ISNA(VLOOKUP($B2,inv_tbl,1,FALSE)),0,K2+L2)	calculates switched line total served by remote
K	total residential lines per remote	=IF(ISNA(VLOOKUP($B2,inv_tbl,1,FALSE)),0,VLOOKUP($B2,inv_tbl,4,FALSE)/VLOOKUP($B2,inv_tbl,2,FALSE))	calculates total residential lines served by remote
L	total business + public lines per remote	=IF(ISNA(VLOOKUP($B2,inv_tbl,1,FALSE)),0,VLOOKUP($B2,inv_tbl,5,FALSE)/VLOOKUP($B2,inv_tbl,2,FALSE))	calculates total business and public lines served by remote
M	cumulative BHCA	=IF(A3=A2,M3+H2+N2,H2+N2)	accumulates busy-hour call attempts in host/remote system
N	total BHCA per remote	=IF(ISNA(VLOOKUP($B2,inv_tbl,1,FALSE)),0,VLOOKUP($B2,inv_tbl,65,FALSE)/VLOOKUP($B2,inv_tbl,2,FALSE))	total BHCA generated by remote
O	total interoffice traffic per remote,CCS	=IF(ISNA(VLOOKUP($B2,inv_tbl,1,FALSE)),0,VLOOKUP($B2,inv_tbl,66,FALSE)/VLOOKUP($B2,inv_tbl,2,FALSE))*io_fraction	total interoffice busy hour traffic generated by remote, including remote-host traffic
P	switch inv per host	=IF($A2<>$A1,VLOOKUP($W2,sw_inv_tbl,IF(OR('loop db inputs'!$B$2=8,'loop db inputs'!$B$2=1),3,9))+D2/line_fill*VLOOKUP($W2,sw_inv_tbl,IF(OR('loop db inputs'!$B$2=8,'loop db inputs'!$B$2=1),6,12))-W2/6*inputs!$C$37+AL2*inputs!$C$37+AQ2*inputs!$C$97/2-Z2*inputs!$C$24,0)*sw_install_mult	total sw inv per host, using total lines in system for table entry and directly-served lines for variable investment calculation

Workbook: **R50A_switching_io.xls**
Worksheet: **host remote**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
Q	total per line wire center inv per system	=IF(A1<>A2,AY2/W2,0)	calculates total average wire center investment per line for host/remote system
R	switch inv per remote	=(VLOOKUP($J2,sw_inv_tbl,IF(OR('loop db inputs'!$B$2=8,'loop db inputs'!$B$2=1),4,10))+J2/line_fill*VLOOKUP($J2,sw_inv_tbl,IF(OR('loop db inputs'!$B$2=8,'loop db inputs'!$B$2=1),7,13))-AA2*inputs!$C$24)*sw_install_mult	computes remote switch investment
S	cumulative switch inv per system	=IF(A3=A2,S3+P2+R2,P2+R2)	accumulates total switching investment for host/remote system
T	repeated wire center inv per line	=IF(A1<>A2,Q2,T1)	repeats wire center investment per line in all records for host/remote system
U	avg switch inv per line in system	=IF(A1<>A2,S2/W2,0)	computes overall average switch investment per line for host/remote system
V	repeated average switch inv per line	=IF(A2<>A1,U2,V1)	repeats average switch investment per line for all records in host/remote system
W	total lines in system	=X2+Y2	calculates total lines in host/remote system
X	total residential lines in system	=IF(A3=A2,X3+E2+K2,E2+K2)	calculates total residential lines in host/remote system
Y	total business + public lines in system	=IF(A3=A2,Y3+F2+L2,F2+L2)	calculates total business + public lines in host/remote system
Z	DLC lines per host wire center	=IF($A1<>$A2,VLOOKUP(A2,inv_tbl,57,FALSE),0)	computes total DLC lines served from host wire center
AA	DLC lines per remote wire center	=VLOOKUP(B2,inv_tbl,57,FALSE)	calculates total DLC lines served by remote
AB	repeated HR ring term inv/line	=IF(A2<>A1,BH2,AB1)	repeats terminal investment per line for host/remote ring for all records in system
AC	cumulative local direct traffic, CCS	=IF($A3=$A2,AC3+((host_res*(1-hr_fraction)+remote_res*(1-rh_fraction))*res_loc_dir+(host_bus*(1-hr_fraction)+remote_bus*(1-rh_fraction))*bus_loc_dir)*0.5,((host_res*(1-hr_fraction)+remote_res*(1-rh_fraction))*res_loc_dir+(host_bus*(1-hr_fraction)+remote_bus*(1-rh_fraction))*bus_loc_dir)*0.5)	accumulates local direct-routed traffic for host/remote system
AD	total local direct trunks per host	=IF($A1<>$A2,IF(AC2<=trfc_thresh,VLOOKUP(AC2,trk_table,2),CEILING(AC2/trk_occ,1)),0)	computes local direct trunks required per host from traffic table
AE	cumulative local tandem traffic, CCS	=IF($A3=$A2,AE3+(host_res+remote_res)*res_loc_tdm+(host_bus+remote_bus)*bus_loc_tdm,(host_res+remote_res)*res_loc_tdm+(host_bus+remote_bus)*bus_loc_tdm)	accumulates local tandem-routed traffic for host/remote system

Workbook: **R50A_switching_io.xls**
Worksheet: **host remote**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
AF	total local tandem trunks per host	=IF($A1<>$A2,IF(AE2<=trfc_thresh,VLOOKUP(AE2,trk_table,2),CEILING(AE2/trk_occ,1)),0)	computes local tandem trunks required per host from traffic table
AG	cumulative intraLATA direct traffic, CCS	=IF($A3=$A2,AG3+((host_res+remote_res)*res_LATA_dir+(host_bus+remote_bus)*bus_LATA_dir)*0.5,((host_res+remote_res)*res_LATA_dir+(host_bus+remote_bus)*bus_LATA_dir)*0.5)	accumulates intraLATA direct-routed traffic for host/remote system
AH	total intraLATA direct trunks per host	=IF($A1<>$A2,IF(AG2<=trfc_thresh,VLOOKUP(AG2,trk_table,2),CEILING(AG2/trk_occ,1)),0)	computes intraLATA direct trunks trunks required per host from traffic table
AI	cumulative intraLATA tandem traffic, CCS	=IF($A3=$A2,AI3+(host_res+remote_res)*res_LATA_tdm+(host_bus+remote_bus)*bus_LATA_tdm,(host_res+remote_res)*res_LATA_tdm+(host_bus+remote_bus)*bus_LATA_tdm)	accumulates intraLATA tandem-routed traffic for host/remote system
AJ	total intraLATA tandem trunks per host	=IF($A1<>$A2,IF(AI2<=trfc_thresh,VLOOKUP(AI2,trk_table,2),CEILING(AI2/trk_occ,1)),0)	computes intraLATA tandem trunks trunks required per host from traffic table
AK	cumulative OS traffic, CCS	=IF($A3=$A2,AK3+(host_res+remote_res)*res_OS+(host_bus+remote_bus)*bus_OS,(host_res+remote_res)*res_OS+(host_bus+remote_bus)*bus_OS)	accumulates operator services traffic for host/remote system
AL	total OS trunks per host	=IF($A1<>$A2,IF(AK2<=trfc_thresh,VLOOKUP(AK2,trk_table,2),CEILING(AK2/trk_occ,1)),0)	computes operator services trunks trunks required per host from traffic table
AM	cumulative direct-routed access traffic, CCS	=IF($A3=$A2,AM3+(host_res+remote_res)*res_acc_dir+(host_bus+remote_bus)*bus_acc_dir,(host_res+remote_res)*res_acc_dir+(host_bus+remote_bus)*bus_acc_dir)	accumulates direct-routed access traffic for host/remote system
AN	total direct-routed access trunks per host	=IF($A1<>$A2,IF(AM2<=trfc_thresh,VLOOKUP(AM2,trk_table,2),CEILING(AM2/trk_occ,1)),0)	computes direct access trunks trunks required per host from traffic table
AO	cumulative tandem-routed access traffic, CCS	=IF($A3=$A2,AO3+(host_res+remote_res)*res_acc_tdm+(host_bus+remote_bus)*bus_acc_tdm,(host_res+remote_res)*res_acc_tdm+(host_bus+remote_bus)*bus_acc_tdm)	accumulates tandem-routed access traffic for host/remote system
AP	total tandem-routed access trunks per host	=IF($A1<>$A2,IF(AO2<=trfc_thresh,VLOOKUP(AO2,trk_table,2),CEILING(AO2/trk_occ,1)),0)	computes tandem access trunks trunks required per host from traffic table
AQ	total A links per host	=IF(A1<>A2,2*CEILING(M2*inputs!$F$63,1),0)	computes total A signaling links per host
AR	SA lines per host	=IF(A1<>A2,VLOOKUP(A2,loop_in_tbl,8),0)	calculates total special access lines per host
AS	SA lines per remote	=VLOOKUP(B2,loop_in_tbl,8)	calculates total special access lines per remote
AT	cumulative SA lines	=IF(A3=A2,AT3+AS2,AS2)	accumulates special access lines in host/remote system
AU	total SA lines per system	=IF(A1<>A2,AR2+AT2,0)	calculates total special access lines for host/remote system
AV	total switched trunks per host	=AP2+AN2+AL2+AJ2+AH2+AF2+AD2	calculates total switched trunks per host
AW	wire center inv per host	=IF($A1<>$A2,VLOOKUP($D2,wc_inv,7),0)	computes wire center investment for host wire center

Workbook: **R50A_switching_io.xls**
Worksheet: **host remote**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
AX	wire center inv per remote	=VLOOKUP($J2,wc_inv,7)	computes wire center investment for remote wire center
AY	cumulative wire center inv	=IF(A3=A2,AY3+AW2+AX2,AW2+AX2)	accumulates wire center investment for host/remote system
AZ	host ADM inv -- HR ring	=IF(A1<>A2,IF(BF2=0,inputs!$C$159+(CEILING((BC2+BD2)*(1+transit_fac)/2/inputs!$C$165/7,1)-12)*inputs!$C$149,IF(CEILING((BC2+BD2)*(1+transit_fac)/2/inputs!$C$165/28,1)<=12,inputs!$C$158,CEILING((BC2+BD2)*(1+transit_fac)/2/inputs!$C$165/28/max_rate,1)*inputs!$C$157))+CEILING((BC2+BD2)*(1+transit_fac)/2/inputs!$C$165/28,1)*inputs!$C$164,0)	computes transmission terminal investment at host location for host/remote ring
BA	remote ADM inv -- HR ring	=IF(BF2=0,inputs!$C$159+(CEILING((BB2)*(1+transit_fac)/2/inputs!$C$165/7,1)-12)*inputs!$C$149,IF(CEILING(BB2*(1+transit_fac)/2/inputs!$C$165/28,1)<=12,inputs!$C$158,CEILING(BB2*(1+transit_fac)/2/inputs!$C$165/28/max_rate,1)*inputs!$C$157))+CEILING(BB2*(1+transit_fac)/2/inputs!$C$165/28,1)*inputs!$C$164	computes transmission terminal investment for remote wire center
BB	total ring DS0s per remote	=IF(O2<trfc_thresh,VLOOKUP(O2,trk_table,2),CEILING(O2/trk_occ,1))	calculates total DS0s on ring for remote
BC	total HR ring DS0s, host trfc only	=IF(A1<>A2,IF(G2<trfc_thresh,VLOOKUP(G2,trk_table,2),CEILING(G2/trk_occ,1)),0)	calculates total DS-0s contributed to host/remote ring by host
BD	cumulative remote DS0s	=IF(A3=A2,BD3+BB2,BB2)	accumulates ring DS0s for host/remote system
BE	> OC3 determination	=IF(A1<>A2,IF(CEILING((BD2+BC2)*(1+transit_fac)/2/inputs!$C$165/28,1)>3,1,0),0)	indicates whether ring capacity exceeds OC-3
BF	HR ring > OC3 ind	=IF(A1<>A2,BE2,BF1)	repeats ring capacity indication
BG	cumulative HR ring terminal investment	=IF(A3=A2,BG3+AZ2+BA2,AZ2+BA2)	accumulates investment in terminal equipment for host/remote ring
BH	HR ring terminal inv per line	=IF(A1<>A2,BG2/W2,0)	computes average investment per line in all host/remote ring terminal equipment

Workbook: **R50A_switching_io.xls**
Worksheet: **ring io**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
A	Remote		
B	Remote Vert (NECA)		
C	Remote Horiz (NECA)		
D	NECA Co Code		
E	Host		
F	Host Vert (NECA)		
G	Host Horiz (NECA)		
H			
I	Wire Center		
J	WC Vert (NECA)		
K	WC Horiz (NECA)		
L	NECA Co Code		
M	Tandem		
N	Tandem Vert (NECA)		
O	Tandem Horiz (NECA)		
P			
Q	Remote		
R	Remote Connects to CLLI (CLLI #1)		
S	Distance From Remote to CLLI #1, mi.		
T	Remote Connects to CLLI (CLLI #2)		
U	Distance from Remote to CLLI #2, mi.		
V	Ring Connector Node #1		
W	Ring Connector Node #2		
X	Ring Connector Distance, mi		
Y			
Z	Wire Center		
AA	Wire Center Connects to CLLI (CLLI #1)		
AB	Distance from Wire Center to CLLI #1, mi.		

Workbook: **R50A_switching_io.xls**
Worksheet: **ring io**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
AC	Wire Center Connects to CLLI (CLLI #2)		
AD	Distance from Wire Center to CLLI #2, mi.		
AE	DS-3 Equivalents		
AF	DS-3 Equivalents from Spur(s)		
AG	Ring Connector Node #1		
AH	Ring Connector Node #2		
AI	Ring Connector Distance, mi.		
AJ	Total Ring Connector Distance (mi)		
AK	Total Number of Ring Connectors		
AL			
AM	CLLI		
AN	Distance (mi)		
AO	DS-3 Equivalents		
AP	DS-3 Equivalents from Spur(s)		
AQ			
AR	Spur-Connected CLLI		
AS	Spur Connects To CLLI		
AT	Spur Distance, mi.		
AU	Spur CLLI DS-3 Equivalents		
AV			
AW	Ring System Interconnection CLLI #1		
AX	CLLI #1 Homes on Tandem		
AY	CLLI #1 Connects to CLLI (CLLI #2)		
AZ	CLLI # 2 Homes on Tandem		
BA	Ring System Interconnector Distance, mi.		
BB			

Workbook: **R50A_switching_io.xls**
Worksheet: **distance inputs**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
A	wire center		
B	STP A link distance sum		
C	local tandem distance		
D	OS Tandem Distance		
E	Ring Distance		
F	NECA Company Code		
G	NECA Vert Coord		
H	NECA Horiz Coord		
I	Serving Tandem		
J	Tandem NECA Company Code		
K	NECA Tandem Vert Coord		
L	NECA Tandem Horiz Coord		
M	Tandem LATA (From NECA Data)		
N	WC Connects to BOC CLLI		
O	Total DS-3 Equivalents in Ring		
P			
Q	Company Code		
R	Total tandems in study area		
S	Total OS tdms in study area		
T	Total tandem/STP A-Link distance		
U	Total STP pairs in study area		
V	Total STP/STP distance		
W	Total Tandem Mesh Distance		
X	Total Inter-Ring Distance		
Y	Total Number of Ring Connectors		
Z	Total Inter-Ring System Distance		
AA	Total Number of Inter-Ring System Connectors		

Workbook: **R50A_switching_io.xls**
Worksheet: **distance inputs**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
AB	Total Number of Rings Intersecting a Tandem		
AC	total unidentified tdm distance		

Workbook: **R50A_switching_io.xls**
Worksheet: **loop db inputs**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
A	wire center		
B	operating company indicator		
C	area, sq mi		
D	total lines		
E	business lines		
F	res lines		
G	public lines		
H	SA lines		
I	DLC lines		
J	feeder pole inv		
K	feeder buried fiber plcmt inv		
L	feeder buried copper plcmt inv		
M	feeder u/g fiber plcmt inv		
N	feeder u/g copper plcmt inv		
O	feeder manhole inv		

Workbook: **R50A_switching_io.xls**
Worksheet: **tandem and STP investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Row	B	C	D	Description
2	Tandem investment calculations			
3				
4	total tandems in service area		=D46	
5	total business lines in service area		=inputs!H39	
6	total residential lines in service area		=inputs!H38	
7	total public access lines in service area		=inputs!H40	
8	total tandem-routed interoffice CCS		=(D5+D7)*(inputs!F90+inputs!F92+inputs!F94)+D6*(inputs!F79+inputs!F81+inputs!F83)	
9	total special access lines in service area		=inputs!H41	
10	total tandem DS-3s		=D8/trk_occ/28	
11				
12	total common equipment investment		=D4*(inputs!$C$86+(inputs!$C$89-1)*inputs!$C$86/'tandem and STP investment'!$D$4*MIN('tandem and STP investment'!$D$34:$D$35))*(1-inputs!$C$130)	
13	per-line switch common equipment investment		=D12/(D5+D6+D7)	
14	total wire center investment		=D4*(inputs!$E$141*inputs!$D$141+inputs!$C$139)*(1-inputs!$C$130)	
15	per-line wire center investment		=D14/(D5+D6+D7)	
16				
17	STP investment calculations			
18	total STP pairs in service area		=VLOOKUP($D$44,tdm_tbl,5,FALSE)	
19				
20	total STP investment		=(D18+D25)*(inputs!$C$96+((D51+D54+D55)/inputs!C94-inputs!C93*D25)/(2*D18)*(inputs!C95-inputs!C96)/(inputs!C93))+(D4+H7+'tandem and STP investment'!D18*4*inputs!C101)*inputs!C97+D25*inputs!C95	
21	total STP wire center investment		=D18*(inputs!$E$139*inputs!$D$139+inputs!$C$139)	
22	STP wire center investment per line		=D21/(D5+D6+D7)	
23	total investment per line		=(D21+D20)/(D5+D6+D7)	
24	excess STP capacity, links		=D18*inputs!C93*2-SUMPRODUCT('wire center	

Workbook: **R50A_switching_io.xls**
Worksheet: **tandem and STP investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Row	B	C	D	Description
			investment'!F2:F2200,'wire center investment'!Z2:Z2200)	
25	excess STP capacity required		=TRUNC((D55+D54+D51)/(inputs!C94*inputs!C93))	
26	Total tandem-routed BHCA			
27				
28		business	=D5*(inputs!F90+inputs!F92+inputs!F94)/inputs!D77*100	
29		residential	=D6*(inputs!F79+inputs!F81+inputs!F83)/inputs!D76*100	
30				
31	Excess tandem real time capacity, BHCA		=D4*inputs!C84*inputs!C88-'tandem and STP investment'!D28-'tandem and STP investment'!D29	
32	Excess tandem trunk capacity, trunks		=D4*inputs!C85*inputs!C87-'tandem and STP investment'!D8/inputs!C36	
33				
34	Excess tandem switches, real-time basis		=D31/inputs!C84*inputs!C88	
35	Excess tandem switches, trunk basis		=D32/inputs!C85*inputs!C87	
36				
37				
38	Signaling link calculations			
39				
40				
41				
42				
43				
44		NECA company code	=neca_code	
45				
46		total tandems	=VLOOKUP($D$44,tdm_tbl,2,FALSE)	
47		total tdm/STP distance	=VLOOKUP($D$44,tdm_tbl,4,FALSE)	
48		avg tdm/STP distance	=IF(D46=0,0,D47/D46)	
49		avg D link investment, per link	=IF(H33=0,0,D53*D48/H33)	

Workbook: **R50A_switching_io.xls**
Worksheet: **tandem and STP investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Row	B	C	D	Description
50				
51		total links	=SUMPRODUCT('wire center investment'!F2:F2200,'wire center investment'!Z2:Z2200)	
52		total link investment	=SUMPRODUCT('wire center investment'!F2:F2200,'wire center investment'!AA2:AA2200)	
53		average link inv	=IF(D51=0,0,D52/D51)	
54		total tandem A links	=2*(D4+H7)	
55		total C links	=4*(D18)*inputs!C101	
56		equiv tdm A links/C links/line	=(D54+D55)/(D5+D6+D7)	
57				
58				
59	Total SCP investment per line		=inputs!F61	
60	Total SCP wire center investment per line		=(inputs!$E$139*inputs!$D$139+inputs!$C$139)/(D5+D6+D7)	
61				
62	Average ring distance per node, mi		=IF(COUNT('ring io'!AN:AN)=0,0,SUM('ring io'!AN:AN)/COUNT('ring io'!AN:AN))	
63	Average tandem distance, mi		=SUM('distance inputs'!C:C)/COUNT('distance inputs'!C:C)	
64	Ring + interconnector distance adjustment factor		=IF(SUM('ring io'!AN:AN)-'distance inputs'!AC2=0,0,(SUM('ring io'!AN:AN)+'distance inputs'!$X$2+'distance inputs'!$Z$2)/(SUM('ring io'!AN:AN)-'distance inputs'!AC2))	This calculation produces an adjustment factor applied to ring distances to accommodate the additional distance covered by inter-ring connections; it is applied to the ring distance calculation in the wire center investment sheet

Workbook: **R50A_switching_io.xls**
Worksheet: **tandem and STP investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Row	F	G	H	Description
7	number of operator tandems		=VLOOKUP($D$44,tdm_tbl,3,FALSE)	
8	total operator traffic, CCS		=D5*inputs!F91+'tandem and STP investment'!D6*inputs!F80	
9	total operator DS-3s		=H8/trk_occ/28	
10				
11	total operator positions		=H8/(inputs!C114*inputs!C115)	
12				
13	total OS tdm common equipment		=H7*inputs!C86	
14				
15	total OS tdm, per line		=H13/(D5+D6+D7)	
16				
17	total operator position investment		=H11*inputs!C113	
18				
19	total operator pos. investment/line		=H17/(D6+D5+D7)	
20				
21				
22	total OS tdm wire center		=H7*(inputs!$E$141*inputs!$D$141+inputs!$C$141)	
23				
24	total OS tdm wire center, per line		=H22/(D5+D6+D7)	
25				
26				
27				
28				
29	total additional bridge ADMs required		=4*'distance inputs'!Y2+2*'distance inputs'!AA2	The calculations in H29 - H35 compute investment in ADMs and DCSs for tandems and OS tandems as well as for inter-ring connections to produce an overall common ADM/DCS investment (H30) per line added to all lines in study area

Workbook: **R50A_switching_io.xls**
Worksheet: **tandem and STP investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Row	F	G	H	Description
30	total added ADM and DCS investment per line		=IF(H29<=0,0,(H29*inputs!C157+H31+H32+H34+H35)/('tandem and STP investment'!D5+'tandem and STP investment'!D6+'tandem and STP investment'!D7+D9))	
31	total tandem ADM inv per tdm loc		=IF($D$4=0,0,inputs!$C$157*'distance inputs'!AB2)	
32	total tandem DCS inv per tdm loc		=IF($D$4=0,0,$D$4*inputs!$C$164*CEILING($D$10/$D$4,1))	
33	average interoffice distance, mi		=SUMPRODUCT(output!C2:C5000,'wire center investment'!BO2:BO5000)/SUM(output!C2:C5000)	
34	total OS tdm ADM inv per loc		=IF(OS_tdm_count=0,0,OS_tdm_count*inputs!$C$157*CEILING($H$9/48/OS_tdm_count,1))	
35	total OS tdm DCS inv per loc		=IF(OS_tdm_count=0,0,OS_tdm_count*inputs!$C$164*CEILING($H$9/OS_tdm_count,1))	
36				
37	entrance facility calculations			The calculations in this section develop investment in entrance facilities, including terminal equipment, cable, and structure; they apply only to BOCs and large ICOs (operating company types 8 and 1)
38				
39		terminal multiplexer, per line	=IF(H50=0,0,H50*CEILING((H47+H48)/672/inputs!C165/H50/48,1)*inputs!C157/(D5+D6+D7+D9))	
40		cable investment, per line	=inputs!C38*H49*inputs!C192/(D5+D6+D7+D9)	
41		u/g placement, per line	=$H$50*inputs!$C$38*inputs!$E$196/($D$5+$D$6+$D$7+$D$9)	
42		buried placement, per line	=$H$50*inputs!$C$38*inputs!$E$195/($D$5+$D$6+$D$7+$D$9)	
43		pole inv, per line	=$H$50*inputs!$C$38*inputs!$E$194/($D$5+$D$6+$D$7+$D$9)	
44		pullbox inv, per line	=$H$50*inputs!$C$38*inputs!$E$197/($D$5+$D$6+$D$7+$D$9)	
45		conduit inv, per line	=$H$50*inputs!$C$38*inputs!$E$198/($D$5+$D$6+$D$7+$D$9)	
46		total per line e.f. investment	=IF(tdm_count>0,SUM(H39:H45),0)	
47		total SA lines	=D9	

Workbook: **R50A_switching_io.xls**
Worksheet: **tandem and STP investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Row	F	G	H	Description
48		total switched access trunks	=SUM('wire center investment'!$BS$2:$BS$5000)-'tandem and STP investment'!H47	
49		total OC-48s, w/fill	=CEILING((H47+H48)/inputs!C165/672/48,1)	
50		no. of entrance facilities	=D4*inputs!C40	

Workbook: **R50A_switching_io.xls**
Worksheet: **wire center investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
A	location	='loop db inputs'!A2	repeats wire center location ID
B	switches required	=IF(F2=0,0,MAX(0,CEILING(F2/line_fill/inputs!$C$17,1), CEILING((BM2*IF(('loop db inputs'!E2+'loop db inputs'!G2)/F2 <inputs!$C$22,inputs!$C$20/inputs!$C$19,inputs!$C$20+(inputs!$C$21-inputs!$C$20)*((('loop db inputs'!E2+'loop db inputs'!G2)/F2)-inputs!$C$22)/(1-inputs!$C$22))/inputs!$C$19)/VLOOKUP(F2,sw_capacity,2),1), CEILING(BN2/VLOOKUP(F2,sw_capacity,3),1)))	computes number of switches required in wire center by considering switch port, real time, and traffic limits
C	total lines	='loop db inputs'!D2	Repeats total lines, including switched and special access, served by wire center
D	total residential lines	='loop db inputs'!F2	repeats total residential lines from loop db input sheet
E	total business + public lines	='loop db inputs'!E2+'loop db inputs'!G2	calculates sum of business and public lines in wire center
F	total switched lines	='loop db inputs'!E2+'loop db inputs'!F2+'loop db inputs'!G2	calculates total switched lines (residential + business + public) in wire center
G	host/remote indicator (user defined)	=IF(AND(COUNTA('host remote'!A:A)>1,hr_enable),IF(ISNA(VLOOKUP(A2,host_list,1,FALSE)),IF(ISNA(VLOOKUP(A2,remote_tbl,1,FALSE)),"A","R"),"H"),"")	Indicates switch type according to user-invoked options: H = host R = remote A = autonomous blank = aggregated investment selected
H	installed EO switching per line	=IF(AND(sw_type="H",B2>1),(1-1/B2)*BU2+BV2/B2,BU2+BV2+BW2+BX2)	calculates end office switching investment per line according to switch type
I	MDF/protector investment per line	=IF('loop db inputs'!D2=0,0,inputs!$C$23*('loop db inputs'!D2-'loop db inputs'!I2)/'loop db inputs'!D2)	calculates total main distribution frame and protector investment per line, with adjustment for DLC-served lines (which do not require MDF/protector investment in wire center)
J	end office wire center per line	=IF(F2=0,0,IF(OR(sw_type="",sw_type="A"),1/F2*(VLOOKUP('wire center investment'!F2,wc_inv,7)+IF(B2>1,B2*VLOOKUP(F2/B2,wc_inv,6),0)),IF(sw_type="R",BZ2,IF(AND(sw_type="H",B2>1),BZ2+B2/F2*VLOOKUP(F2/B2,wc_inv,6),BZ2))))	calculates per-line investment in wire center facilities
K	total local direct-routed traffic, CCS	=(bus_public_lines*bus_loc_dir+res_lines*res_loc_dir)*0.5	computes total offered load for wire center for local direct-routed traffic
L	total local direct trunks required (equiv per line)	=IF($C2=0,0,1/$C2*IF(G2="H",VLOOKUP(A2,hr_tbl,30,FALSE),IF(K2<=trfc_thresh,VLOOKUP(K2,trk_table,2),CEILING(K2/inputs!$C$36,1))))	computes total local direct trunks required according to total offered load calculation and user-set inputs for maximum trunk occupancy

Workbook: **R50A_switching_io.xls**
Worksheet: **wire center investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
M	local direct trunk investment per line	=IF($C2=0,0,$C2*L2/$AR2*$AU2)	calculates share of total interoffice facility investment assigned to local direct trunks
N	total local tandem-routed traffic, CCS	=bus_public_lines*bus_loc_tdm+res_lines*res_loc_tdm	computes total offered load for wire center for local tandem-routed traffic
O	total local tdm trks required (equiv per line)	=IF($C2=0,0,1/$C2*IF(G2="H",VLOOKUP(A2,hr_tbl,32,FALSE),IF(N2<=trfc_thresh,VLOOKUP(N2,trk_table,2),CEILING(N2/inputs!$C$36,1))))	computes total local tandem trunks required according to total offered load calculation and user-set inputs for maximum trunk occupancy
P	local tdm trk invest per line	=IF($C2=0,0,C2*O2/$AR2*$AU2)	calculates share of total interoffice facility investment assigned to local tandem trunks
Q	total OS traffic, CCS	=bus_public_lines*bus_OS+res_lines*res_OS	computes total offered load for wire center for operator services traffic
R	OS trks required (equiv per line)	=IF(C2=0,0,1/C2*IF(G2="H",VLOOKUP(A2,hr_tbl,38,FALSE),IF(Q2<=trfc_thresh,VLOOKUP(Q2,trk_table,2),CEILING(Q2/inputs!$C$36,1))))	computes total ooperator services trunks required according to total offered load calculation and user-set inputs for maximum trunk occupancy
S	OS trk invest per line	=IF($C2=0,0,C2*R2/$AR2*$AU2)	calculates share of total interoffice facility investment assigned to operator services trunks
T	tdm invest per line	=IF(C2=0,0,IF(tdm_count>0,('tandem and STP investment'!$D$13+inputs!$C$37*('wire center investment'!O2+AL2+AF2))*inputs!$C$25*(1+intertdm_frac),inputs!$C$80))	computes per-line investment in tandem switching equipment, including common equipment and trunk ports; selects surrogate value if company has no tandems in study area
U	tandem wire center inv per line	=IF(tdm_count>0,'tandem and STP investment'!$D$15,inputs!$D$80)	computes per-line investment in tandem wire center facility; selects surrogate value if company has no tandems in study area Assumes tandem shares wire center with at least one end office switch
V	OS tdm invest per line	=IF(C2=0,0,IF(OS_tdm_count>0,('tandem and STP investment'!$H$15+inputs!$C$37*'wire center investment'!R2),inputs!$C$81))	computes per-line investment in operator tandem switching equipment, including common equipment and trunk ports; selects surrogate value if company has no OS tandems in study area
W	OS tandem wire center inv per line	=IF(OS_tdm_count>0,'tandem and STP investment'!$H$24,inputs!$D$81)	computes per-line investment in operator tandem wire center facility; selects surrogate value if company has no OS tandems in study area
X	operator position inv per line	='tandem and STP investment'!$H$19	repeats investment per line in operator position equipment

Workbook: **R50A_switching_io.xls**
Worksheet: **wire center investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
Y	STP inv per line	=IF(F2=0,0,IF(STP_count>0,('tandem and STP investment'!$D$23+Z2*(inputs!$C$97/2)),inputs!$C$79))	computes STP investment per line; if company has no STPs in study area, calculation produces surrogate value
Z	# links required (equiv per line)	=IF(C2=0,0,1/C2*IF(G2="H",VLOOKUP(A2,hr_tbl,43,FALSE),2*CEILING((bus_public_lines*bus_BHCA+res_lines*res_BHCA)*inputs!$F$63,1))+IF(OR('loop db inputs'!B2=8,COUNT('loop db inputs'!$B$2:$B$5000)>50),'tandem and STP investment'!$D$56,0))	total signaling links required by switches in wire center, expressed per line
AA	link investment per line	=IF($C2=0,0,C2*Z2/$AR2*$AU2+IF(STP_count>0,0,inputs!$D$82))	assigns signaling link share of total interoffice facility investment per line; adds surrogate value for tandem A links if company has no STPs in study area
AB	total direct routed access traffic, CCS	=bus_public_lines*bus_acc_dir+res_lines*res_acc_dir	computes total offered load for wire center for direct routed access traffic
AC	total direct routed access trunks (equiv per line)	=IF(C2=0,0,1/C2*IF(G2="H",VLOOKUP(A2,hr_tbl,40,FALSE),IF(AB2<=trfc_thresh,VLOOKUP(AB2,trk_table,2),CEILING(AB2/inputs!$C$36,1)))+AF2)	computes total direct-routed access trunks required according to total offered load calculation and user-set inputs for maximum trunk occupancy
AD	dedicated access trk inv per line	=IF($C2=0,0,C2*AC2/$AR2*$AU2)	calculates share of total interoffice facility investment assigned to direct-routed access trunks
AE	total tandem-routed access traffic, CCS	=bus_public_lines*bus_acc_tdm+res_lines*res_acc_tdm	computes total offered load for wire center for tandem routed access traffic
AF	total tandem-routed access trunks (equiv per line)	=IF(C2=0,0,1/C2*IF(G2="H",VLOOKUP(A2,hr_tbl,42,FALSE),IF(AE2<=trfc_thresh,VLOOKUP(AE2,trk_table,2),CEILING(AE2/inputs!$C$36,1))))	computes total tandem-routed access trunks required according to total offered load calculation and user-set inputs for maximum trunk occupancy
AG	switched access trk inv per line	=IF($C2=0,0,C2*AF2/$AR2*$AU2)	calculates share of total interoffice facility investment assigned to switched access trunks
AH	total intraLATA direct-routed traffic, CCS	=(bus_public_lines*bus_LATA_dir+res_lines*res_LATA_dir)*0.5	computes total offered load for wire center for direct-routed intraLATA toll traffic
AI	total intraLATA direct trunks (equiv per line)	=IF(C2=0,0,1/C2*IF(G2="H",VLOOKUP(A2,hr_tbl,34,FALSE),IF(AH2<=trfc_thresh,VLOOKUP(AH2,trk_table,2),CEILING(AH2/inputs!$C$36,1))))	computes total direct-routed intraLATA toll trunks required according to total offered load calculation and user-set inputs for maximum trunk occupancy
AJ	intraLATA trk inv (direct) per line	=IF($C2=0,0,C2*AI2/$AR2*$AU2)	calculates share of total interoffice facility investment assigned to direct-routed intraLATA toll trunks
AK	total intraLATA tandem-routed traffic, CCS	=bus_public_lines*bus_LATA_tdm+res_lines*res_LATA_tdm	computes total offered load for wire center for tandem-routed intraLATA toll traffic

Workbook: **R50A_switching_io.xls**
Worksheet: **wire center investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
AL	total intraLATA tandem trunks (equiv per line)	=IF(C2=0,0,1/C2*IF(G2="H",VLOOKUP(A2,hr_tbl,36,FALSE),IF(AK2<=trfc_thresh,VLOOKUP(AK2,trk_table,2),CEILING(AK2/inputs!$C$36,1))))	computes total tandem-routed intraLATA toll trunks required according to total offered load calculation and user-set inputs for maximum trunk occupancy
AM	intraLATA trk inv (tandem) per line	=IF($C2=0,0,C2*AL2/$AR2*$AU2)	calculates share of total interoffice facility investment assigned to tandem-routed intraLATA toll trunks
AN	total public telephone investment per line	=IF(F2=0,0,'loop db inputs'!G2*inputs!$C$120/F2)	calculates investment in public telephone station equipment per line
AO	normalized SA lines	=IF(C2=0,0,1/C2*IF(G2="H",VLOOKUP(A2,hr_tbl,47,FALSE),'loop db inputs'!H2))	calculates special access fraction of total lines; adds host/remote totals for host switches when host/remote calculations enabled
AP	normalized SA investment	=IF($C2=0,0,C2*AO2/$AR2*$AU2)	assigns special access fraction of interoffice investment per line
AQ	total switched trunks	=IF(C2=0,0,C2*(AF2+'wire center investment'!AI2+'wire center investment'!AC2+'wire center investment'!Z2+'wire center investment'!R2+'wire center investment'!O2+'wire center investment'!L2+AL2))	calculates total switched trunks in wire center (not normalized to line count)
AR	total DS-0 equivalents, with SA	=IF(C2=0,0,C2*(AF2+'wire center investment'!AI2+'wire center investment'!AC2+'wire center investment'!Z2+'wire center investment'!R2+'wire center investment'!O2+'wire center investment'!L2+AL2+AO2))	calculates total DS-0 circuits required, including special access lines
AS	SA fraction of DS-0s	=1-AQ2/AR2	calculates special access fraction of total DS-0s
AT	total fiber cable investment per line	=IF(C2=0,0,1/C2*(BO2*inputs!$C$192))	calculates total optical fiber cable investment per line
AU	total facility investment per line	=AT2+AV2+AW2+AX2+AY2+AZ2+IF(AND(ring_ind=0,loc_tdm_ind=0),CC2,0)	calculates total per-line investment in cable and structure, including poles, manholes, conduit, and buried and underground placement
AV	total aerial structure (poles) inv per line	=IF(C2=0,0,BO2*inputs!$E$194/C2)	calculates total investment per line in poles for interoffice facilities
AW	total u/g structure (conduit plcmt) inv per line	=IF(C2=0,0,BO2*inputs!$E$196/C2)	calculates total investment per line in conduit placement for interoffice facilities
AX	total pullbox inv per line	=IF(C2=0,0,BO2*inputs!$E$197/C2)	calculates total investment per line in pullboxes for interoffice facilities
AY	total buried plcmt inv per line	=IF(C2=0,0,BO2*inputs!$E$195/C2)	calculates total investment per line in buried placement for interoffice facilities
AZ	total conduit inv per line	=IF(C2=0,0,BO2*inputs!$E$198/C2)	calculates total investment per line in conduit for interoffice facilities

Workbook: **R50A_switching_io.xls**
Worksheet: **wire center investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
BA	total DS-1 equivalents (w/sizing factor)	=CEILING(AR2/inputs!$C$165/24,1)	calculates total DS-1s for wire center, including facility sizing factor
BB	total DS-3 equivalents	=CEILING(BA2/28,1)	calculates total DS-3 equivalents from DS-1 total
BC	transmission terminal investment per line	=IF(sw_type="R",VLOOKUP(A2,remote_tbl,27,FALSE),IF(C2=0,0,1/C2*(IF(BP2=1,(inputs!$C$159-(12-CEILING((BA2+(K2+AI2)/24/inputs!$C$165)/7,1)*inputs!$C$149)),(IF(BB2<=12,inputs!$C$158,inputs!$C$157)+IF(CF2>max_rate,(CEILING(CF2/max_rate,1)-1)*inputs!$C$157)+CEILING(BB2/3,1)*inputs!$C$159))+'tandem and STP investment'!$H$30+inputs!$C$164*BB2)+IF(sw_type="H",VLOOKUP(A2,hr_tbl,28,FALSE),0))+1/C2*IF(BO2<inputs!$C$163,0,inputs!$C$162*(CEILING(BO2/inputs!$C$163,1)-1))+IF(AND(ring_ind=0,loc_tdm_ind=0),CB2,0))	computes total transmission terminal investment per line, including regenerators and additional ADMs required for inter-ring connections, tandem and OS tandem ring connections; includes capacity for ring transiting traffic
BD	land investment per line	=IF(F2=0,0,1/F2*VLOOKUP(F2,wc_inv,8))	calculates land investment per line for wire center
BE	total DLC lines	='loop db inputs'!I2	repeats total DLC line count for wire center
BF	total common transport inv per line	=P2+AG2+AM2	calculates total investment per line in common (tandem) transport facilities
BG	total dedicated transport per line	=AD2+AP2	calculates total investment in dedicated transport facilities
BH	common fraction	=IF($BF2+$BG2+$BK2=0,0,$BF2/($BF2+$BG2+$BK2))	calculates common transport fraction of total transport facilities investment
BI	direct fraction	=IF($BF2+$BG2+$BK2=0,0,$BK2/($BF2+$BG2+$BK2))	calculates direct transport fraction of total transport facilities investment
BJ	dedicated fraction	=IF($BF2+$BG2+$BK2=0,0,$BG2/($BF2+$BG2+$BK2))	calculates dedicated transport fraction of total transport facilities investment
BK	total direct transport inv per line	=M2+S2+AJ2	calculates total investment per line in direct transport facilities
BL	ring distance	=IF(ring_ind=1,VLOOKUP(A2,ring_list,2,FALSE)*ring_dstnc_adj,0)	obtains ring distance (or spur distance for off-ring wire centers) from distance inputs table for companies for which rings are constructed; distance increased by adjustment factor to account for inter-ring connections
BM	BHCA	=bus_public_lines*bus_BHCA+res_lines*res_BHCA	calculates total busy-hour call attempts for wire center
BN	total BH offered traffic, CCS	=('loop db inputs'!$E2+'loop db inputs'!$G2)*inputs!$D$73+'loop db inputs'!$F2*inputs!$D$72	calculates total busy-hour offered load for wire center

Workbook: **R50A_switching_io.xls**
Worksheet: **wire center investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
BO	effective interoffice distance	=IF(ring_ind=1,BL2,IF(BT2=0,2*VLOOKUP(A2,dist_tbl,3,FALSE),2*avg_tdm_dstnc))	calculates effective interoffice distance as ring distance (or spur distance) if rings are calculated for company, otherwise produces distance to nearest BOC wire center (doubled to allow for route diversity)
BP	small office indicator	=IF('loop db inputs'!D2<sm_off_ind,1,0)	indicates (=1) if switched line total in wire center falls below user-set small office threshold value
BQ	channel bank investment for unmultiplexed SA lines per line	=IF(C2=0,0,1/C2*inputs!$C$160*CEILING(inputs!$C$161*'loop db inputs'!H2*(1-BE2/C2)/inputs!$C$165/24,1))	computes channel bank investment required to multiplex special access lines not served by DLC
BR	spare		
BS	total access circuits	=AR2*BJ2	
BT	ML ind	=IF(ISNA(VLOOKUP(A2,dist_tbl,1,FALSE)),1,0)	missing location indicator; provided as check for wire centers in loop data not appearing in distance data; normally 0
BU	autonomous switch investment per line	=IF(C2=0,0,IF(sw_type="A",1/C2*VLOOKUP(F2/B2/line_fill,sw_inv_tbl,IF(OR(BY2=8,BY2=1),2,8))+VLOOKUP(F2/B2/line_fill,sw_inv_tbl,IF(OR(BY2=8,BY2=1),5,11))-inputs!$C$37/6-inputs!$C$24*(BE2)/'loop db inputs'!D2+(Z2*inputs!$C$97/2+C2/F2*inputs!$C$37*(L2*2+O2+R2+AC2+AF2+AI2*2+AL2)),IF(AND(sw_type="H",B2>1),1/C2*VLOOKUP(F2*(1-1/B2)/B2/line_fill,sw_inv_tbl,IF(OR(BY2=8,BY2=1),2,8))+VLOOKUP(F2*(1-1/B2)/B2/line_fill,sw_inv_tbl,IF(OR(BY2=8,BY2=1),5,11))-inputs!$C$37/6-inputs!$C$24*(BE2)/'loop db inputs'!D2+(Z2*inputs!$C$97/2+C2/F2*inputs!$C$37*(L2*2+O2+R2+AC2+AF2+AI2*2+AL2)),0)))*sw_install_mult	computes investment per line in autonomous, or "stand-alone," switches; if host switch appears in multiple-switch wire centers, autonomous calculation applied to all but the first switch in the wire center
BV	host switch investment per line	=IF(sw_type="H",VLOOKUP(A2,hr_tbl,22,FALSE),0)	obtains host switch investment per line from host/remote calculations
BW	remote switch investment per line	=IF(sw_type="R",VLOOKUP(A2,remote_tbl,21,FALSE),0)	obtains remote switch investment per line from host/remote calculations
BX	aggregate switch investment	=IF(sw_type="",IF(OR(BY2=8,BY2=1),inputs!$C$3,inputs!$C$2)+inputs!$C$4*LN(F2/B2/inputs!$C$18)-inputs!$C$37/6-inputs!$C$24*(BE2)/'loop db inputs'!D2+(Z2*inputs!$C$97/2+C2/F2*inputs!$C$37*(L2*2+O2+R2+AC2+AF2+AI2*2+AL2)),0)/line_fill*sw_install_mult	computes end office switch investment per line when host/remote calculations are not enabled using aggregated investment input values that address host, remote, and antonomous switches
BY	company type	='loop db inputs'!B2	repeats operating company type code
BZ	host/remote wire center inv per line	=IF(sw_type="H",VLOOKUP(A2,hr_tbl,20,FALSE),IF(sw_type="R",VLOOKUP(A2,remote_tbl,19,FALSE),0))	obtains per-line wire center investment from host/remote calculations

Workbook: **R50A_switching_io.xls**
Worksheet: **wire center investment**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
CA	spare		determines distance over which facilities must be leased for companies without tandems in study area; the distance is the tandem distance between the BOC wire center to which the switch connects and the BOC tandem
CB	leased facility quasi-investment per line, terminal	=IF(AND(CD2=0,C2>0),term_equiv_inv*AR2/C2,0)	estimates surrogate investment for leased facility terminal equipment using monthly cost factor and representative monthly tariff input
CC	leased facility quasi-investment per line, facility	=IF(AND(CD2=0,C2>0),fac_equiv_inv*AR2/C2,0)	estimates surrogate investment for leased facility using monthly cost factor and representative monthly tariff input
CD	local tandem indicator (1 = yes)	=IF(VLOOKUP(A2,dist_tbl,6,FALSE)=VLOOKUP(A2,dist_tbl,10,FALSE),1,0)	indicates whether company has local tandem
CE	ring indicator (1 = yes)	=IF(OR(ISNA(VLOOKUP(A2,ring_list,1,FALSE)),BT2=1),0,1)	indicates whether rings have been calculated for company
CF	effective DS3s in local ring	=IF(OR(BT2=1,transit_fac=1,CE2=0),0,VLOOKUP(A2,ring_list,5,FALSE)*(1+transit_fac)/2/(1-transit_fac))	obtains total DS-3 count in ring, including contributions from small offices connected by spurs to wire centers on ring; transiting traffic adjustment made in terminal investment calculation
CG	spare		obtains tandem distance for BOC wire center to which small office connects if company has no tandems in study area

Workbook: **R50A_switching_io.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
A	wire center	='wire center investment'!A2	repeats wire center location code
B	total switched lines	='wire center investment'!F2	repeats total switched line count for wire center
C	end office switching inv per line	='wire center investment'!H2	repeats end office switching investment per line
D	MDF/protector inv per line	='wire center investment'!I2	repeats MDF/protector investment per line; applies to non-DLC lines
E	end office wire center inv per line	='wire center investment'!J2	repeats end office wire center investment per line
F	land per line	='wire center investment'!BD2	repeats wire center land investment per line
G	local tdm switching per line	='wire center investment'!T2	repeats tandem investment per line
H	local tdm wire center per line	='wire center investment'!U2	repeats wire center investment for local tandem per line
I	OS tdm switching per line	='wire center investment'!V2	repeats operator tandem investment per line
J	OS tdm wire center per line	='wire center investment'!W2	repeats wire center investment per line for OS tandem
K	OS trunk inv per line	='wire center investment'!S2	repeats investment per line in operator trunks
L	operator position inv per line	='wire center investment'!X2	repeats operator positions investment per line
M	common transport, u/g cable inv per line	=BH2*BV2	assigns cable facility investment to underground common transport
N	common transport, buried cable inv per line	=BI2*BV2	assigns cable facility investment to buried common transport
O	common transport, aerial cable inv per line	=BJ2*BV2	assigns cable facility investment to aerial common transport
P	common transport, pole inv per line	=BK2*BV2	assigns pole investment to common transport including effects of sharing interoffice and feeder structure
Q	common transport, conduit inv per line	=BL2*BV2	assigns conduit investment to common transport including effects of sharing interoffice and feeder structure
R	common transport, pullbox inv per line	=BM2*BV2	assigns pullbox investment to common transport including effects of sharing interoffice and feeder structure
S	common transmission terminal inv per line	=BV2*'wire center investment'!BC2	assigns transmission terminal investment to common transport

Workbook: **R50A_switching_io.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
T	direct transport, u/g cable inv per line	=BH2*BW2	assigns cable facility investment to underground direct transport
U	direct transport, buried cable inv per line	=BI2*BW2	assigns cable facility investment to buried direct transport
V	direct transport, aerial cable inv per line	=BJ2*BW2	assigns cable facility investment to aerial direct transport
W	direct transport, pole inv per line	=BK2*BW2	assigns pole investment to direct transport including effects of sharing interoffice and feeder structure
X	direct transport, conduit inv per line	=BL2*BW2	assigns conduit investment to direct transport including effects of sharing interoffice and feeder structure
Y	direct transport, pullbox inv per line	=BM2*BW2	assigns pullbox investment to direct transport including effects of sharing interoffice and feeder structure
Z	direct transmission terminal inv per line	=BW2*'wire center investment'!BC2	assigns transmission terminal investment to direct transport
AA	dedicated transport, u/g cable inv per line	=BH2*BX2	assigns cable facility investment to underground dedicated transport
AB	dedicated transport, buried cable inv per line	=BI2*BX2	assigns cable facility investment to buried dedicated transport
AC	dedicated transport, aerial cable inv per line	=BJ2*BX2	assigns cable facility investment to aerial dedicated transport
AD	dedicated transport, pole inv per line	=BK2*BX2	assigns pole investment to dedicated transport including effects of sharing interoffice and feeder structure
AE	dedicated transport, conduit inv per line	=BL2*BX2	assigns conduit investment to dedicated transport including effects of sharing interoffice and feeder structure
AF	dedicated transport, pullbox inv per line	=BM2*BX2	assigns pullbox investment to dedicated transport including effects of sharing interoffice and feeder structure
AG	dedicated transmission terminal inv per line	=BX2*'wire center investment'!BC2+'tandem and STP investment'!$H$46+'wire center investment'!BQ2	assigns transmission terminal investment to dedicated transport
AH	equiv per line local direct trunks	='wire center investment'!L2	repeats total local direct trunk count expressed per line

Workbook: **R50A_switching_io.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
AI	equiv per line local tandem trunks	='wire center investment'!O2	repeats total local tandem trunk count expressed per line
AJ	equiv per line intraLATA direct trunks	='wire center investment'!AI2	repeats total intraLATA direct trunk count expressed per line
AK	equiv per line intraLATA tandem trunks	='wire center investment'!AL2	repeats total intraLATA tandem trunk count expressed per line
AL	equiv per line direct-routed access trunks	='wire center investment'!AC2+'wire center investment'!AO2	repeats total direct-routed access trunk count expressed per line
AM	equiv per line tandem-routed access trunks	='wire center investment'!AF2	repeats total tandem-routed accss trunk count expressed per line
AN	equiv per line operator trunks	='wire center investment'!R2	repeats total operator trunk count expressed per line
AO	SCP inv per line	=IF(OR('loop db inputs'!B2=8,STP_count>0),'tandem and STP investment'!$D$59,inputs!$C$82)	determines SCP investment per line as calculated value or surrogate value for companies without STPs in study area
AP	SCP+STP wire center inv per line	=IF(OR('loop db inputs'!B2=8,STP_count>0),('tandem and STP investment'!$D$60+'tandem and STP investment'!$D$22),inputs!$D$79)	repeats wire center investment per line for SCP and STP
AQ	STP inv per line	='wire center investment'!Y2	repeats STP investment per line
AR	signaling link inv per line	='wire center investment'!AA2	repeats signaling link investment per line
AS	total public telephone inv per line	='wire center investment'!AN2	repeats public telephone station equipment investment per line
AT	total residential annual DEMs per line	**=inputs!$F$44**	repeats average annual residential DEMs per line
AU	total business annual DEMs per line	**=inputs!$F$43**	repeats average annual business DEMs per line
AV	total fdr pullbox inv per line	=IF('loop db inputs'!D2=0,0,'loop db inputs'!O2/'loop db inputs'!D2-BO2*('loop db inputs'!O2/'loop db inputs'!D2)/('loop db inputs'!O2/'loop db inputs'!D2+BG2))	computes feeder pullbox investment per line with effects of sharing with interoffice structure
AW	copper fdr u/g placement per line	=IF('loop db inputs'!D2='loop db inputs'!I2,0,IF('loop db inputs'!N2=0,0,'loop db inputs'!N2/('loop db inputs'!D2-'loop db inputs'!I2)-$BQ2*('loop db inputs'!N2/('loop db inputs'!D2-'loop db inputs'!I2))/('loop db inputs'!N2/('loop db inputs'!D2-'loop db inputs'!I2)+BD2)))	computes copper feeder underground placement per line with effects of sharing with interoffice structure
AX	fiber fdr u/g placement per line	=IF('loop db inputs'!I2=0,0,IF('loop db inputs'!M2=0,0,'loop db inputs'!M2/'loop db inputs'!I2-$BQ2*('loop db inputs'!M2/'loop db inputs'!I2)/('loop db inputs'!M2/'loop db inputs'!I2+BD2)))	computes fiber feeder underground placement per line with effects of sharing with interoffice structure

Workbook: **R50A_switching_io.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
AY	copper feeder buried plcmt per line	=IF('loop db inputs'!D2='loop db inputs'!I2,0,IF('loop db inputs'!L2=0,0,'loop db inputs'!L2/('loop db inputs'!D2-'loop db inputs'!I2)-$BS2*('loop db inputs'!L2/('loop db inputs'!D2-'loop db inputs'!I2))/('loop db inputs'!L2/('loop db inputs'!D2-'loop db inputs'!I2)+BE2)))	computes copper feeder buried placement investment per line with effects of sharing with interoffice structure
AZ	fiber feeder buried plcmt per line	=IF('loop db inputs'!I2=0,0,IF('loop db inputs'!K2=0,0,'loop db inputs'!K2/'loop db inputs'!I2-$BS2*('loop db inputs'!K2/'loop db inputs'!I2)/('loop db inputs'!K2/'loop db inputs'!I2+BE2)))	computes fiber feeder buried placement investment per line with effects of sharing with interoffice structure
BA	total fdr pole inv per line	=IF('loop db inputs'!D2=0,0,('loop db inputs'!J2/'loop db inputs'!D2-BU2*('loop db inputs'!J2/'loop db inputs'!D2)/('loop db inputs'!J2/'loop db inputs'!D2+BF2)))	computes feeder pole investment per line with effects of sharing with interoffice structure
BB			
BC			
BD	total transport, u/g plcmt unadj inv per line	='wire center investment'!AW2	repeats underground placement investment for transport facilities for use in feeder sharing calculation
BE	total transport, buried plcmt unadj inv per line	='wire center investment'!AY2	repeats buried placement investment for transport facilities for use in feeder sharing calculation
BF	total transport, pole unadj inv per line	='wire center investment'!AV2	repeats pole placement investment for transport facilities for use in feeder sharing calculation
BG	total transport, pullbox unadj inv per line	='wire center investment'!AX2	repeats pullbox placement investment for transport facilities for use in feeder sharing calculation
BH	total transport, u/g cable inv per line	=IF('loop db inputs'!D2=0,0,'wire center investment'!AT2*inputs!$C$172+output!BD2-output!BQ2*BD2/(BD2+('loop db inputs'!M2+'loop db inputs'!N2)/'loop db inputs'!D2))	computes final total transport underground investment per line including effects of structure sharing with feeder
BI	total transport, buried cable inv per line	=IF('loop db inputs'!D2=0,0,('wire center investment'!AT2+'wire center investment'!BO2*inputs!$C$171)*inputs!$C$169+BE2-BS2*BE2/(BE2+('loop db inputs'!K2+'loop db inputs'!L2)/'loop db inputs'!D2))	computes final total transport buried investment per line including effects of structure sharing with feeder
BJ	total transport, aerial cable inv per line	='wire center investment'!AT2*inputs!$C$178	calculates total aerial cable investment per line for transport
BK	total transport, pole inv per line	=IF('loop db inputs'!D2=0,0,BF2-BU2*BF2/(BF2+'loop db inputs'!J2/'loop db inputs'!D2))	computes final total transport pole investment per line including effects of structure sharing with feeder
BL	total transport, conduit inv per line	='wire center investment'!AZ2	computes final transport conduit investment per line
BM	total transport, pullbox inv per line	=IF('loop db inputs'!D2=0,0,BG2-BO2*BG2/(BG2+'loop db inputs'!O2/'loop db inputs'!D2))	computes final total transport pullbox investment per line including effects of structure sharing with feeder

Workbook: **R50A_switching_io.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
BN	min pullbox inv per line (i/o, fdr)	=IF('loop db inputs'!$D2=0,0,MIN('loop db inputs'!$O2/'loop db inputs'!$D2,BG2))	determines minimum pullbox investment per line between interoffice and feeder facilities for use in structure sharing calculation
BO	basic pullbox inv reduction per line	=BN2*inputs!$C$184	computes pullbox investment reduction per line resulting from sharing of structure between interoffice and feeder facilities; applied to both interoffice and feeder totals
BP	min u/g plcmt inv per line (i/o, fdr)	=IF('loop db inputs'!$D2=0,0,MIN(BD2,('loop db inputs'!$M2+'loop db inputs'!$N2)/'loop db inputs'!$D2))	determines minimum underground placement investment per line between interoffice and feeder facilities for use in structure sharing calculation
BQ	basic u/g plcmt reduction per line	=BP2*inputs!$C$184	computes underground placement investment reduction per line resulting from sharing of structure between interoffice and feeder facilities; applied to both interoffice and feeder totals
BR	min buried plcmt inv per line (i/o, fdr)	=IF('loop db inputs'!$D2=0,0,MIN(BE2,('loop db inputs'!$K2+'loop db inputs'!$L2)/'loop db inputs'!$D2))	determines minimum buried placement investment per line between interoffice and feeder facilities for use in structure sharing calculation
BS	basic buried plcmt reduction per line	=BR2*inputs!$C$184	computes buried placement investment reduction per line resulting from sharing of structure between interoffice and feeder facilities; applied to both interoffice and feeder totals
BT	min pole inv per line (i/o, fdr)	=IF('loop db inputs'!$D2=0,0,MIN(BF2,'loop db inputs'!$J2/'loop db inputs'!$D2))	determines minimum pole investment per line between interoffice and feeder facilities for use in structure sharing calculation
BU	basic pole reduction per line	=BT2*inputs!$C$184	computes pole investment reduction per line resulting from sharing of structure between interoffice and feeder facilities; applied to both interoffice and feeder totals
BV	common fraction	='wire center investment'!BH2	repeats common investment fraction of total for use in assigning various investment to common transport
BW	direct fraction	='wire center investment'!BI2	repeats direct investment fraction of total for use in assigning various investment to direct transport
BX	dedicated fraction	='wire center investment'!BJ2	repeats dedicated investment fraction of total for use in assigning various investment to dedicated transport

Workbook: **R50A_switching_io.xls**
Worksheet: **output**

Equation Listing

HAI Model, v5.0A
Switching/Interoffice Module

Column	Name	Formula	Description
BY	ML indicator	='wire center investment'!BT2	repeats missing location indicator; normally zero