# HAI Model

## Release 5.2a-MA

## *Model Description*

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# 1. Introduction

## 1.1. Overview

The HAI Model, Release 5.2a for Massachusetts ("HM 5.2a-MA") has been developed by HAI Consulting, Inc. ("HAI"), of Boulder, Colorado, at the request of AT&T for the purpose of estimating the forward-looking economic costs of:

Basic local telephone service;

Unbundled network elements ("UNEs"); and

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. [1]

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. [2]

The Joint Board includes the following functional elements as required components of universal service:

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;

[1] 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, *see*, Implementation of the Local Competition Provisions in the Telecommunications Act of 1996, CC Docket No. 96-98, Interconnection between Local Exchange Carriers and Commercial Mobile Radio Service Providers, CC Docket No. 95-185, First Report and Order, 11 FCC Rcd 15499 (1996) (*Local Competition Order*), para 672.

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

touch tone capability;

access to 911 services, operator services, directory assistance, and telecommunications relay service for the hearing-impaired.

Many other local exchange company ("LEC") services, such as toll calling, custom calling and CLASS[SM] features, private line services and white pages directory listings, are excluded from this definition of universal service. However, the modeled network is sized to reflect the existence of these services. In the case of switching features such as CLASS, the costs of those features are included in the basic price of switches assumed by the model, so the cost of the local switching UNE includes those features as well. Model users may specify which UNEs are included in the calculation of 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, including the cost of features supported by end office switch software
- Common Transport
- Dedicated Transport
- Direct Transport
- Tandem Switching
- Signaling Links
- Signal Transfer Point ("STP")
- Service Control Point ("SCP")
- Operator Systems
- Public Telephones

The Model also estimates the per-minute TSLRIC cost of providing local network interconnection and interLATA access. These are estimated for connection points at end office and tandem switches.

The Model constructs a "bottom up" estimate of 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 demand data, particularly data describing customer locations, line demand, and traffic volumes, serve as the starting point. Customers locations are determined through geocoding, and a clustering algorithm is used to develop groupings of customers that have a realistic correlation to efficient distribution areas. The Local Exchange Routing Guide ("LERG") licensed from Telcordia Technologies, Inc., is used to identify and locate incumbent local exchange carrier ("ILEC") wire centers. 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.

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.

Using these data, the Model calculates required network investments by detailed plant category. Next, it calculates the capital carrying cost of these investments. It then adds operations expenses, including both network-related expenses and various non-network expenses, such as corporate overhead, to compute the total monthly cost of universal service, the UNEs identified previously, 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 be displayed on a study area, density zone,

[3] wire center, Census Block Group ("CBG"),

[4]

or individual customer cluster basis.

This document describes the structure and operation of the HM 5.2a-MA, including a discussion of various inputs to the Model. Section 1.2 discusses similarities and differences between HM 5.2a-MA and the Synthesis Model ("SM")

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[3] HM 5.2a differentiates among density zones based on the number of subscriber access lines per square mile of service area.

[4] 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 single isolated customer locations, up to locations served by more than 1,800 lines.. See, Section 5.4 below, for a description of the spatial and size criteria used by HM 5.2a in forming customer clusters.

[5] platform developed by the Federal Communications Commission ("FCC"). Section 2 summarizes changes made to the Model between the last version of the Model filed with the FCC, HM 5.0a, 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 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. Finally, Appendix D describes the calculation of interoffice network distances in HM 5.2a-MA.

## 1.2. Evolution of the HAI Model

The evolution of the HAI Model is described in Appendix A of this model description.

### 1.2.1. Characteristics of HM 5.2a-MA

HM 5.0a, as submitted to the FCC, was responsive to each of the Commission's requirements as presented in the *Universal Service Order*,

[6] the requirements outlined in the FCC's Further Notice of Proposed Ruling Making on cost modeling,

[7] the public notice guidance provided by the Commission subsequent to its release of the

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[5] The FCC proxy cost model platform was originally called the Hybrid Proxy Cost Model ("HCPM") but is now referred to as the HCPM/HAI Synthesis Cost Proxy Model., or the Synthesis Model., with the term "HCPM" often being used to refer to the outside plant algorithms developed by the FCC. *See*, *http:// www.fcc.gov/ccb/apb/hcpm*.

[6] Federal-State Joint Board on Universal Service, CC Docket No. 96-45, Report and Order, 12 FCC Rcd 8776 (1997) (*Universal Service Order*), as corrected by Federal-State Joint Board on Universal Service, *Errata*, CC Docket No. 96-45, FCC 97-157 (rel. June 4, 1997).

[7] Federal-State Joint Board on Universal Service, Forward-Looking Mechanism for High Cost Support for Non-Rural LECs, CC Docket Nos. 96-45, 97-160, Further Notice of Proposed Rulemaking, 12 FCC Rcd 18514 (1997) *(Further Notice)*.

*Further Notice*, and additional *ex parte* interaction with the FCC during 1998. HM 5.2a-MA preserves, and in several respects described herein, further enhances, the revolutionary advances in the modeling of local telephone network costs first introduced in HM 5.0a. In particular, it incorporates the following attributes of HM 5.0a

The use of actual geocoded customer locations where available, and a process for reasonably assigning surrogate locations otherwise;

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

The option to reconcile distribution route miles with an independent measure of the amount of cable required to connect customer locations;

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 (optional);

An enhanced optimizing algorithm for the creation of efficient interoffice Synchronous Optical Network ("SONET") transport rings, including an improved treatment of independent telephone company ("ICO") wire centers homing on the tandem that can most efficiently serve the ICO wire center, regardless of ownership of the tandem.

[8]

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

Further enhancements incorporated by HM 5.2a-MA are identified in Section 2.

### 1.2.2. Similarities and Differences Between HM 5.2a-MA and the SM Platform

The SM is documented in an FCC report titled "The Hybrid Cost Proxy Model Customer Location and Loop Design Modules," by C.A. Bush, D. M. Kennet, J. Prisbrey, and W.W.

[8] The previous version of the HAI Model, HM 5.0a, required that ICO switches be homed on the nearest Bell Operating Company tandem.

Sharkey of the FCC and Vaikunth Gupta of Panum Telecom, LLC.[9] The current version of the SM locates customers using a road surrogate methodology like that used in HM 5.2a-MA. In the *Model Platform Order*, the FCC determined that the geocoding process used in HM 5.2a-MA, where available, was preferred to any alternative customer location processes and tentatively adopted the geocoding process for use in the SM; relying on road surrogating only where geocoded locations for customers were not available.[10] In the *USF Inputs Order*, the FCC reaffirmed its finding that geocoding was the preferred method for locating customers, however, because of concerns about the proprietary nature of current geocoding software, the FCC chose to use road surrogating in the SM for determining customer locations.[11] Once customer locations are determined, the SM then clusters those locations as does HM 5.2a-MA, although it uses a somewhat different clustering mechanism that the developers claim is more efficient. It overlays a matrix or grid of microcells on each cluster and determines the number of locations within each microcell. According to the SM developers, this allows it to design more precisely the distribution network required to connect the locations to the Serving Area Interface(s) ("SAI") for each cluster by targeting only those microcells that contain customer locations. One of its two distribution network design algorithms determines the minimum cost spanning tree required to connect the occupied microcells. The emphasis is on designing the minimum plant necessary to serve the occupied microcells. The feeder design in the SM is also based on the minimum cost spanning tree approach.

## *2. Summary of Changes Between HM 5.0a and HM 5.2a-MA*

This section summarizes the changes between HM 5.2a-MA and the release of the Model that was filed with the FCC in January 1998, HM 5.0a. These changes are reflected in the subsequent discussion of how HM 5.2a-MA operates, presented in Sections 4 and 6.

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[9] Documentation of the SM Model can be obtained over the internet by selecting report in the Common Carrier Bureau's home page *http://www.fcc.gov/ccb/apd/hcpm*. The home page is updated on the first and third Tuesday of each month.

[10] *Model Platform Order*, para. 31.

[11] In the Matter of Federal-State Joint Board on Universal Service, CC Docket 96-45, and Forward Looking Mechanism for High Cost Support for Non-rural LECs, CC Docket 97-160, Tenth Report and Order, Released November 2, 1999 (*USF Inputs Order)*, para. 36.

## 2.1. User Interface

Includes several new inputs to the user interface that reflect new capabilities that HM 5.2a-MA provides to the user.

Reflects changes in the default values of some existing inputs resulting from the availability of new information, the results of regulatory proceedings, and/or further consideration by the developers of the HAI Model.

! Allows for a more efficient implementation of host-remote relationships by including an access table input of existing host-remote relationships from the LERG, which the user can modify if appropriate through the interactive mode for entering such relationships that was introduced in HM 5.0a, rather than starting from scratch to make such entries.

## 2.2. Database

For customer locations in a census block ("CB") that are not geocoded, surrogate locations are uniformly distributed along the roads in the CB, rather than along boundaries of the CB as in HM 5.0a.

[12]

Locations, area, and aspect ratios of rectangles representing customer location clusters more accurately reflect the actual shape of those clusters by eliminating the requirement that the rectangle's axes be aligned in a north-south, east-west orientation.

[13]

Includes strand distance in the data record for each main cluster to represent the amount of cable that is theoretically required to connect locations within a main cluster and its associated outlier clusters.

## 2.3. Distribution Module

[12] HM 5.0a located non-geocoded customers along the periphery of the CB.

[13] The aspect ratio is now determined from the minimum rectangle that bounds the assigned cluster shape.

Allows the user the option to "normalize" the computed total distribution route distance to the strand distance in each cluster. The user can also specify a multiplier to be applied to the strand distance separately in each density zone before performing this normalization, or can allow the Model to use a built-in strand distance multiplier calculation.

When the user does not invoke the strand distance normalization option, ensures the Model produces enough distribution route distance to reach the corners of the cluster rectangles where customers may be located.

Eliminates the potential for double counting drop structure for multi-dwelling buildings such as duplexes and four-plexes.

Distinguishes between aerial cable on poles and block/building cable by allowing the user to specify the amount of cable that is actually building/block cable.

Includes poles for aerial cable in all density zones.

Alters investment in high-density and low-density digital loop carrier ("DLC") channel units when the maximum copper distribution cable distance exceeds a user adjustable input threshold.

Corrects the calculation that adds remote terminals ("RTs") in outlier clusters in the Calculations worksheet to use subscriber road cable distance instead of T1 road cable distance, and also corrects the RT investment calculations in cases where there is more than one RT in a given customer cluster.

Includes new copper cable sizing inputs that do not vary with density zone, in keeping with "fill factor" inputs recently being prescribed by various state commissions and in recognition of the fact that modularity in cable size leads to effective fill factors that can be significantly less than the corresponding input values.

Adopts investment for SAIs based on the result of an FCC examination of both indoor and outdoor SAIs

## 2.4. Feeder Module

Computes the weighted average structure sharing fraction for each of the six structure sharing inputs (i.e., three types of structure – aerial, buried, and underground – each for distribution and feeder cable) for each wire center based on the actual mix of density zones to which clusters in the wire center belong.

## 2.5. Switching and Interoffice Module

Allows the user to specify percentages of various traffic types by switch size: percentage of total traffic that is interoffice; percentage of total traffic that is operator-assisted; percentage of local traffic that is direct-routed; percentage of intraLATA traffic that is tandem-routed; and percentage of interLATA traffic that is tandem-routed. This capability permits the user to specify different traffic patterns that may exist in areas where different switch sizes are typically used, such as a different breakdown between intra-switch and inter-switch traffic in rural, suburban and urban areas.

Incorporates the investment values for Bell Operating Company ("BOC") and ICO switches adopted by the FCC in the *USF Inputs Order*.

Properly applies the analog line circuit offset for DLC lines to switched lines only.

Decreases the investment in interoffice terminals in small wire centers that are connected to high-capacity (multiple OC-48) rings.

Adds sufficient digital cross connect systems to ensure logical rings comprising a physical ring can be fully interconnected.

Adds sufficient OC-3 multiplexers to ensure the interconnection of circuits between different physical rings, and between the ring "systems" that comprise the rings connecting wire centers served by a given tandem switch, can be done at a DS-1 level of granularity.

Calculates required tandem capacity and investment on a LATA-by-LATA basis, rather than for the study area as a whole.

Substantially reduces run time through the use of more efficient ring-generating code.

Allows the user to specify the facilities-equivalent investment for leased facilities in an "a+bx" form, where the "a" term is a fixed amount and the "b" term a per-mile amount.

## 2.6. Expense Modules

Includes modifications to the USOA Detail worksheet to account for deferred taxes resulting from Internal Revenue Service ("IRS") treatment of depreciation.

Wire Center Expense Module contains new columns in the Investment Inputs worksheet to accommodate weighted average structure sharing percentages for each structure category.

Density Zone Expense Module includes new cells in the Input worksheet for residential and business Dial Equipment Minutes ("DEMs") per line in order to make output columns available in the Switching/Interoffice Module for reporting weighted average structure fractions and A-line totals per wire center.

Density Zone Expense Module includes adjusted operator wages calculation to reflect monthly wages and updated (1996) input operator wages.

Density Zone Expense Module produces state-wide results for UNEs in the form specified by Verizon. This is done through the addition of a new worksheet labeled "Rate Summary."

Allows the user to enter an expense to investment (E/I) ratio for each plant category in the ARMIS 99 Actuals worksheet of an Expense Module. When set, the user-defined ratio will override the module's default calculation of the E/I ratio based on the ARMIS expense and investment information. In HM 5.2a-MA, the worksheet is pre-coded with the ratios specified by the FCC in its *USF Inputs Order*

.[14]

Applies the Network Interface Device ("NID") yearly operations expense to the total number of lines.

## 2.7. Distance File

Adds information on LATAs and tandem counts necessary to allow the Switching and Interoffice Module to calculate tandem capacity and investment in each LATA individually.

With certain restrictions, homes ICO wire centers on the nearest tandem switch, regardless

[14] In the Matter of Federal-State Joint Board on Universal Service, CC Docket 96-45, and Forward Looking Mechanism for High Cost Support for Non-rural LECs, CC Docket 97-160, Tenth Report and Order, Released November 2, 1999.

of the ownership of the tandem. BOC wire centers continue to be homed on a tandem owned by the BOC.

For a set of wire centers belonging to a given ICO that home on a particular tandem, the ring code designates the wire center in the set that is located closest to the tandem to be the “gateway” wire center for the set. The gateway wire center serves to connect the tandem and all remaining wire centers in the set.

3.

# *Components of the Local Exchange Network*

This section describes the network configuration and components modeled in HM 5.2a-MA. Figures 1, 2 and 3 depict the relationships among the loop, switching, interoffice, and signaling network components.

## *3.1. Loop Description*

Figure 1 depicts the loop model utilized in HM 5.2a-MA.  Section 3.1.1 defines the serving area.  Section 3.1.2 provides a general description of the loop, shown in Figure 1.  Section 3.1.3 describes the loop components in more detail.

**Figure 1 Loop Components**

### *3.1.1. 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 5.2a-MA the serving areas equate to main customer clusters and their associated outlier clusters, as discussed in Section 6.2.

### *3.1.2. 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 SAIs in each serving area, where they are cross-connected to copper distribution cables. Fiber feeder cables extend to a DLC RT in the serving area, where optical digital signals are demultiplexed and converted to analog electrical 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 connected 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: 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.

[15] In urban areas, aerial distribution cable may also be attached directly to the outside of buildings, in what is called a "block cable" arrangement, or, in high-rise buildings, may consist

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[15] 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.

of interior cable usually located in vertical “risers” that extend from floor to floor. The Model treats such riser cable and its associated costs as being part of the distribution network.

[16] In a jurisdiction where riser costs are borne by building owners, the Model user can set the riser cable costs to zero so the Model will not include any costs for such cable.

### *3.1.3. Local Loop Components*

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

*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.

*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 on or close to the subscriber’s property. A pedestal contains the block terminal when distribution cable is buried.

*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 require multiple SAIs. Distribution structure components

[16] To the extent that riser cable is separately tariffed or otherwise excluded from the loop UNE, the per-foot cost of riser cable can be set to $0.

may consist of poles, trenches and conduit.

17

*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 RT converts analog signals for individual lines into a digital format and multiplexes them 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.

Several utilities, e.g., electric utilities, LECs, interexchange carriers ("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.

## 3.2. 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.

### 3.2.1. 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

[17] 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

normally contains at least one end office 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**

### *3.2.2. 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 IXC points of presence ("POPs") via dedicated trunks, and to operator tandems via operator trunks.

### *3.2.3. 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**

### *3.2.4. 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, in a forward-looking network, carry signals in SONET format. Both economic and service reliability 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 improved reliability. Use of rings and redundant point-to-point links in this fashion provides an extremely reliable connection 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.

### *3.2.5. 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 and Transport Area ("LATA").

### *3.2.6. Service Switching Points and Signaling Links*

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

### *3.2.7. 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").

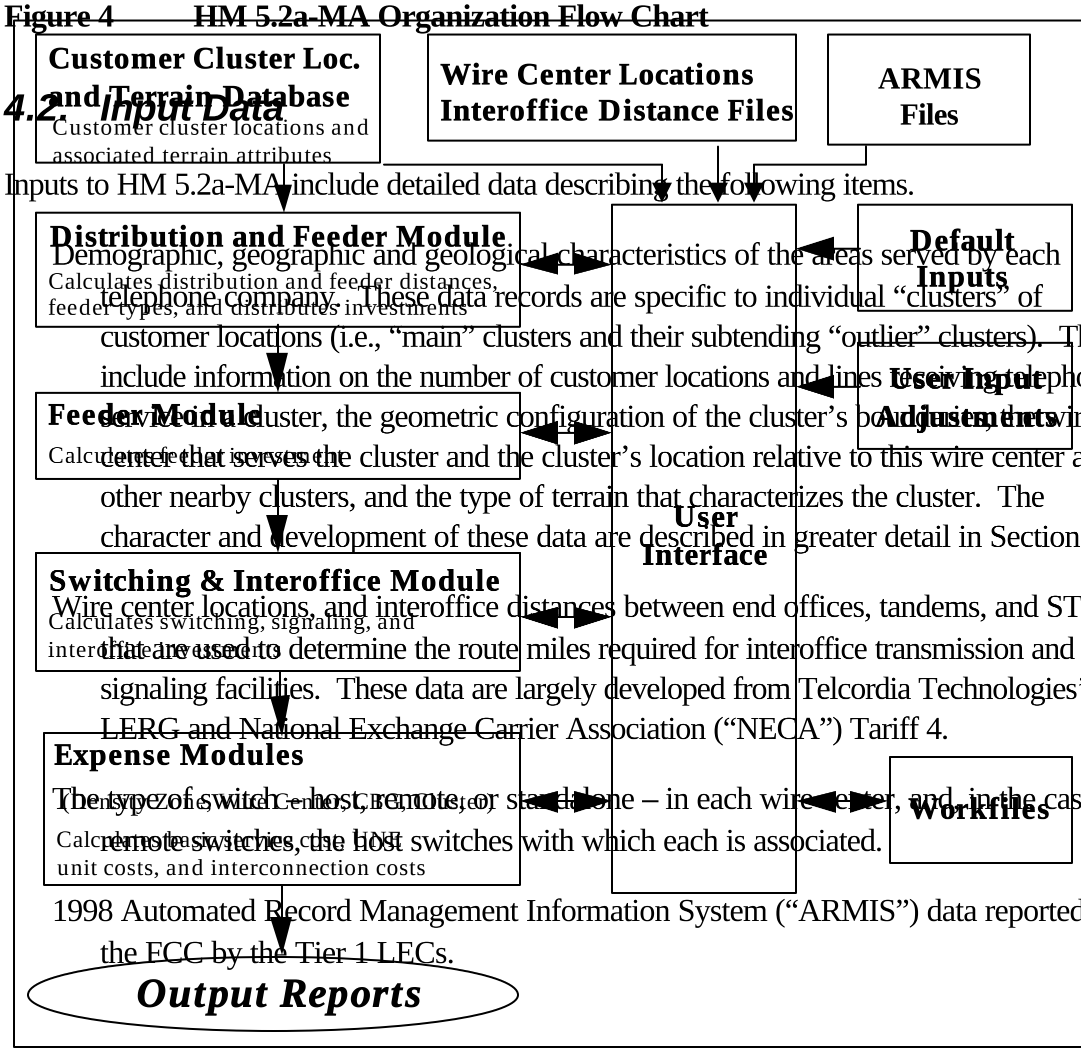
4.

# HM 5.2a-MA Model Organization, Structure and Logic

## 4.1. Overview of HM 5.2a-MA Organization

Figure 4 shows the relationships among the various modules contained within HM 5.2a-MA. An overview of each component of the Model follows.

**Figure 4 HM 5.2a-MA Organization Flow Chart**




## 4.2. Input Data

Inputs to HM 5.2a-MA 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 that are used to determine the route miles required for interoffice transmission and signaling facilities. These data are largely developed from Telcordia Technologies' LERG and National Exchange Carrier Association ("NECA") Tariff 4.

The type of switch – host, remote, or standalone – in each wire center, and, in the case of remote switches, the host switches with which each is associated.

1998 Automated Record Management Information System ("ARMIS") data reported to the FCC by the Tier 1 LECs.

[18] These data provide information about current demand levels that the LEC must serve, and relationships between the LEC's 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 judgments of independent subject matter expert consultants to HAI.

## *4.3. Workfiles*

A "workfile" is created from the input data files and calculating modules when a particular state/company (i.e., study area) combination is run for the first time. As a complete run of the HM 5.2a-MA progresses, intermediate outputs from HM 5.2a-MA's constituent modules are stored in the run's workfile. Once the run is complete, its workfile may be examined. The principal final results of the Model's analysis is presented in the Expense Module spreadsheets that are generated when the Model is run; however, a great deal of additional information 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 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. This greatly shortens execution times and allows users examining the Model's Excel workbooks to focus on the Model's fundamental engineering logic.

## *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,

[18] The FCC defines Tier 1 LECs as those with more than $100 million in annual revenues from regulated services.

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.

[19] Because one of the several criteria used by the model to decide that DLC over fiber is the appropriate choice is that the feeder distance exceeds a user-adjustable maximum copper feeder distance, the user can force the model to use all fiber feeder by setting this maximum distance to zero.

If 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 from the center of the cluster to the farthest customer location in the 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.

[20]

The HM 5.2a-MA Distribution Module serves each outlier cluster from the outliers' associated main cluster with analog copper cable if the distance from the DLC RT in the main cluster to the farthest subscriber in the outlier cluster does not exceed the user-adjustable maximum analog copper distance parameter, and if the outlier cluster has no other outlier clusters connected to it.

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[19] The criteria for selecting fiber feeder cable is described in greater detail in Section 6.3.6.

[20] 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.

21

In all other cases, the Distribution Module connects the main and outlier cluster with digital loop carrier equipment using copper-based T1 digital transmission terminating in a T1 terminal in the outlier cluster.

22 Once the outlier cluster has been reached, analog copper distribution cables are used to serve the customers located in the outlier cluster, while the T1 transmission system extends on to further outliers as necessary.

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 pullboxes for fiber optic cable). 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.

## 4.7. Switching and Interoffice Module

The Switching and Interoffice Module computes investments for end office switching, tandem

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[21] Such an outlier cluster is termed a “first order” outlier. Outliers associated with a given main cluster are “daisy-chained” together if appropriate to achieve the most economic overall serving arrangement.

[22] 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.

switching, signaling, and interoffice transmission facilities. The user can designate which specific wire center locations house host, remote, and stand-alone switches, respectively, as well as specify inputs for the per-line investments associated with each type of switch. In doing so, user can accept the existing host-remote relationships specified in the LERG and included in the HM 5.2a-MA database, specify a set of modifications to those pre-defined relationships, or enter a set of relationships from scratch. The last two options are done through the user interface mechanism for entering host-remote relationships. Rather than differentiating between host, remote, and stand-alone switches, the user can alternatively specify that each wire center is to be served as an "amalgamated" switch. This choice is made through the user interface. HM 5.2a-MA will 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 associated remotes, if the host/remote/standalone switch specification option is selected; for linking "gateway" switches to the switches that home on them; and for linking host switches to each other, to stand-alone switches and to the tandem switches on which they home.

[23] 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 5.2a-MA'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 individual customer cluster.

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[23] 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.

[24] 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, income taxes on equity return, and other taxes. 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. Further detail about network investments and costs is available from the workfile associated with a Model run.

The Distribution, Feeder, and Switching and Interoffice Modules provide network investments by specific plant category to the Expense Modules. The Expense Modules use ARMIS data, user inputs, and other sources that are used to derive information on network operating and maintenance expense relationships.

5.

[24] Although HM 5.2a 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.

# *Input Data*

Flowcharts describing the development processes used to prepare the input data for HM 5.2a-MA are attached as Appendix C to this document.

## *5.1. Line Type Counts by Study Area*

The HAI Model develops counts of access lines by type (i.e., residence, single line business, multi-line business, public telephone and special access lines) for each distinct NECA Study Area are developed from several data sources. These include:

ARMIS 43-08: 1999 data;

ARMIS 43-01: 1999 data;

NECA USF Loops filing: 1996 data;

USTA report: 1995 data;

RUS report: 1995 data;

USF Data Request: 1993 data;

ARMIS-based line factors.

The general rules by which the data source is selected are as follows.

When the NECA Study Area name matches exactly ARMIS Company name, line types are populated 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.

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.

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.

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

Of these possibilities, HM 5.2a-MA uses option (a).

## *5.2. Wire Center List*

The source of the wire center information used in the National Access Line Model, developed by PNR and Associates of Jenkintown, PA ("PNR"), is Telcordia Technologies' LERG database, dated August 1, 1997.

[25] 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 Telcordia by AT&T and WorldCom.

Switching entities (wire centers) in the SLED with Common Language Location Identifier ("CLLI™") codes not marked as end offices are removed from the 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. In such cases, HM 5.2a-MA assigns the wire centers to the local carrier having the greatest number of active NPA-NXX codes. If active NPA-NXX codes are equal among companies within a multi-carrier wire center, 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 with CBs as well as their serving wire center. The PNR National Access Line Model, Version 2.0 ("NALM") performs both of these tasks. The PNR NALM uses PNR survey information, Telcordia Technologies' LERG, Business Location Research ("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.

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

### *5.3.1. Residence Counts*

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

The Metromail household database (described in section 5.4.1, below) is geocoded to the "point" level.

[26] In addition to recording the precise six-decimal place latitude and longitude of this household, the CB associated with its location 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.

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.

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.

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 5.2, above.

[27]

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[26] 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.

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

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

The implications of the foregoing 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 5.2a-MA 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.

28

### *5.3.2. Business Counts*

Business location counts are developed by applying the following process:

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 businesses, the CB associated with each business's location is recorded as well.

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 multi-line business lines such as Centrex and PBX lines are developed. This model is based on an 800,000 firm sample.

Because the D&B national business database contains records for only about 11 million of an estimated total of 12 million U.S. businesses, and because the businesses that it misses are almost certainly small businesses, an additional one million non-D&B

[28] 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 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.

[29]

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.

[30]

### 5.3.3. Location and Line Counts by Wire Center

HM 5.2a-MA uses wire center 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 wire center are then assumed to be served by that wire center.

The customer location approach introduced in HM 5.0 and continued in HM 5.2a-MA is fundamentally different from that of versions of the HAI Model prior to HM 5.0 – or any other approach that uses arbitrary geographic delineators such as CBs, CBGs or latitude and longitude grid cells. Because HM 5.2a-MA's approach identifies the actual locations of a large majority of telephone customers to within fifty feet from the center of the roads on which they are located, it produces the 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.

### 5.3.4. Residence Location Data

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[29] 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.

[30] 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.

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 deliverable postal addresses (and telephone numbers, when available). The file is compiled primarily from telephone white pages directory data, but also uses 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. 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.

[31]

To ensure that the data captured are the most accurate available, the file 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.

### *5.3.5. 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.

The information is organized by D-U-N-S number, a nine digit identification sequence that 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 Standard Industry Classification ("SIC") code of the establishment.

### *5.3.6. Geocoding*

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[31] 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.

Geocoding is used in order to most accurately assign known customer locations to physical locations. Geocoding is also known as location coding. It involves the assignment of latitude and longitude coordinates to street addresses. Geocoding software is sophisticated enough to provide information regarding the source and precision of the latitude/longitude 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 in a less granular fashion to the CBG level, or higher. Almost uniformly, geographical address locations are derived from enhanced versions of the U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing ("TIGER") database.

To perform its geocoding, PNR uses a program by Qualitative Marketing Software called Centrus™ Desktop, which allows geocoding on two levels. The first is a match to the actual address -- which is the only type of geocoding used in HM 5.2a-MA 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 determines 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 5.2a-MA

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.

32

Location codes generated by Centrus Desktop indicate the accuracy of the geocode. For purposes of customer location clustering in the HM 5.2a-MA only those geocodes assigned at the 6-decimal place point location made directly to the street segment are used.

33

While the software and data used allow for a much more comprehensive output of data elements, for use in HM 5.2a-MA customer location, the following addressing elements are extracted:

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

### *5.3.7. Gross-up*

The above-derived precisely geocoded locations are 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

[32] 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 5.2a data.

[33] 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 simply be geocoded as at midblock.

TIGER file road locations. 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 roads within the CB,

[34] giving double weight to interior roads. Placing surrogate locations in this fashion provides a conservatively high dispersion of customer locations because it does not account for further clustering within a CB, such as small villages or neighborhoods separated by green space.

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.

## 5.4. Customer Location Clustering

### 5.4.1. 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, an efficient determination of 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 or non-degenerate area may initially exceed 1800 lines in size.

[35]

[34] Road locations are taken from the TIGER files, excluding certain types of roads along which customers are unlikely to be located, such as: limited access highway segments, road segments that are in tunnels or underpasses, vehicular trails and roads passable only be four-wheel-drive vehicles; highway access ramps, ferry crossings, pedestrian walkways and stairways, alleys for service vehicles, and driveways.

[35] The 1,800 line limit is consistent with a maximum DLC size of 2,016 lines at 90% occupancy. But if single customer locations, such as a large office or apartment building, by themselves exceed 1,800 lines, such clusters are not split. Furthermore, the final gross-up of PNR data to

No point in a cluster may be farther than two miles from its nearest neighbor in the cluster.

Note that other than 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 two 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.

### *5.4.2. Clustering Algorithm*

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

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.

[36]

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

the study area line counts and the addition of special access lines and public telephone, may cause a cluster to ultimately have more than 1,800 lines. As necessary, the Model will place multiple DLC RTs/SAIs to serve such "oversized" clusters.

[36] 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 fixed and does not depend on the local latitude of the cell. Thus, raster cells do not enlarge as one moves south toward the equator.

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 1,800 residence and business switched lines, or include a point more than two miles from its nearest neighbor).

[37] If none of these conditions would be violated, the adjoining cell plus its immediate neighbors will be added to the initial cell's cluster.

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.

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

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 lines are classified as "main" clusters. Clusters that contain from one to four lines 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.

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

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

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

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

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[37] 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 check to ensure that no cells added to a cluster exceed 17,700 (= 18,000 - 2*150) feet from the cluster's centroid.

In addition to creating chains to associate outlier clusters to a main cluster, the clustering algorithm calculates the area of the minimum rectangle covering, or "bounding," the convex hull of each cluster and the "aspect ratio" of this rectangle, which is the ratio of its length to its height.

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

The description of the HM 5.2a-MA Distribution Module in Section 6.3 provides greater detail on the Model's engineering of outside plant to serve main and outlier clusters.

## 5.5. 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:

- Converts the latitude and longitude coordinates provided by PNR for cluster centroids to the V&H coordinates used in the LERG to locate wire centers;
- Ensures that modeled distribution rectangles have an aspect ratio and area that reflects a minimum dimension equal to twice the default drop length for that cluster's density range;
- Calculates radial distances between main clusters and their serving wire center;
- Calculates radial distances between outlier clusters and main clusters, and main clusters to wire center;
- Computes omega angles between main feeders and the clusters they serve and computes alpha angles between clusters and their subfeeders;
- Calculates rectilinear (right angle) distances between main clusters and their serving wire center, and between outlier clusters and main clusters.
- Assigns terrain and line density zone characteristics to the cluster based on the characteristics of the covering CBG.

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. 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 the database. Each of these cluster records contains the following information:

Identity of the LEC and wire center serving the cluster;

Location 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 line 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 that are represented by this cluster, the average loop distribution distance of its subtending outlier clusters and total number of outlier lines;

The strand distance for each main cluster representing the amount of cable theoretically required to connect all locations associated with a main cluster and the outlier clusters associated with it, assuming connections occur along right angle routes.
[38]

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

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[38] That is, the path between two points extends up (or down) parallel to one axis of a coordinate system, and rightward (or leftward) parallel to an axis at right angles to the first axis. In this way, the route forms the two legs of a right triangle whose hypotenuse is the straight line connecting the two points.

| 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 Indicator | Special Lines | Employees |
| Outlier Quad | Public Lines | FracWCLine |
| Outlier Omega | Single Line Business | AvgLoopDist |
| Outlier Alpha | Households | TotOutLine |
| Outlier Radial Distance | Strand Distance | |

### *6.1.2. Wire Center Locations and Interoffice Distances*

Calculations to determine total route-miles of interoffice facilities require as inputs wire center location information for the ring distance program to configure its SONET rings and compute effective interoffice distances, as described below in Section 6.5.3.2. These data are calculated from the SLED file, which contains information from the 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 1999 ARMIS 43-08 Operating Data Reports. ARMIS data are submitted to the FCC annually by all Tier 1 LECs.

[39] The following elements of these data are extracted.

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[39] 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). As noted earlier, Tier 1 LECs are those with more than $100 million in annual revenues from regulated services over

The number of residential access lines, including all residential switched access lines – both 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.

[40]

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

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

[41]

### *6.1.4. User Inputs*

There are over 1400 user-definable values in HM 5.2a-MA. 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 publicly-available information, where possible, augmented by its own collective judgment and the opinions of 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. The HM 5.2a-MA Inputs Portfolio ("HIP") that accompanies the Model also contains a complete description of each user definable input, as well as the supporting information upon which the default input values are based.

## *6.2. Outside Plant Engineering*

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fifty carriers qualify as Tier 1.

[40] *Ibid.* at 1-2.

[41] *Id.* at 2.

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 5.2a-MA.

**Figure 2 HM 5.2a-MA Organization Flow Chart**

## 4.2. Input Data

Inputs to HM 5.2a-MA 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 that are used to determine the route miles required for interoffice transmission and signaling facilities. These data are largely developed from Telcordia Technologies' LERG and National Exchange Carrier Association ("NECA") Tariff 4.

The type of switch – host, remote, or standalone – in each wire center, and, in the case of remote switches, the host switches with which each is associated.

1998 Automated Record Management Information System ("ARMIS") data reported to the FCC by the Tier 1 LECs.

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The FCC defines Tier 1 LECs as those with more than $100 million in annual revenues from regulated services.

These data provide information about current demand levels that the LEC must serve, and relationships between the LEC's 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 judgments of independent subject matter expert consultants to HAI.

## 4.3. Workfiles

A "workfile" is created from the input data files and calculating modules when a particular state/company (i.e., study area) combination is run for the first time. As a complete run of the HM 5.2a-MA progresses, intermediate outputs from HM 5.2a-MA's constituent modules are stored in the run's workfile. Once the run is complete, its workfile may be examined. The principal final results of the Model's analysis is presented in the Expense Module spreadsheets that are generated when the Model is run; however, a great deal of additional information 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 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. This greatly shortens execution times and allows users examining the Model's Excel workbooks to focus on the Model's fundamental engineering logic.

## 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.

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The criteria for selecting fiber feeder cable is described in greater detail in Section 6.3.6.

Because one of the several criteria used by the model to decide that DLC over fiber is the appropriate choice is that the feeder distance exceeds a user-adjustable maximum copper feeder distance, the user can force the model to use all fiber feeder by setting this maximum distance to zero.

If 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 from the center of the cluster to the farthest customer location in the 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.

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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.

The HM 5.2a-MA Distribution Module serves each outlier cluster from the outliers' associated main cluster

with analog copper cable if the distance from the DLC RT in the main cluster to the farthest subscriber in the outlier cluster does not exceed the user-adjustable maximum analog copper distance parameter, and if the outlier cluster has no other outlier clusters connected to it.
0.0.

Such an outlier cluster is termed a "first order" outlier. Outliers associated with a given main cluster are "daisy-chained" together if appropriate to achieve the most economic overall serving arrangement. In all other cases, the Distribution Module connects the main and outlier cluster with digital loop carrier equipment using copper-based T1 digital transmission terminating in a T1 terminal in the outlier cluster.
0.0.

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. Once the outlier cluster has been reached, analog copper distribution cables are used to serve the customers located in the outlier cluster, while the T1 transmission system extends on to further outliers as necessary.

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 pullboxes for fiber optic cable). 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.

## *4.7. Switching and Interoffice Module*

The Switching and Interoffice Module computes investments for end office switching, tandem switching, signaling, and interoffice transmission facilities. The user can designate which specific wire center locations house host, remote, and stand-alone switches, respectively, as well as specify inputs for the per-line investments associated with each type of switch. In doing so, user can accept the existing host-remote relationships specified in the LERG and included in the HM 5.2a-MA database, specify a set of modifications to those pre-defined relationships, or enter a set of relationships from scratch. The last two options are done through the user interface mechanism for entering host-remote relationships. Rather than differentiating between host, remote, and stand-alone switches, the user can alternatively specify that each wire center is to be served as an "amalgamated" switch. This choice is made through the user interface. HM 5.2a-MA will 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 associated remotes, if the host/remote/standalone switch specification option is selected; for linking "gateway" switches to the switches that home on them; and for linking host switches to each other, to stand-alone switches and to the tandem switches on which they home.

0.0.

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.

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 5.2a-MA'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 individual customer cluster.

0.0.

Although HM 5.2a 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.

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, income taxes on equity return, and other taxes. 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. Further detail about network investments and costs is available from the workfile associated with a Model run.

The Distribution, Feeder, and Switching and Interoffice Modules provide network investments by specific plant category to the Expense Modules. The Expense Modules use ARMIS data, user inputs, and other sources that are used to derive information on network operating and maintenance expense relationships.

5.

# *Input Data*

Flowcharts describing the development processes used to prepare the input data for HM 5.2a-MA are attached as Appendix C to this document.

## *5.1. Line Type Counts by Study Area*

The HAI Model develops counts of access lines by type (i.e., residence, single line business, multi-line business, public telephone and special access lines) for each distinct NECA Study Area are developed from several data sources. These include:

ARMIS 43-08: 1999 data;

ARMIS 43-01: 1999 data;

NECA USF Loops filing: 1996 data;

USTA report: 1995 data;

RUS report: 1995 data;

USF Data Request: 1993 data;

ARMIS-based line factors.

The general rules by which the data source is selected are as follows.

When the NECA Study Area name matches exactly ARMIS Company name, line types are populated 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.

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.

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.

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

Of these possibilities, HM 5.2a-MA uses option (a).

## *5.2. Wire Center List*

The source of the wire center information used in the National Access Line Model, developed by PNR and Associates of Jenkintown, PA ("PNR"), is Telcordia Technologies' LERG database, dated August 1, 1997.

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These LERG data are augmented by data from NECA Tariff 4.

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 Telcordia by AT&T and WorldCom.

Switching entities (wire centers) in the SLED with Common Language Location Identifier ("CLLI™") codes not marked as end offices are removed from the 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. In such cases, HM 5.2a-MA assigns the wire centers to the local carrier having the greatest number of active NPA-NXX codes. If active NPA-NXX codes are equal among companies within a multi-carrier wire center, 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 with CBs as well as their serving wire center. The PNR National Access Line Model, Version 2.0 ("NALM") performs both of these tasks. The PNR NALM uses PNR survey information, Telcordia Technologies' LERG, Business Location Research ("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:

The Metromail household database (described in section 5.4.1, below) is geocoded to the "point" level.

0.0.

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.

In addition to recording the precise six-decimal place latitude and longitude of this household, the CB associated with its location 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.

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.

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.

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 5.2, above.

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

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

The implications of the foregoing 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 5.2a-MA 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.

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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.

### *5.3.2. Business Counts*

Business location counts are developed by applying the following process:

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 businesses, the CB associated with each business's location is recorded as well.

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 multi-line business lines such as Centrex and PBX lines are developed. This model is based on an 800,000 firm sample.

Because the D&B national business database contains records for only about 11 million of an estimated total of 12 million U.S. businesses, and because the businesses that it misses are almost certainly small businesses, an additional one million non-D&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.

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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.

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.

0.0.

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.

### *5.3.3. Location and Line Counts by Wire Center*

HM 5.2a-MA uses wire center 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 wire center are then assumed to be served by that wire center.

The customer location approach introduced in HM 5.0 and continued in HM 5.2a-MA is fundamentally different from that of versions of the HAI Model prior to HM 5.0 – or any other approach that uses arbitrary geographic delineators such as CBs, CBGs or latitude and longitude grid cells. Because HM 5.2a-MA's approach identifies the actual locations of a large majority of telephone customers to within fifty feet from the center of the roads on which they are located, it produces the 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.

### *5.3.4. 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 deliverable postal addresses (and telephone numbers, when available). The file is compiled primarily from telephone white pages directory data, but also uses 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. 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.

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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.

To ensure that the data captured are the most accurate available, the file 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.

### *5.3.5. 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.

The information is organized by D-U-N-S number, a nine digit identification sequence that 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 Standard Industry Classification ("SIC") code of the establishment.

### *5.3.6. Geocoding*

Geocoding is used in order to most accurately assign known customer locations to physical locations. Geocoding is also known as location coding. It involves the assignment of latitude and longitude coordinates to street addresses. Geocoding software is sophisticated enough to provide information regarding the source and precision of the latitude/longitude 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 in a less granular fashion to the CBG level, or higher. Almost uniformly, geographical address locations are derived from enhanced versions of the U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing ("TIGER") database.

To perform its geocoding, PNR uses a program by Qualitative Marketing Software called Centrus™ Desktop, which allows geocoding on two levels. The first is a match to the actual address -- which is the only type of geocoding used in HM 5.2a-MA 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 determines 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 5.2a-MA

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.

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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 5.2a data.

Location codes generated by Centrus Desktop indicate the accuracy of the geocode. For purposes of customer location clustering in the HM 5.2a-MA only those geocodes assigned at the 6-decimal place point location made directly to the street segment are used.

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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 simply be geocoded as at midblock.

While the software and data used allow for a much more comprehensive output of data elements, for use in HM 5.2a-MA customer location, the following addressing elements are extracted:

Address
City
State
ZIP
ZIP+4
Latitude

Longitude
Census Block
Match Code
Location Code

### 5.3.7. Gross-up

The above-derived precisely geocoded locations are 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 road locations. 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 roads within the CB,

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Road locations are taken from the TIGER files, excluding certain types of roads along which customers are unlikely to be located, such as: limited access highway segments, road segments that are in tunnels or underpasses, vehicular trails and roads passable only be four-wheel-drive vehicles; highway access ramps, ferry crossings, pedestrian walkways and stairways, alleys for service vehicles, and driveways.

giving double weight to interior roads. Placing surrogate locations in this fashion provides a conservatively high dispersion of customer locations because it does not account for further clustering within a CB, such as small villages or neighborhoods separated by green space.

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.

## 5.4. Customer Location Clustering

### 5.4.1. 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, an efficient determination of 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 or non-degenerate area may initially exceed 1800 lines in size.

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The 1,800 line limit is consistent with a maximum DLC size of 2,016 lines at 90% occupancy. But if single customer locations, such as a large office or apartment building, by themselves exceed 1,800 lines, such clusters are not split. Furthermore, the final gross-up of PNR data to the study area line counts and the addition of special access lines and public telephone, may cause a cluster to ultimately have more than 1,800 lines. As necessary, the Model will place multiple DLC RTs/SAIs to serve such "oversized" clusters.

No point in a cluster may be farther than two miles from its nearest neighbor in the cluster.

Note that other than 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 two 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.

### 5.4.2. Clustering Algorithm

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

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.

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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 fixed and does not depend on the local latitude of the cell. Thus, raster cells do not enlarge as one moves south toward the equator.

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 1,800 residence and business switched lines, or include a point more than two miles from its nearest neighbor).

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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 check to ensure that no cells added to a cluster exceed 17,700 (= 18,000 - 2*150) feet from the cluster's centroid.

If none of these conditions would be violated, the adjoining cell plus its immediate neighbors will be added to the initial cell's cluster.

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.

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

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 lines are classified as "main" clusters. Clusters that contain from one to four lines 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.

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

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

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

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 area of the minimum rectangle covering, or "bounding," the convex hull of each cluster and the "aspect ratio" of this rectangle, which is the ratio of its length to its height.

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

The description of the HM 5.2a-MA Distribution Module in Section 6.3 provides greater detail on the Model's engineering of outside plant to serve main and outlier clusters.

## 5.5. 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:

- Converts the latitude and longitude coordinates provided by PNR for cluster centroids to the V&H coordinates used in the LERG to locate wire centers;
- Ensures that modeled distribution rectangles have an aspect ratio and area that reflects a minimum dimension equal to twice the default drop length for that cluster's density range;
- Calculates radial distances between main clusters and their serving wire center;
- Calculates radial distances between outlier clusters and main clusters, and main clusters to wire center;
- Computes omega angles between main feeders and the clusters they serve and computes alpha angles between clusters and their subfeeders;
- Calculates rectilinear (right angle) distances between main clusters and their serving wire center, and between outlier clusters and main clusters.
- Assigns terrain and line density zone characteristics to the cluster based on the characteristics of the covering CBG.

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. 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 the database. Each of these cluster records contains the following information:

Identity of the LEC and wire center serving the cluster;

Location 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 line 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 that are represented by this cluster, the average loop distribution distance of its subtending outlier clusters and total number of outlier lines;

The strand distance for each main cluster representing the amount of cable theoretically required to connect all locations associated with a main cluster and the outlier clusters associated with it, assuming connections occur along right angle routes.

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That is, the path between two points extends up (or down) parallel to one axis of a coordinate system, and rightward (or leftward) parallel to an axis at right angles to the first axis. In this way, the route forms the two legs of a right triangle whose hypotenuse is the straight line connecting the two points.

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 Indicator | Special Lines | Employees |
| Outlier Quad | Public Lines | FracWCLine |
| Outlier Omega | Single Line Business | AvgLoopDist |
| Outlier Alpha | Households | TotOutLine |
| Outlier Radial Distance | Strand Distance | |

### *6.1.2. Wire Center Locations and Interoffice Distances*

Calculations to determine total route-miles of interoffice facilities require as inputs wire center location information for the ring distance program to configure its SONET rings and compute effective interoffice distances, as described below in Section 6.5.3.2. These data are calculated from the SLED file, which contains information from the 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 1999 ARMIS 43-08 Operating Data Reports. ARMIS data are submitted to the FCC annually by all Tier 1 LECs.

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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). As noted earlier, Tier 1 LECs are those with more than $100 million in annual revenues from regulated services over fifty carriers qualify as Tier 1.

The following elements of these data are extracted.

The number of residential access lines, including all residential switched access lines – both 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.

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*Ibid*. at 1-2.

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

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

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*Id*. at 2.

### 6.1.4. User Inputs

There are over 1400 user-definable values in HM 5.2a-MA. 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 publicly-available information, where possible, augmented by its own collective judgment and the opinions of 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. The HM 5.2a-MA Inputs Portfolio ("HIP") that accompanies the Model also contains a complete description of each user definable input, as well as the supporting information upon which the default input values are based.

## 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 5.2a-MA.

## *4.2. Input Data*

Inputs to HM 5.2a-MA 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 that are used to determine the route miles required for interoffice transmission and signaling facilities. These data are largely developed from Telcordia Technologies' LERG and National Exchange Carrier Association ("NECA") Tariff 4.

The type of switch – host, remote, or standalone – in each wire center, and, in the case of remote switches, the host switches with which each is associated.

1998 Automated Record Management Information System ("ARMIS") data reported to the FCC by the Tier 1 LECs.

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The FCC defines Tier 1 LECs as those with more than $100 million in annual revenues from regulated services.

These data provide information about current demand levels that the LEC must serve, and relationships between the LEC's 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 judgments of independent subject matter expert consultants to HAI.

## *4.3. Workfiles*

A "workfile" is created from the input data files and calculating modules when a particular state/company (i.e., study area) combination is run for the first time. As a complete run of the HM 5.2a-MA progresses, intermediate outputs from HM 5.2a-MA's constituent modules are stored in the run's workfile. Once the run is complete, its workfile may be examined. The principal final results of the Model's analysis is presented in the Expense Module spreadsheets that are generated when the Model is run; however, a great deal of additional information 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 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

**Figure 3 HM 5.2a-MA Organization Flow Chart**

he workfile associated with a Model run.
The Distribution, Feeder, and Switching and Interoffice Modules provide network investments by specific plant category to the Expense Modules. The Expense Modules use ARMIS data, user inputs, and other sources that are used to derive information on network operating and maintenance expense relationships.

# 5. *Input Data*

Flowcharts describing the development processes used to prepare the input data for HM 5.2a-MA are attached as Appendix C to this document.

## *5.1. Line Type Counts by Study Area*

The HAI Model develops counts of access lines by type (i.e., residence, single line business, multi-line business, public telephone and special access lines) for each distinct NECA Study Area are developed from several data sources. These include:

ARMIS 43-08: 1999 data;
ARMIS 43-01: 1999 data;
NECA USF Loops filing: 1996 data;
USTA report: 1995 data;
RUS report: 1995 data;
USF Data Request: 1993 data;
ARMIS-based line factors.

The general rules by which the data source is selected are as follows.

When the NECA Study Area name matches exactly ARMIS Company name, line types are populated 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.

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.

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.

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

Of these possibilities, HM 5.2a-MA uses option (a).

## 5.2. Wire Center List

The source of the wire center information used in the National Access Line Model, developed by PNR and Associates of Jenkintown, PA ("PNR"), is Telcordia Technologies' LERG database, dated August 1, 1997.

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These LERG data are augmented by data from NECA Tariff 4.

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 Telcordia by AT&T and WorldCom.

Switching entities (wire centers) in the SLED with Common Language Location Identifier ("CLLI™") codes not marked as end offices are removed from the 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. In such cases, HM 5.2a-MA assigns the wire centers to the local carrier having the greatest number of active NPA-NXX codes. If active NPA-NXX codes are equal among companies within a multi-carrier wire center, 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 with CBs as well as their serving wire center. The PNR National Access Line Model, Version 2.0 ("NALM") performs both of these tasks. The PNR NALM uses PNR survey information, Telcordia Technologies' LERG, Business Location Research ("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:

The Metromail household database (described in section 5.4.1, below) is geocoded to the "point" level.

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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.

In addition to recording the precise six-decimal place latitude and longitude of this household, the CB associated with its location 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.

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.

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.

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 5.2, above.

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

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

The implications of the foregoing 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 5.2a-MA 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.

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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.

### *5.3.2. Business Counts*

Business location counts are developed by applying the following process:

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 businesses, the CB associated with each business's location is recorded as well.

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 multi-line business lines such as Centrex and PBX lines are developed. This model is based on an 800,000 firm sample.

Because the D&B national business database contains records for only about 11 million of an estimated total of 12 million U.S. businesses, and because the businesses that it misses are almost certainly small businesses, an additional one million non-D&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.

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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.

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.

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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.

### 5.3.3. Location and Line Counts by Wire Center

HM 5.2a-MA uses wire center 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 wire center are then assumed to be served by that wire center.

The customer location approach introduced in HM 5.0 and continued in HM 5.2a-MA is fundamentally different from that of versions of the HAI Model prior to HM 5.0 – or any other approach that uses arbitrary geographic delineators such as CBs, CBGs or latitude and longitude grid cells. Because HM 5.2a-MA's approach identifies the actual locations of a large majority of telephone customers to within fifty feet from the center of the roads on which they are located, it produces the 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.

### 5.3.4. 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 deliverable postal addresses (and telephone numbers, when available). The file is compiled primarily from telephone white pages directory data, but also uses 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. 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.

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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.

To ensure that the data captured are the most accurate available, the file 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.

### *5.3.5. 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.

The information is organized by D-U-N-S number, a nine digit identification sequence that 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 Standard Industry Classification ("SIC") code of the establishment.

### *5.3.6. Geocoding*

Geocoding is used in order to most accurately assign known customer locations to physical locations. Geocoding is also known as location coding. It involves the assignment of latitude and longitude coordinates to street addresses. Geocoding software is sophisticated enough to provide information regarding the source and precision of the latitude/longitude 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 in a less granular fashion to the CBG level, or higher. Almost uniformly, geographical address locations are derived from enhanced versions of the U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing ("TIGER") database.

To perform its geocoding, PNR uses a program by Qualitative Marketing Software called Centrus™ Desktop, which allows geocoding on two levels. The first is a match to the actual address -- which is the only type of geocoding used in HM 5.2a-MA 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 determines 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 5.2a-MA

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.

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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 5.2a data.

Location codes generated by Centrus Desktop indicate the accuracy of the geocode. For purposes of customer location clustering in the HM 5.2a-MA only those geocodes assigned at the 6-decimal place point location made directly to the street segment are used.

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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 simply be geocoded as at midblock.

While the software and data used allow for a much more comprehensive output of data elements, for use in HM 5.2a-MA customer location, the following addressing elements are extracted:

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

### *5.3.7. Gross-up*

The above-derived precisely geocoded locations are 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 road locations. 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 roads within the CB,

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Road locations are taken from the TIGER files, excluding certain types of roads along which customers are unlikely to be located, such as: limited access highway segments, road segments that are in tunnels or underpasses, vehicular trails and roads passable only be four-wheel-drive vehicles; highway access ramps, ferry crossings, pedestrian walkways and stairways, alleys for service vehicles, and driveways.

giving double weight to interior roads. Placing surrogate locations in this fashion provides a conservatively high dispersion of customer locations because it does not account for further clustering within a CB, such as small villages or neighborhoods separated by green space.

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.

## *5.4. Customer Location Clustering*

### *5.4.1. 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, an efficient determination of 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 or non-degenerate area may initially exceed 1800 lines in size.

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The 1,800 line limit is consistent with a maximum DLC size of 2,016 lines at 90% occupancy. But if single customer locations, such as a large office or apartment building, by themselves exceed 1,800 lines, such clusters are not split. Furthermore, the final gross-up of PNR data to the study area line counts and the addition of special access lines and public telephone, may cause a cluster to ultimately have more than 1,800 lines. As necessary, the Model will place multiple DLC RTs/SAIs to serve such "oversized" clusters.

No point in a cluster may be farther than two miles from its nearest neighbor in the cluster.

Note that other than 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 two 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.

### *5.4.2. Clustering Algorithm*

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

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.

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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 fixed and does not depend on the local latitude of the cell. Thus, raster cells do not enlarge as one moves south toward the equator.

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 1,800 residence and business switched lines, or include a point more than two miles from its nearest neighbor).

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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 check to ensure that no cells added to a cluster exceed 17,700 (= 18,000 - 2*150) feet from the cluster's centroid.

If none of these conditions would be violated, the adjoining cell plus its immediate neighbors will be added to the initial cell's cluster.

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.

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

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 lines are classified as "main" clusters. Clusters that contain from one to four lines 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.

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

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

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

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 area of the minimum rectangle covering, or "bounding," the convex hull of each cluster and the "aspect ratio" of this rectangle, which is the ratio of its length to its height.

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

The description of the HM 5.2a-MA Distribution Module in Section 6.3 provides greater detail on the Model's engineering of outside plant to serve main and outlier clusters.

## *5.5. 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:

- Converts the latitude and longitude coordinates provided by PNR for cluster centroids to the V&H coordinates used in the LERG to locate wire centers;
- Ensures that modeled distribution rectangles have an aspect ratio and area that reflects a minimum dimension equal to twice the default drop length for that cluster's density range;
- Calculates radial distances between main clusters and their serving wire center;
- Calculates radial distances between outlier clusters and main clusters, and main clusters to wire center;
- Computes omega angles between main feeders and the clusters they serve and computes alpha angles between clusters and their subfeeders;
- Calculates rectilinear (right angle) distances between main clusters and their serving wire center, and between outlier clusters and main clusters.
- Assigns terrain and line density zone characteristics to the cluster based on the characteristics of the covering CBG.

# 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. 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 the database. Each of these cluster records contains the following information:

Identity of the LEC and wire center serving the cluster;

Location 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 line 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 that are represented by this cluster, the average loop distribution distance of its subtending outlier clusters and total number of outlier lines;

The strand distance for each main cluster representing the amount of cable theoretically required to connect all locations associated with a main cluster and the outlier clusters associated with it, assuming connections occur along right angle routes.

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That is, the path between two points extends up (or down) parallel to one axis of a coordinate system, and rightward (or leftward) parallel to an axis at right angles to the first axis. In this way, the route forms the two legs of a right triangle whose hypotenuse is the straight line connecting the two points.

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 Indicator | Special Lines | Employees |
| Outlier Quad | Public Lines | FracWCLine |
| Outlier Omega | Single Line Business | AvgLoopDist |
| Outlier Alpha | Households | TotOutLine |
| Outlier Radial Distance | Strand Distance | |

### *6.1.2. Wire Center Locations and Interoffice Distances*

Calculations to determine total route-miles of interoffice facilities require as inputs wire center location information for the ring distance program to configure its SONET rings and compute effective interoffice distances, as described below in Section 6.5.3.2. These data are calculated from the SLED file, which contains information from the 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 1999 ARMIS 43-08 Operating Data Reports. ARMIS data are submitted to the FCC annually by all Tier 1 LECs.

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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). As noted earlier, Tier 1 LECs are those with more than $100 million in annual revenues from regulated services over fifty carriers qualify as Tier 1.

The following elements of these data are extracted.

The number of residential access lines, including all residential switched access lines – both 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.

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*Ibid*. at 1-2.

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

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

0.0.

*Id*. at 2.

### 6.1.4. User Inputs

There are over 1400 user-definable values in HM 5.2a-MA. 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 publicly-available information, where possible, augmented by its own collective judgment and the opinions of 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. The HM 5.2a-MA Inputs Portfolio ("HIP") that accompanies the Model also contains a complete description of each user definable input, as well as the supporting information upon which the default input values are based.

## 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 5.2a-MA.

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 maximum analog copper distance whose default value is 18,000 feet. 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 that typically exists.

### *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.

*AERIAL STRUCTURE*

AERIAL STRUCTURE TYPICALLY CONSISTS OF POLES.

[42] 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 5.2A-MA COMPUTES THE TOTAL INVESTMENT IN AERIAL DISTRIBUTION AND FEEDER STRUCTURE ASSOCIATED WITH A CLUSTER 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.

*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.

[43] THE TOTAL INVESTMENT IN BURIED STRUCTURE IS A FUNCTION OF TOTAL ROUTE MILEAGE,

[42] In the two highest density zones, aerial cable is assumed to consist of a user adjustable mix of intrabuilding riser cable, "block cable" attached to buildings, and cable strung from poles.

[43] 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.

THE FRACTION OF BURIED STRUCTURE, INVESTMENT IN PROTECTIVE SHEATHING AND FILLING, AND THE DENSITY-RANGE-SPECIFIC COST OF TRENCHING.

*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 5.2A-MA 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 5.2A-MA 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 CLUSTER IS ASSUMED TO HAVE THE TERRAIN CHARACTERISTICS OF THE CBG IN WHICH IT PREDOMINATELY FALLS.

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IF THE ROCK DEPTH IN A SERVING AREA IS LESS THAN A USER-DEFINABLE ROCK DEPTH THRESHOLD, A ROCK PLACEMENT MULTIPLIER INCREASES STRUCTURE INVESTMENT IN POLES, CONDUIT PLACEMENT, AND TRENCHING, BECAUSE IT IS MORE DIFFICULT TO PLACE THESE STRUCTURES IN ROCK THAN IN SOIL.

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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.

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WATER TABLE DEPTH DOES NOT HAVE A SIGNIFICANT EFFECT ON TRENCHING COSTS, BUT

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[44] 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.

[45] The 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.

[46] 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.

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 THOSE 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 MODEL REFLECT BEST FORWARD-LOOKING, ECONOMIC PRACTICES FOR THE VARIOUS UTILITIES INVOLVED.

### *6.2.4. LINE DENSITY CONSIDERATIONS*

A NUMBER OF PARAMETERS, SUCH AS THE MIXTURE OF UNDERGROUND, BURIED, AND AERIAL PLANT, AND THE AMOUNT OF SHARING OF STRUCTURE COSTS WITH OTHER UTILITIES, ARE DEPENDENT ON LINE DENSITY ZONE OF THE SERVING AREA. WHILE ENTIRE SERVING AREAS ARE ASSOCIATED WITH A GIVEN DENSITY ZONE FOR PURPOSES OF ACCUMULATING DENSITY ZONE RESULTS, HM 5.2A-MA MAKES A SEPARATE DENSITY ZONE DETERMINATION FOR THE MAIN CLUSTER AND THE OUTLIER CLUSTERS, BASED ON THE CBG TO WHICH EACH PREDOMINATELY BELONGS, WHEN IT IS SELECTING WHICH DENSITY-ZONE-DEPENDENT FACTORS TO USE IN A CALCULATION. 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*

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. IN ADDITION TO NOMINAL BURIED AND AERIAL FRACTIONS, THE USER MAY SPECIFY 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.

[47] 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

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[47] 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 5.2a 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.

INVERSE FASHION) FROM ITS NATIONAL DEFAULT VALUE 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 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 SET AT A DEFAULT VALUE OF 75 PERCENT.

## 6.3. DISTRIBUTION MODULE

### 6.3.1. TREATMENT OF MAIN CLUSTERS

THE DISTRIBUTION MODULE 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 FOR THE MAIN CLUSTERS IS A "GRID" TOPOLOGY, IN WHICH TAPERING BACKBONE CABLES RUN FROM THE SAI(S), WHILE BRANCH CABLES EXTEND PERPENDICULAR TO THE BACKBONE CABLES PAST THE INDIVIDUAL SUBSCRIBER LOCATIONS. THE BACKBONE CABLES EXTEND TO WITHIN A LOT DEPTH OF THE "NORTH AND SOUTH" CLUSTER BOUNDARIES, AND THE BRANCH CABLES RUN TO WITHIN A LOT WIDTH OF THE EAST AND WEST CLUSTER BOUNDARIES.

MAIN CLUSTERS WITH TOTAL AREAS LESS THAN 0.03 SQUARE MILES AND LINE DENSITIES GREATER THAN 30,000 LINES PER SQUARE MILE ARE ASSUMED TO CONSIST OF HIGH-RISE BUILDINGS AND ACCORDED SPECIAL TREATMENT APPROPRIATE FOR SUCH BUILDINGS. 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.

[48] THE OCCUPIED BUILDING SPACE IN SQUARE FEET IS CALCULATED AS FOLLOWS:

OCCUPIED SPACE = 1,500 * # HOUSEHOLDS + 200 * # EMPLOYEES.

FOR CLUSTERS NOT DEFINED AS CONTAINING HIGH-RISES, 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. THE MODEL 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 CONSERVATIVELY UNDERESTIMATE THE EFFECTIVE LOT SIZE OF DETACHED HOMES BECAUSE IT IS COUNTING TOO HIGH A NUMBER OF EQUIVALENT CUSTOMER

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[48] 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.

LOCATIONS. THIS UNDERESTIMATE OF EFFECTIVE LOT SIZE WILL IN TURN CONSERVATIVELY OVERESTIMATE THE AMOUNT OF DISTRIBUTION PLANT THAT IS PLACED COMPARED TO THE AMOUNT THAT ACTUALLY IS NECESSARY TO SERVE THIS AREA.

IN ALL CASES, THE MODULE PERFORMS A TEST TO ENSURE THAT THE LONGEST COMBINED BACKBONE AND BRANCH CABLE RUN DOES NOT EXCEED THE USER-ADJUSTABLE MAXIMUM ANALOG COPPER DISTANCE. IF THE MAXIMUM DISTANCE WOULD OTHERWISE BE EXCEEDED, THE MODEL WILL ASSUME THE FEEDER AND SUBFEEDER ARE FIBER OPTICS, AND EXTEND THE FIBER SUBFEEDER "CONNECTING CABLES" FROM THE CENTROID OF THE CLUSTER TO TWO OR MORE DLC RTS (AND ADJACENT SAIS) POSITIONED TO REDUCE THE LENGTH OF BACKBONE CABLE, BRANCH CABLE, OR BOTH 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 SUB-AREAS.

### *6.3.2. TREATMENT OF OUTLIER CLUSTERS*

OUTLIER CLUSTERS, EACH CONSISTING OF ONE OR MORE CUSTOMER LOCATIONS, ARE SERVED BY THE NEAREST MAIN CLUSTER. A MAIN CLUSTER AND ITS ASSOCIATED 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 THE MAXIMUM ANALOG COPPER DISTANCE, 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, SUBSCRIBER ROAD 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.

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 EITHER AN AERIAL OR BURIED DROP CABLE CONTAINING SEVERAL WIRE PAIRS FROM THE DISTRIBUTION CABLE TO THE NID LOCATED ON THE WALL OF THE PREMISES. HM 5.2A-MA 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. NOTE THAT HM 5.2A-MA ACCOUNTS FOR THE FACT THAT DROP STRUCTURE (E.G., TRENCHING) IS LIKELY TO BE SHARED WHERE MULTIPLE-HOUSEHOLD DWELLINGS SUCH AS DUPLEXES AND FOUR-PLEXES ARE BEING SERVED. THE DISTRIBUTION MODULE COMPUTES DROP INVESTMENT BY ASSIGNING THE TOTAL DROP MATERIAL AND STRUCTURE INVESTMENT TO EACH SINGLE-LINE BUSINESS LINE AND TO EACH DETACHED HOUSEHOLD. FOR SINGLE-FAMILY ATTACHED DWELLINGS, DUPLEXES, FOUR-PLEXES, AND OTHER MULTIPLE-DWELLING-UNIT BUILDINGS, IT ASSIGNS THE DROP MATERIAL INVESTMENT TO EACH LINE AND THE DROP STRUCTURE INVESTMENT TO EACH OCCUPIED BUILDING. THE MODEL ESTIMATES THE NUMBER OF BUILDINGS OF EACH TYPE BY

CONSULTING AN INPUT TABLE SHOWING NATIONWIDE OCCUPANCY RATES BY BUILDING TYPE AND BY DENSITY ZONE.

### *6.3.4. NORMALIZATION OF DISTRIBUTION DISTANCES*

AT THE DISCRETION OF THE USER, THE DISTANCES ASSOCIATED WITH THE DISTRIBUTION NETWORK FOR A GIVEN MAIN CLUSTER -- THE CONNECTING CABLE, IF ANY, BETWEEN THE MAIN FEEDER TERMINATION AND DLC RTS IN THE MAIN CLUSTER, THE DISTRIBUTION BACKBONE AND BRANCH CABLES IN MAIN CLUSTERS, THE CABLES CONNECTING OUTLIER CLUSTERS TO MAIN CLUSTERS, AND THE DISTRIBUTION CABLE WITHIN THE OUTLIER CLUSTERS -- CAN BE ADJUSTED SO THE SUM OF THEIR DISTANCES, REFERRED TO AS THE DISTRIBUTION ROUTE DISTANCE ("DRD"), IS NORMALIZED TO A FUNCTION OF THE STRAND DISTANCE.

[49] THE NORMALIZATION, IF DONE, IS BASED ON THE FOLLOWING LOGIC AND METHODOLOGY.

THERE MAY BE REASONS WHY THE STRAND DISTANCE ASSOCIATED WITH A GIVEN CLUSTER IN THE HM 5.2A-MA DATABASE IS SYSTEMATICALLY OVER-ESTIMATED OR UNDER-ESTIMATED. EXAMPLES OF SUCH SYSTEMATIC BIASES MIGHT INCLUDE 1) THE CONSERVATIVE OVER-ESTIMATION OF CUSTOMER DISPERSION, AND THUS STRAND DISTANCE, DUE TO THE USE OF SURROGATE LOCATIONS; AND 2) THE NEED TO CONSIDER A ROUTE-TO-AIR MULTIPLIER THAT CAPTURES THE FACT THAT DISTRIBUTION CABLE CANNOT ALWAYS BE "BEELINE ROUTED" BETWEEN CUSTOMERS.

[50] THUS, THERE IS A USER-ADJUSTABLE STRAND DISTANCE MULTIPLIER THAT CAN BE SPECIFIED ON A PER-DENSITY-ZONE BASIS TO ELIMINATE SUCH SYSTEMATIC BIASES.

IF THE DRD NORMALIZATION IS TURNED ON, THE MODEL MODIFIES THE DRD ON A CLUSTER-BY-CLUSTER BASIS AS FOLLOWS. FIRST, IT CALCULATES THE MODIFIED STRAND DISTANCE FOR A CLUSTER USING THE SPECIFIED STRAND DISTANCE MULTIPLIER FOR THE DENSITY ZONE

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[49] THE STRAND DISTANCE IS AN INDEPENDENT MEASURE OF THE AMOUNT OF ROUTE MILEAGE REQUIRED TO CONNECT ALL THE POINTS THAT REPRESENT CUSTOMER LOCATION TO EACH OTHER, APPROPRIATELY ADJUSTED TO ELIMINATE DROPS, SINCE THE DRD DOES NOT INCLUDE DROPS. THE STRAND DISTANCE IS BASED ON GRAPH THEORY, AND IS REFERRED TO AS A MINIMUM SPANNING TREE ("MST") OF THE POINTS THAT REPRESENT THE CUSTOMER LOCATIONS.

[50] IN HM 5.2A-MA, THE STRAND DISTANCE IS CALCULATED BASED ON "RIGHT ANGLE ROUTING" BETWEEN CUSTOMER LOCATIONS, AND THEREFORE ALREADY ACCOUNTS FOR THE FACT THAT DISTRIBUTION CABLE IS NOT DIRECTED IN A STRAIGHT LINE FROM LOCATION TO LOCATION.

IN WHICH THE CLUSTER FALLS. SECOND, IT CALCULATES A DRD ADJUSTMENT FACTOR AS THE RATIO OF THE MODIFIED STRAND DISTANCE TO THE DRD FOR THE CLUSTER.. FINALLY, IT APPLIES THIS DRD ADJUSTMENT FACTOR TO EVERY COMPONENT OF THE DISTRIBUTION PLANT IDENTIFIED ABOVE AS BEING A CONTRIBUTOR TO THE DRD.

IF THE USER DOES NOT INVOKE THE NORMALIZATION OPTION, THE MODEL NEVERTHELESS ENSURES THAT THE DRD IN EACH CLUSTER IS LARGE ENOUGH TO REACH THE CORNERS OF THE CLUSTER RECTANGLE THAT MAY BE OCCUPIED BY CUSTOMERS, USING RIGHT-ANGLE ROUTING. FOR A CLUSTER WITH TWO CUSTOMER LOCATIONS, THIS MINIMUM DISTANCE IS THE SUM OF THE HEIGHT AND WIDTH OF THE RECTANGLE LESS TWO DROP LENGTHS FOR THE CLUSTER'S DENSITY ZONE, UNDER THE ASSUMPTION THAT CUSTOMERS ARE LOCATED AT DIAGONALLY OPPOSITE CORNERS OF THE RECTANGLE. FOR A CLUSTER WITH THREE CUSTOMER LOCATIONS, THE MINIMUM DISTANCE IS THE SUM OF THE HEIGHT AND 1.5 TIMES THE WIDTH, ASSUMING CUSTOMERS ARE LOCATED AT THREE CORNERS OF THE RECTANGLE. FINALLY, FOR A CLUSTER WITH FOUR OR MORE CUSTOMER LOCATIONS, THE MINIMUM DISTANCE IS THE SUM OF THE HEIGHT AND TWICE THE WIDTH OF THE RECTANGLE, ASSUMING CUSTOMERS ARE LOCATED AT ALL FOUR CORNERS OF THE RECTANGLE.

### *6.3.5 INVESTMENT CAP TO REFLECT POTENTIAL WIRELESS TECHNOLOGIES*

HM 5.2A-MA PERMITS THE SPECIFICATION OF A USER-ADJUSTABLE CAP ON THE MODEL'S RELEVANT WIRELINE INVESTMENTS TO REFLECT POTENTIALLY MORE ECONOMICAL WIRELESS DISTRIBUTION TECHNOLOGIES. IN HM 5.2A-MA, 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.

THE OPTIONAL CAP CALCULATION CONSIDERS THE INVESTMENT IN TWO DIFFERENT WIRELESS SYSTEMS: A "POINT-TO-POINT" SYSTEM SERVING CUSTOMERS ON A ONE-TO-ONE BASIS, AND A "BROADCAST" SYSTEM SERVING A NUMBER OF CUSTOMERS FROM A SHARED BASE STATION. THE POINT-TO-POINT INVESTMENT IS ASSUMED TO BE A FIXED AMOUNT PER LINE SERVED; THE BROADCAST SYSTEM INVESTMENT IS STRUCTURED AS A FIXED BASE STATION INVESTMENT SERVING UP TO A GIVEN MAXIMUM NUMBER OF CUSTOMERS, WITH THE INVESTMENT IN THE BASE STATION DISTRIBUTED AMONG THE NUMBER OF CUSTOMERS THAT USE IT, PLUS A PER-LINE INVESTMENT IN THE RADIO TERMINAL EQUIPMENT AT EACH CUSTOMERS' PREMISES. GENERALLY, THE BROADCAST SYSTEM IS MORE EXPENSIVE THAN THE POINT-TO-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 INVESTMENT IN THE TWO WIRELESS SYSTEMS FOR A GIVEN SERVING

AREA, THEN COMPARES THE INVESTMENT IN THE LOWER-COST SYSTEM TO THE WIRELINE INVESTMENT. IF THE MOST ECONOMICAL WIRELESS SYSTEM'S INVESTMENT IS LOWER, THE MODEL ZEROES OUT THE INVESTMENT IN THE WIRELINE DISTRIBUTION COMPONENTS FOR THAT SERVING AREA, AND SUBSTITUTES THE INVESTMENT IN THE WIRELESS DISTRIBUTION SYSTEM, WHILE RETAINING THE FEEDER PORTION OF THE WIRELINE NETWORK. FEEDER IS ALWAYS ASSUMED TO BE FIBER FOR AREAS SERVED BY WIRELESS DISTRIBUTION.

### 6.3.6 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 DISTANCE. IN ALL CASES, COPPER DISTRIBUTION CABLE IS USED TO LINK SAIS TO CUSTOMER PREMISES. THE MODEL SELECTS FIBER FEEDER IF ANY OF THE FOLLOWING CONDITIONS ARE MET.

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 VALUE IS 9,000 FT.

A LIFE-CYCLE COST ANALYSIS OF FIBER VERSUS COPPER FEEDER ON THE ROUTE SHOWS THAT FIBER IS MORE ECONOMICAL.

51

THE LONGEST DISTRIBUTION CABLE RUN FROM THE WIRE CENTER TO THE FARTHEST CORNER OF A MAIN CLUSTER IS GREATER THAN THE MAXIMUM ANALOG COPPER DISTANCE.

THERE IS AT LEAST ONE OUTLIER CLUSTER CONNECTED TO THE MAIN CLUSTER.

THE WIRELESS INVESTMENT CAP IS INVOKED AND LEADS TO THE CONCLUSION THAT ONE

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[51] THE LIFE-CYCLE COSTS OF FIBER AND 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.

OF THE TWO WIRELESS SYSTEMS IS THE LEAST-COST SOLUTION FOR THE SERVING AREA.[52]

### 6.3.7 "STEERING" FEEDER ROUTES

IN HM 5.2A-MA 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 LEAVE FEEDER ROUTE STEERING "OFF" AND HAVE THE MODULE CALCULATE FEEDER DISTANCES USING "RIGHT ANGLE ROUTING" IN THE FOUR CARDINAL COMPASS DIRECTIONS.

### 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 THE BUILDING. IN SUCH CASES, THE SAI, LOCATED IN THE BUILDING, IS LESS EXPENSIVE THAN THE OUTDOOR SAI. HM 5.2A-MA THUS DIFFERENTIATES BETWEEN OUTDOOR AND INDOOR SAIS, THE FORMER

[52] 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.

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 B40 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." THE SECOND IS DESIGNATED "LOW DENSITY" DLC. BOTH ARE GR-303 COMPLIANT.

[53]

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, THE MODEL ASSUMES "HIGH DENSITY" DLC. THE THRESHOLD IS USER-ADJUSTABLE, WITH A DEFAULT VALUE OF 480 LINES.

THE DISTRIBUTION MODULE PERFORMS ALL CALCULATIONS INVOLVING DLC INVESTMENT. THE PARAMETERS INVOLVED IN THIS CALCULATION ARE IDENTIFIED AS ITEMS B63 THROUGH B76 IN APPENDIX B. THE INVESTMENTS INCLUDE USER-ADJUSTABLE AMOUNTS FOR SITE AND POWERING (B63), FOR COMMON EQUIPMENT (B66), AND FOR CHANNEL UNITS (B67). HM 5.2A-MA INCREASES INVESTMENT IN <u>HIGH</u>-DENSITY DLC CHANNEL UNITS WHEN THE MAXIMUM COPPER DISTRIBUTION CABLE LENGTH EXCEEDS A USER-ADJUSTABLE DISTANCE TO ACCOUNT FOR ADDITIONAL INVESTMENT REQUIRED FOR EXTENDED-RANGE CHANNEL UNITS NEEDED FOR THE LONGER DISTRIBUTION LENGTHS. ON THE OTHER HAND, <u>LOW</u>-DENSITY DLC CHANNEL UNIT INVESTMENT IS DECREASED WHEN THE COPPER DISTRIBUTION

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[53] 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 INTEGRATING A DLC SYSTEM WITH AN END OFFICE SWITCH.

cable distance falls below the user-adjustable distance threshold because the default investment for low-density DLC channel units is for an extended-range unit. Other inputs in the range of B63-76 specify, for example, the number of fiber strands per RT, the maximum number of 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 channel units of the type required to provide the appropriate type of service on the analog and digital (T1) pairs served by the DLC.

### *6.3.9 Calculation of Distribution Investments*

The Model uses the customer location and cluster data, including cluster sizes and locations, number of lines, and line 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 to 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 B50 (basic distribution and drop components), B63 through B76 (DLC components), B195 (structure sharing), and B212 through B215 (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 B19 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 90 lines and the sizing factor set by the Model is 0.75, then the target cable size determined by the Model is 90/.75, or 120 pairs. However, cables are available only in discrete sizes, as shown in Item B10 in 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 90/200, or 0.45. Generally, the average achieved distribution fill is significantly less than is indicated by the raw cable sizing factors shown in Item B19. The Model outputs display this average actually-achieved fill both at the SAI and at the MDF.

Second, as discussed earlier, the 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 5.2a-MA, stated as the percentage of total structure costs assigned to the telephone company, are shown in ItemB195 of Appendix B. The amount of structure sharing depends both on the type of structure -- poles and trenching -- and the density zone. In underground installations, the Model assumes, conservatively, that there is no sharing of the conduit itself, only excavation and restoration costs.

Finally, HM 5.2a-MA offers an optional cap on distribution investment as discussed, above. This cap, enabled by Parameter B43, 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 B44; the other system's cost is parameterized by a base station cost, B45, maximum customers served by a base station, B47, and per-line radio system equipment cost, B46.

## 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 at the centroid of the main cluster each serving area. Figure 6 displays the basic main feeder and subfeeder architecture assumed in the Model.

[54] 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.

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[54] 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.

**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 ANGLES OF ±45E WITH THE MAIN FEEDER ROUTES.

[55] EACH MAIN CLUSTER IS SERVED BY THE MAIN FEEDER ROUTE ASSOCIATED WITH THE

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[55] BECAUSE HM 5.2A 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.

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 OF 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 NOT ASSUMED TO SHARE CONDUIT WHEN THEY FOLLOW THE SAME ROUTE, HOWEVER.

### 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.

[56] 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.

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[56] IF NO CLUSTER CENTROIDS FALL WITHIN A GIVEN QUADRANT OF A WIRE CENTER, NO FEEDER ROUTE WILL BE PROVIDED IN THAT QUADRANT.

[57] 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 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 5.2A-MA APPLIES STRAIGHTFORWARD TRIGONOMETRIC CALCULATIONS TO COMPUTE MAIN FEEDER AND SUBFEEDER DISTANCES.

[58] THE MODEL COMPUTES SUFFICIENT SUBFEEDER CABLE TO CONNECT THE MAIN FEEDER ROUTE TO THE CENTROID OF EACH MAIN CLUSTER. COPPER SUBFEEDER 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.

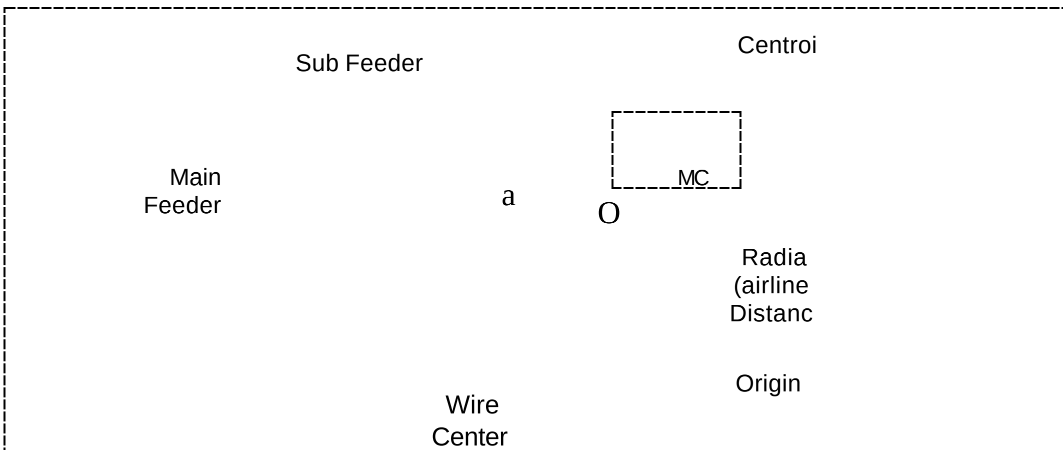


**FIGURE 7 DETERMINATION OF CLUSTER LOCATIONS AND DISTANCES**

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

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THE CABLE ASSUMED IN THE MODEL.

[58] 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.

require more capacity than segments near the periphery. HM 5.2a-MA 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.

**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. The number of pairs resulting from this calculation for a given cluster

IS MAINTAINED ALL THE WAY BACK TO THE WIRE CENTER, EVEN IF THE CABLE SUBSEQUENTLY PASSES THROUGH AN AREA WITH A HIGHER SIZING FACTOR THAT MIGHT OTHERWISE ALLOW FEWER PAIRS. IN THIS WAY, THE MODEL ENSURES THE NUMBER OF PAIRS REQUIRED TO SERVE A GIVEN CLUSTER DOES NOT VARY ALONG A CABLE ROUTE. 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, WHICH IS A USER-ADJUSTABLE QUANTITY WITH A DEFAULT VALUE OF FOUR.

[59] 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 THE USER-ADJUSTABLE FIBER STRAND FILL FACTOR INTO ACCOUNT.

#### *6.4.2.3. MAIN FEEDER SEGMENT SIZING*

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.

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[59] BECAUSE A DLC TERMINAL REQUIRES A MINIMUM OF TWO FIBERS, ONE FOR EACH DIRECTION OF TRANSMISSION, THE HM 5.2A DEFAULT OF FOUR FIBERS PROVIDES COMPLETE REDUNDANCY.

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 B51 THROUGH B62 AND B77 THROUGH B80, DESCRIBED IN APPENDIX B. THE FEEDER MODULE ALSO CALCULATES TERRAIN IMPACTS USING INPUTS B21 THROUGH B24. IT ALLOWS THE USER TO ENABLE FEEDER STEERING AND TO SET THE ROUTE/AIR RATIO USING B27 AND B28, RESPECTIVELY; CAN OVERRIDE THE CALCULATED ASPECT RATIO OF THE MAIN CLUSTER AND THEREBY FORCE MAIN CLUSTERS TO BE SQUARE USING B29; AND SPECIFIES EXCAVATION AND RESTORATION COSTS (JOINTLY WITH DISTRIBUTION) USING B212 THROUGH B215.

## 6.5. SWITCHING AND INTEROFFICE MODULE

### 6.5.1. OVERVIEW

THIS MODULE PRODUCES NETWORK INVESTMENT ESTIMATES IN THE FOLLOWING CATEGORIES:

*SWITCHING AND WIRE CENTER INVESTMENT* -- THIS CATEGORY INCLUDES INVESTMENT IN LOCAL AND TANDEM SWITCHES, ALONG WITH ASSOCIATED INVESTMENTS IN WIRE CENTER FACILITIES, INCLUDING BUILDINGS, LAND, POWER SYSTEMS AND DISTRIBUTING FRAMES.

*SIGNALING NETWORK INVESTMENT* -- THIS INCLUDES INVESTMENT IN STPS, SCPS AND SIGNALING LINKS.

*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).

*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.

[60] 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 THE FOLLOWING:

B81-B92 AND B188-B191, FOR END OFFICE SWITCHING;

B93-B98, FOR THE WIRE CENTER IN WHICH THE END OFFICE SWITCHES AND TANDEMS ARE HOUSED;

B114-B137, FOR INTEROFFICE TRANSMISSION TERMINALS, MEDIA AND STRUCTURES;

B152-B158, FOR TANDEM SWITCHING;

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[60] HM 5.2A INCLUDES A SET OF INTEROFFICE DISTANCE CALCULATIONS PRODUCED FROM WIRE CENTER LOCATION INFORMATION FROM BELLCORE'S LERG AND FROM NECA TARIFF 4.

B159-B172, FOR INTEROFFICE SIGNALING; AND

B173-B176, FOR OPERATOR SERVICES AND PUBLIC TELEPHONE.

IN ADDITION, INPUTS B99 THROUGH B113 SPECIFY VARIOUS TRAFFIC PARAMETERS; OTHER 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 SPECIFIED BY B138 THROUGH B151. FINALLY, THERE IS A SET OF INPUTS REPRESENTING SURROGATE PER-LINE INVESTMENT IN VARIOUS SWITCHING AND SIGNALING EQUIPMENT COMPONENTS BY SMALL ICOS, APPEARING AS B177 THROUGH B187. 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 TELCORDIA TECHNOLOGY DOCUMENTS.

[61] 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 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. IN HM 5.2A-MA, THESE CAN BE SPECIFIED SEPARATELY FOR DIFFERENT SWITCH SIZES TO CAPTURE, FOR INSTANCE, A DIFFERENT BREAKDOWN OF INTRA-SWITCH AND INTER-SWITCH TRAFFIC BETWEEN RURAL, SUBURBAN AND URBAN AREAS.

### *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.

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[61] BELL COMMUNICATIONS RESEARCH, *LATA SWITCHING SYSTEMS GENERIC REQUIREMENTS, SECTION 17: TRAFFIC CAPACITY AND ENVIRONMENT,* TR-TSY-000517, ISSUE 3, MARCH 1989.

#### *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 clusters 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 less than this figure. Otherwise, it equips the wire center with two or more switches of equal size to meet this size limitation. For instance, if a wire center must serve, 90,000 ports, the Model will compute the investment required for two 45,000-port switches.

[62]

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 multiplier varies between 1.2 and 2.0, depending on business line penetration,

[63] 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

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

[63] 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.

BUSINESS AND RESIDENCE CUSTOMERS. DEFAULT VALUES OF THE BUSINESS AND RESIDENTIAL HOLDING TIME MULTIPLIERS ARE UNITY. 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 5.2A-MA ALLOWS THE USER TO SELECT BETWEEN ONE OF TWO METHODS FOR ENGINEERING AND COSTING END OFFICE SWITCHING SYSTEMS. IN ONE, THE MODEL IDENTIFIES AND TREATS THE SWITCHING SYSTEMS AS BEING EXPLICIT COMBINATIONS OF HOSTS, REMOTES AND STAND-ALONE SWITCHING, ASSIGNING A SWITCH TYPE TO EACH CLLI USED BY THE MODEL. IN THE OTHER, THE MODEL ASSUMES A BLENDED PORTFOLIO OF SWITCH TECHNOLOGIES, AND DOES NOT ASSOCIATE PARTICULAR CLLIS WITH PARTICULAR SWITCH TYPES. SINCE THE BLENDED CONFIGURATION IS ASSUMED IN THE DEFAULT MODE, IT IS DESCRIBED FIRST.

THE BLENDED PORTFOLIO IS APPROPRIATE WHEN ACCURATE DATA ON THE SEPARATE PURCHASE PRICES OF HOST, REMOTE AND STANDALONE SWITCHES OF VARYING CAPACITIES ARE NOT AVAILABLE TO THE USER, WHEN THE USER LACKS INFORMATION ON WHICH WIRE CENTER SHOULD CONTAIN WHICH OF THESE SWITCH TYPES, AND/OR WHEN A SIMPLIFIED CALCULATION OF THE INTEROFFICE NETWORK IS DESIRED. IN THIS MODE, THE TOTAL INVESTMENT IN A SWITCH IS DESCRIBED BY THE FUNCTION A + B * L, WHERE L IS THE LINE CAPACITY OF THE SWITCH, AND A AND B ARE USER-ADJUSTABLE INPUT VALUES. THIS FUNCTION AVERAGES THE INVESTMENT FUNCTION PER-LINE INVESTMENTS OVER A PORTFOLIO OF HOST, REMOTE, AND STANDALONE END OFFICE SWITCHES. THE END OFFICE SWITCHES ARE PLACED ON INTEROFFICE SONET RINGS, AS DESCRIBED IN THE NEXT SECTION, WITH NO CONSIDERATION GIVEN TO THE SEPARATE TYPES OF SWITCHES INVOLVED, FOCUSING INSTEAD, ON A FORWARD-LOOKING OPTIMIZATION INTEROFFICE RING STRUCTURE.

IN THE HOST/REMOTE/STANDALONE MODE, THE INVESTMENT IN EACH TYPE OF SWITCH IS ALSO DESCRIBED BY THE FUNCTIONAL FORM A + B * L, WHERE L IS THE NUMBER OF LINES AND A AND B ARE USER-ADJUSTABLE CONSTANTS SPECIFIED SEPARATELY FOR EACH TYPE OF SWITCH. ALSO, RECOGNIZING THAT THESE SWITCHES COME IN VARIOUS SIZE RANGES, THE USER MAY SPECIFY DEFINE UP TO FOUR SWITCH SIZE RANGES, AND SPECIFY DIFFERENT CONSTANTS FOR EACH SWITCH TYPE IN EACH SIZE RANGE.

THE DATABASE ACCOMPANYING THE MODEL CONTAINS THE LERG DESIGNATIONS OF HOST, remote, and standalone switches. The user may change these assignments through the user interface. Using the LERG or user-adjusted designations, the Model places the hosts and their subtending remotes on SONET rings separate from the interoffice rings discussed in the next section. Host switches may therefore be involved in two of the ring formations processes described in the next subsection – one that forms local host/remote rings, and the other that forms larger interoffice rings connecting hosts, stand-alone switches and tandem switches

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 connect systems ("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. Once the Model computes investments for each switch in the host/remote system, it calculates the average investment per line for all of the lines in the system.

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. However, some or all of these costs may be included in the switch investments that appear in various data sources. In particular, the switch cost parameters adopted by the FCC in its universal service deliberations include the main distribution frame and power costs, as well as telco switch installation costs. The user should ensure that the Model is not double-counting investments in this case, once in the switch investment itself and once in the wire center calculations, by setting appropriate wire center and/or switch installation parameters, to zero.

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 INTEROFFICE 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.

THE MODEL ASSUMES THAT, WITH SOME EXCEPTIONS, ALL INTEROFFICE FACILITIES TAKE THE FORM OF A SET OF INTERCONNECTED SONET FOUR-FIBER BI-DIRECTIONAL LINE SWITCHED RINGS, WITH AS MANY LOGICAL OR COINCIDENT RINGS ASSOCIATED WITH EACH PHYSICAL RING AS ARE NECESSARY TO PROVIDE THE REQUIRED CIRCUIT CAPACITY OF THAT RING. IT USES A PROGRAM WRITTEN IN VISUAL BASIC FOR APPLICATIONS ("VBA") AND THE WIRE CENTER LOCATIONS SPECIFIED AS V&H COORDINATES TO CONFIGURE A SET OF RINGS CONSTITUTING THE INTEROFFICE NETWORK AND TO COMPUTE THE ASSOCIATED INTEROFFICE DISTANCES.

FOR BOC AND ICOS WITH THEIR OWN TANDEM SWITCHES, THE INTEROFFICE RING NETWORK MAY CONSIST OF TWO RING CLASSES: TANDEM/HOST/STAND-ALONE AND HOST/REMOTE. 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.

FOR EACH ILEC THAT DOES NOT OPERATE ITS OWN TANDEM SWITCHES, THE HM 5.2A-MA DISTANCE FILE DESIGNATES A SET OF GATEWAY WIRE CENTERS FOR THAT ILEC.

[64]

EACH GATEWAY SERVES AS THE HOMING POINT FOR A SET OF WIRE CENTERS ASSOCIATED WITH THIS ILEC. THE PURPOSE OF A GATEWAY SWITCH IS TO AVOID THE NEED FOR MULTIPLE LINKS FROM A SET OF PROXIMATE SWITCHES TO A DISTANT TANDEM SWITCH. THE MODEL FORMS GATEWAY RINGS TO CONNECT EACH GATEWAY WIRE CENTER WITH THE WIRE CENTERS THAT HOME ON IT.

THE DISTANCE FILE ASSIGNS EACH GATEWAY WIRE CENTER TO THE TANDEM SWITCH OF ANOTHER COMPANY.

[65] THE MODEL COMPUTES ADDITIONAL INVESTMENT FOR THE FACILITIES THAT CONNECT THE GATEWAY TO ITS ASSIGNED SERVING TANDEM. GATEWAYS MAY BE CONNECTED TO THEIR SERVING TANDEM EITHER THROUGH A DIRECT, REDUNDANT PATH, OR THROUGH A BRIDGING WIRE CENTER (BRIDGING WIRE CENTERS BELONG TO THE SAME OPERATING COMPANY AS THE ASSIGNED SERVING TANDEM). IN THE LATTER CASE, THE MODEL COMPUTES THE INVESTMENT REQUIRED FOR THE CONSTRUCTION OF FACILITIES BETWEEN THE GATEWAY AND THE BRIDGING WIRE CENTER, AND AN EFFECTIVE INVESTMENT CORRESPONDING TO THE COST OF LEASED FACILITIES BETWEEN THE BRIDGING WIRE CENTER AND THE ACTUAL SERVING TANDEM.

IN HM 5.2A-MA, THERE ARE THUS THREE DIFFERENT CLASSES OF RINGS: HOST/REMOTE, TANDEM/HOST/STANDALONE, AND GATEWAY/HOMING. THE METHODOLOGY THAT THE MODEL USES TO DETERMINE THE RINGS IS THE SAME FOR ALL 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, AND GATEWAYS SERVING AS THE HOMING POINT IN THE NETWORK OF GATEWAYS AND THEIR SUBTENDING WIRE CENTERS. THE FOLLOWING DISCUSSION OF FORMING TANDEM/HOST/STANDALONE RINGS IS APPLICABLE TO ALL CLASSES OR RINGS,

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[64] GATEWAY WIRE CENTERS MAY ALSO BE SELECTED FOR ILECS THAT DO OPERATE THEIR OWN TANDEMS WHEN DOING SO SERVES TO REDUCE OVERALL TRANSPORT DISTANCES.

[65] THE INPUT DEVELOPMENT PROCESS ASSIGNS THESE GATEWAYS TO THE NEAREST TANDEM, IRRESPECTIVE OF TANDEM OWNERSHIP.

UNLESS OTHERWISE NOTED.

TO COMPUTE THE SET OF TANDEM/HOST/STANDALONE RINGS, THE HM BEGINS WITH A CASE WHERE ALL WIRE CENTERS ARE DIRECTLY CONNECTED TO THEIR SERVING TANDEM VIA REDUNDANT PATHS.

[66]

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 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 MODEL INCORPORATES AN OPTIMIZING ALGORITHM TO ENSURE THAT IT CONSTRUCTS RINGS EFFICIENTLY. 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.

IN THE PROCESS OF COMPUTING RING CONFIGURATIONS, THE GREATEST SAVING 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 NOT NECESSARILY ALL RINGS. 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

[66] SEE APPENDIX D FOR A FULLER DESCRIPTION OF THESE CALCULATIONS.

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.

WHILE A GIVEN RING MAY SERVE UP TO 16 WIRE CENTERS, AND THUS REQUIRE A CONSIDERABLE TOTAL CAPACITY, THE MODEL DOES NOT PROVIDE EVERY WIRE CENTER ON A RING WITH EQUIPMENT (ADD-DROP MULTIPLEXERS, DIGITAL CROSS CONNECTS, AND MULTIPLEXERS) CAPACITY EQUAL TO THE TOTAL RING CAPACITY. INSTEAD, THE MODEL DETERMINES THE AMOUNT OF EQUIPMENT REQUIRED TO SERVE THE TRAFFIC CAPACITY OF EACH WIRE CENTER. IT THEN PROVIDES NOT ONLY THAT AMOUNT OF EQUIPMENT, BUT AN ADDITIONAL AMOUNT EQUAL IN CAPACITY TO THE TOTAL CAPACITY REQUIREMENT OF ALL WIRE CENTERS ON THE RING. THIS ADDITIONAL EQUIPMENT IS ASSUMED TO BE HOUSED AT ANOTHER "HUBBING" POINT ON THE RING.

[67] IN THIS WAY, THE MODEL IN EFFECT ENVISIONS THERE ARE A NUMBER OF LOGICAL RINGS CARRIED ON A GIVEN PHYSICAL RING, EACH OF WHICH SERVES A SUBSET OF THE WIRE CENTERS ON THE RING, AND WHICH ARE CROSS-CONNECTED AT THE HUBBING POINT USING THE EXTRA EQUIPMENT THE MODEL HAS PROVIDED.

BECAUSE THE MODEL DOES NOT HAVE ALL THE INFORMATION REQUIRED TO DETERMINE "COMMUNITIES OF INTEREST" ON THE RING, THE RESULTING EQUIPMENT CAPACITY IS CONSERVATIVELY HIGH BECAUSE THE MODEL IS UNABLE TO TAKE ADVANTAGE OF THE POTENTIAL REUSE OF CIRCUITS ON DIFFERENT SEGMENTS OF THE RING THAT TYPICALLY HAPPENS DURING THE CONFIGURATION OF CIRCUITS ON A RING. INSTEAD, EACH CIRCUIT IS ASSUMED TO TRAVERSE THE COMPLETE RING IN BOTH DIRECTIONS. ON THE OTHER HAND, OPERATING IN THIS FASHION, THE MODEL AVOIDS EQUIPPING WIRE CENTERS WITH FAR MORE TERMINAL EQUIPMENT CAPACITY THEN THEY REQUIRE TO CARRY THE TRAFFIC TO/FROM THAT WIRE CENTER. THIS IS PARTICULARLY IMPORTANT IN THE CASE OF SMALL (CAPACITY-WISE) WIRE CENTERS SERVED BY A HIGH-CAPACITY RING.

BECAUSE PHYSICAL 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

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[67] BECAUSE HM 5.2A-MA IS A COST MODEL, NOT A DETAILED ENGINEERING MODEL, IT IS NOT NECESSARY TO SPECIFY WHICH PARTICULAR WIRE CENTER HOUSES THE ADDITIONAL EQUIPMENT.

RING DEPENDS STRONGLY 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 PHYSICAL RING – SEE PARAMETER B149 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. 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. THE THRESHOLD CORRESPONDS TO PARAMETER B146 IN APPENDIX B. ITS DEFAULT VALUE IS UNITY, MEANING THAT IN DEFAULT MODE, THE MODEL CONSIDERS ALL SWITCHES TO BE RING CANDIDATES.

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.

[68] 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 ARE ALWAYS PROVIDED IN PAIRS FOR REDUNDANCY AND WILL, IN MOST CASES, TERMINATE AT UNIQUE NODES WITHIN EACH OF THE RING SYSTEMS. THE NODES AND PATHS SELECTED

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[68] A RING SYSTEM IS DEFINED AS THE SET OF NODES, CONNECTORS, SPURS, AND RING CONNECTORS ASSOCIATED WITH A PARTICULAR TANDEM.

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.

In the case of gateway rings, the Model compares the investment associated with a given ring with the investment that would be required if each wire center on the ring were instead directly connected (or connected through a bridging office) to the designated serving tandem. It then selects the alternative that yields the least investment.

The output of the ring-calculating process is a list of the computed host/remote, gateway/homing, and tandem/host/standalone ring configurations. 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, including the "central" wire center (host, gateway, or tandem, depending on the type of ring); 2) the number of logical rings that comprise a single physical ring, based on the total required capacity of the physical ring; 3) the identification of each wire center and the nodes (other wire centers) to which it connects 4) the distance between each wire center and the nodes to which it connects; 5) a list of the wire centers served by spurs and their associated spur distance; 6) a list of the wire centers that serve as inter-ring-system connector nodes and their associated inter-ring-system connector distance; and 7) 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 all of this information has been computed, the Model calculates the required investment in 1) cable and structure, and 2) ring terminal equipment located in the wire centers that are connected to the rings. 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 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 REMAINING 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 MILEAGE 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 FIVE 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.

[69] 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.

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[69] 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").

THE MODEL 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 AND COMPUTES REQUIRED SS7 MESSAGE TRAFFIC ACCORDING TO THE CALL TYPE AND TRAFFIC ASSUMPTIONS DESCRIBED EARLIER TO DETERMINE WHETHER ADDITIONAL A-LINKS ARE NECESSARY TO HANDLE THE MESSAGE TRAFFIC. 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, WITH TWENTY-FIVE OCTETS PER MESSAGE.

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 INVESTMENT 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. THIS DEFAULT VALUE DERIVE FROM THE AT&T CAPACITY COST STUDY. THE MINIMUM INVESTMENT IS $224,000, THIS VALUE DERIVES FROM A BELLSOUTH *EX PARTE*

PRESENTATION TO THE FCC IN THE USF INPUTS PROCEEDING.

[70] BOTH MAY BE CHANGED BY THE USER. 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 $2,444 PER TRANSACTION PER SECOND, BASED ON THE BELLSOUTH *EX* PARTE PRESENTATION TO THE FCC.

#### *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 USER-ADJUSTABLE MAXIMUM TRUNK OCCUPANCY VALUE (DEFAULT 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 5.2A-MA 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.

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[70] EX PARTE LETTER FROM WHIT JORDAN, VICE PRESIDENT OF FEDERAL REGULATORY FOR BELLSOUTH TO THE FCC IN CC DOCKETS 96-45 AND 97-160, DATED AUGUST 7, 1998.

[71] In the Wire Center Expense Module, the capability exists to flexibly aggregate wire center cost results into various categories. Each of the Expense Modules 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 inputsB192-B211 in Appendix B.

[71] Although the HM 5.2a engineers plant based on a cluster level of granularity, the results of its engineering to individual clusters may be rolled up to display cost results at the CBG, density zone and wire center levels.

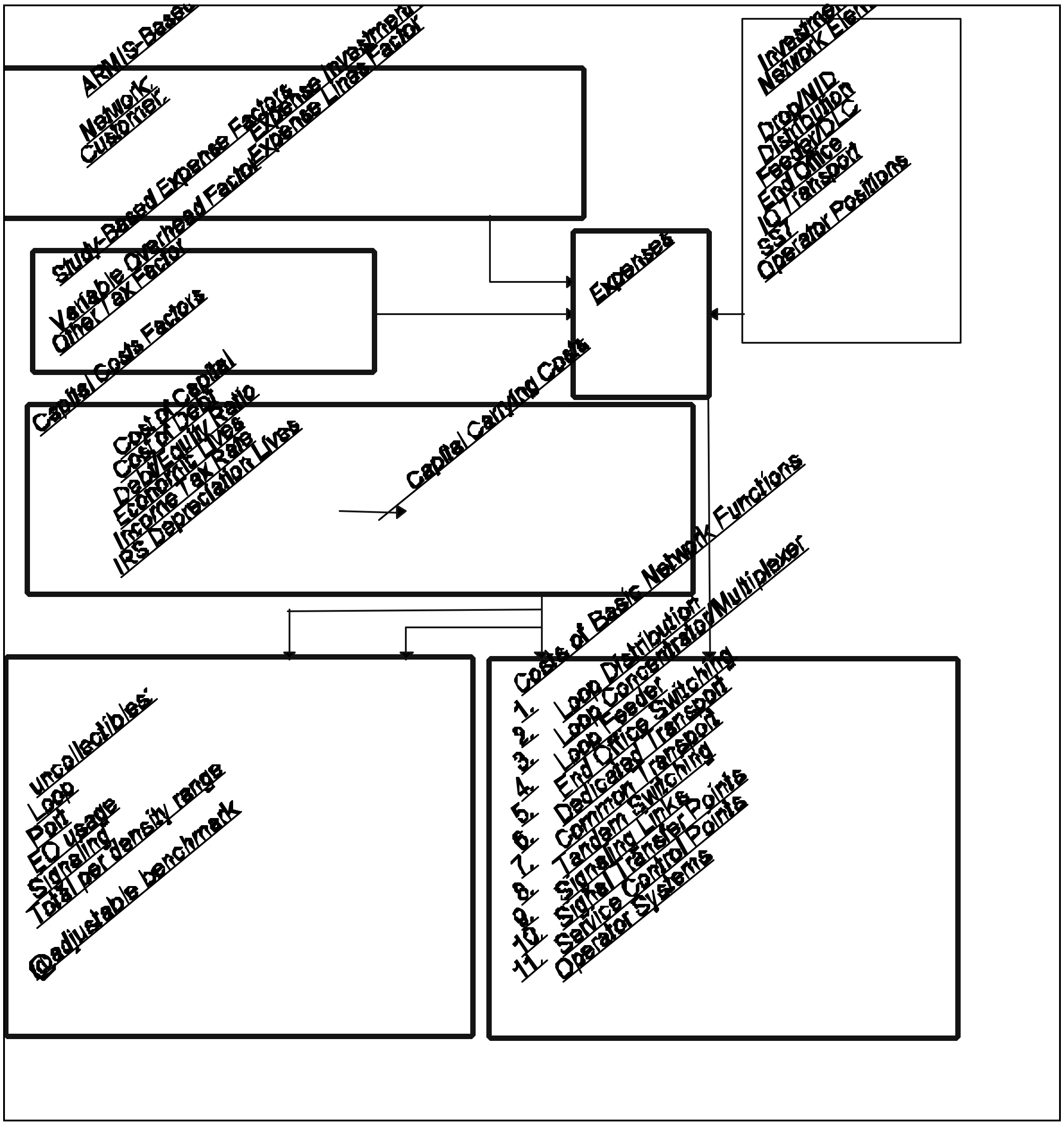


**FIGURE 9 EXPENSE MODULE FLOWS**

### *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:

PLANT INVESTMENT FOR THAT COMPONENT FROM THE RELEVANT INVESTMENT MODULES,

THE RETURN TO THE NET ASSET;

AN INCOME TAX GROSS-UP ON THE EQUITY COMPONENT OF THE RETURN;

THE EXPECTED SERVICE LIFE ADJUSTED FOR NET SALVAGE VALUE (DEPRECIATION) OF THE COMPONENT, AND

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 USER-ADJUSTABLE COMPONENTS. HM 5.2A-MY ASSUMES A 34.5%/63.5? DEBT-EQUITY RATIO, A COST OF DEBT OF 7.86%, AND A COST OF EQUITY OF 10.42%. 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 39.23 PERCENT FEDERAL, STATE AND LOCAL INCOME TAX (“FSLIT”) RATE IS USED TO “GROSS UP” RETURN DOLLARS TO ACHIEVE THIS RESULT.

THE MODEL NOW ACCOUNTS FOR THE EFFECT OF THE ACCELERATED DEPRECIATION RATES ALLOWED BY THE IRS FOR INCOME TAX COMPUTATION PURPOSES. IRS ACCELERATED DEPRECIATION HAS THE EFFECT OF REDUCING THE PRESENT VALUE OF TAX PAYMENTS BY DEFERRING THEM TO LATER YEARS, WHICH IN TURN REDUCES THE LEVELIZED OVERALL COST OF CAPITAL. THE IRSDEPREC WORKSHEET IN THE EXPENSE MODULE IS A TABLE OF IRS MODIFIED ACCELERATED COST RECOVERY SYSTEM (“MACRS”) DEPRECIATION SCHEDULES FOR EACH OF SEVEN TAX CATEGORIES OF PLANT. THESE WERE APPLIED TO THE APPROPRIATE MODEL INVESTMENTS FOR PURPOSES OF CALCULATING THE APPROPRIATE TAX DEPRECIATION.

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[72] BECAUSE THE HAI EXPENSE MODULE ASSUMES THAT THE ENTIRE NETWORK IS IN PLACE AT TIME 0, THE MACRS DEPRECIATION SCHEDULES HAD TO BE ADJUSTED TO CONFORM TO THIS CONVENTION. THIS WAS DONE BY USING TABLE A-2 FROM IRS PUB 946 "3-, 5-,7-,10-,15-, AND 20-YEAR PROPERTY MID-QUARTER CONVENTION PLACED IN SERVICE IN FIRST

The Model now allows regulatory depreciation to be calculated using either straight-line/square life or the Equal Life Group ("ELG") depreciation method used by the FCC. ELG, which is implemented with Bell standard survival curves, is the default option.

[73]

Annual return on average net investment, plus tax gross-up and depreciation expenses are calculated yearly for each of the 23 categories of equipment used in the Model. Default values for equipment service lives of the 23 categories of equipment are based on their projection lives adjusted for net salvage value as determined by the three-way meeting between the FCC, Massachusetts Commission, and Verizon. The table in Section B193 of Appendix B shows the plant categories, and for each, the default values for its economic life and its net salvage value. These economic lives and net salvage percents are user-adjustable.

quarter." Depreciation rates from the last period (which represent a half quarter of depreciation) were added to the first period, and the last period was removed. For 31.5-year property, an adjusted version of Table A-7 was used.

[73] The CGSCurves worksheet in the expense module applies the Bell standard survival curves to investments.

Return is earned only on net capital. 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 each plant category in the KCCFactor worksheet in the Expense Module. The Model calculates a separate capital carrying charge factor for each combination of regulatory depreciation method (square life/ELG) and tax depreciation method (straight line/accelerated).

Given the ability to use alternative regulatory and tax depreciation methods, the user now has several options. Square life regulatory depreciation of assets can be selected along with straight line or IRS accelerated depreciation for income tax purposes. Alternatively, ELG regulatory depreciation can be selected with either straight line or IRS accelerated depreciation for income tax purposes. The KF worksheet in the expense module collects all of the capital carrying cost information from the other development sheets and shows the effect of using these alternative methods. As noted above, ELG regulatory depreciation and IRS accelerated depreciation for tax purposes are the default options.

### *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 5.2A-MA EXPENSE MODULES INCLUDE A USOA DETAIL WORKSHEET THAT BREAKS OUT THE HM 5.2A-MA 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 "99 ACTUALS" WORKSHEET OF THE EXPENSE MODULE.

BOTH THE WIRE CENTER EXPENSE MODULE AND THE DENSITY ZONE EXPENSE MODULE WILL ACCEPT USER-DEFINED EXPENSE RATIOS FOR PLANT-RELATED INVESTMENT CATEGORIES. THE MODULES CALCULATE THE ARMIS-BASED EXPENSE RATIOS IN COLUMN F OF THE "99 ACTUALS" WORKSHEET; HOWEVER, IF THE USER ENTERS A VALUE IN COLUMN H,

[74] THAT VALUE WILL BE USED BY THE MODEL IN ALL EXPENSE CALCULATIONS RELATED TO THE INVESTMENT CATEGORY FOR WHICH A VALUE WAS ENTERED. IF THE USER DOES NOT ENTER A VALUE IN COLUMN H FOR ANY PLANT CATEGORY, THE ARMIS-BASED CALCULATED FACTOR WILL BE USED. IN HM 5.2A-MA, THE EXPENSE FACTORS ADOPTED BY THE FCC IN ITS *FCC INPUTS ORDER* HAVE BEEN PRE-SET IN COLUMN H; THE USER MAY CHANGE THOSE SETTINGS TO REFLECT ADDITIONAL CONSIDERATIONS.

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:

*NETWORK SUPPORT* -- THIS CATEGORY INCLUDES THE EXPENSES ASSOCIATED WITH MOTOR VEHICLES, AIRCRAFT, SPECIAL PURPOSE VEHICLES, GARAGE AND OTHER WORK EQUIPMENT.

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[74] IN THE CASE OF AERIAL, UNDERGROUND, AND BURIED CABLE, THE USER MUST SET FACTORS SEPARATELY FOR FIBER AND COPPER CABLE IN COLUMNS I AND J, RESPECTIVELY. THE MODEL WILL USE THE APPROPRIATE COLUMN AS IT CALCULATES EXPENSES FOR EACH KIND OF CABLE.

*CENTRAL OFFICE SWITCHING* -- THIS INCLUDES END OFFICE AND TANDEM SWITCHING AS WELL AS EQUIPMENT EXPENSES.

*CENTRAL OFFICE TRANSMISSION* -- THIS INCLUDES CIRCUIT EQUIPMENT EXPENSES APPLIED TO TRANSPORT INVESTMENT.

*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. . IN HM 5.2A-MA, USERS CAN MANUALLY INPUT SEPARATE COPPER AND FIBER EXPENSE FACTORS IN PLACE OF THE DEFAULT CABLE MAINTENANCE FACTOR.

*NETWORK OPERATIONS* -- THE NETWORK OPERATIONS CATEGORY INCLUDES POWER, PROVISIONING, ENGINEERING AND NETWORK ADMINISTRATION EXPENSES.

THE MODULE 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. IT DEDUCTS FROM THE RESULTING AMOUNT A USER-ADJUSTABLE 50 PERCENT TO PRODUCE A FORWARD-LOOKING ESTIMATE. THE REDUCTION IS BASED ON THE OBSERVED REDUCTIONS IN PER-LINE NETWORK OPERATIONS EXPENSE OVER THE PAST SEVERAL YEARS IN VERIZON AND ELSEWHERE, PRESUMABLY DUE TO THE FACT THAT THE SET OF ACTIVITIES CLASSIFIED AS NETWORK OPERATIONS IS PARTICULARLY SUBJECT TO THE BENEFICIAL EFFECTS OF NEW OPERATIONS TECHNOLOGY AND OTHER PRODUCTIVITY FACTORS.

#### *6.6.3.2. NON-NETWORK RELATED EXPENSES*

THE EXPENSE MODULE ASSIGNS NON-NETWORK RELATED EXPENSES TO EACH DENSITY RANGE, CENSUS BLOCK GROUP, WIRE CENTER, OR CLUSTER (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:

A) *VARIABLE SUPPORT* THE MODEL, AS A LONG RUN COST MODEL, RECOGNIZES THAT, IN ADDITION TO THE MINUSCULE AMOUNT OF TRUE FIXED OR COMMON OVERHEAD, THERE ARE GENERAL AND ADMINISTRATIVE ("G&A") EXPENSES THAT VARY WITH THE SIZE OF THE FIRM.

[75] For example, if an ILEC did not provide loops, it would be a much smaller company, and would therefore have lower G&A costs. Also large firms have greater variable support expenses than smaller firms. Therefore, the Model includes a forward-looking estimate of G&A or "variable support" costs (including common, fixed overhead) in the TSLRIC estimates for each network element. These variable support expenses may be described as "economic overhead" associated with production of the modeled network elements and services.

> 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

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[75] *See*, Aron, Debra J., "Proper Recovery of Incremental Overheads For Local Number Portabililty," Ameritech Petition for Expedited Reconsideration and Clarification, CC Docket No. 95-116, July 29, 1998.

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.

IN HM 5.2A-MA, USERS ARE ALTERNATIVELY ABLE TO ENTER PER-LINE EXPENSES FOR NON-NETWORK-RELATED EXPENSES, AS WELL AS FOR NETWORK OPERATIONS, RATHER THAN APPLYING THEM AS DESCRIBED ABOVE.

### *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.

*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.

*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.

*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.

*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.)

*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.

*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.

*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.

*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.

*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.

*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.

*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.

*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.

*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. GROUPING WIRE CENTER RESULTS

THE WIRE CENTER EXPENSE MODULE HAS THE CAPABILITY TO FLEXIBLY AGGREGATE WIRE CENTER COST RESULTS INTO VARIOUS CATEGORIES. THE WC WEIGHTS WORKSHEET IS USED TO GATHER COST RESULTS FROM THE INVESTMENT INPUTS WORKSHEET AND TO CALCULATE LINE WEIGHTING FACTORS FOR EACH WIRE CENTER. A NUMERIC CATEGORY DESIGNATION FOR EACH WIRE CENTER MAY ALSO BE MANUALLY ENTERED. IF THE USER ENTERS A VALUE BETWEEN 1 AND 10 IN COLUMN B OF THE WC WEIGHTS WORKSHEET, THAT VALUE WILL BE USED TO FORM A CATEGORY OF ALL WIRE CENTERS HAVING THE SAME DESIGNATION. IF THE USER DOES NOT ENTER A VALUE, THE MODULE WILL USE A TABLE OF COST BREAKPOINTS DEFINED IN THE ZONE SUMMARY WORKSHEET TO GROUP WIRE CENTERS INTO CATEGORIES. THE USER MAY DEFINE ANY SET OF VALUES FOR THE COST BREAKPOINTS (THE DOLLAR AMOUNTS SHOULD REFER TO MONTHLY LOOP COSTS, INCLUDING NID, DISTRIBUTION, SAI, AND FEEDER). THE MODULE WILL THEN USE THE DEFINED BREAKPOINTS TO FORM CATEGORIES OF WIRE CENTERS BASED ON MONTHLY LOOP COST. THE RESULTS OF THE AGGREGATION AS WELL AS THE NUMBER OF LINES IN EACH CATEGORY ARE SHOWN IN THE ZONE SUMMARY WORKSHEET.

#### *6.6.4.3. 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.

[76] 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, ALTHOUGH A PER-LINE, PER-MONTH COST OF LOCAL NUMBER PORTABILITY IS A USER-ADJUSTABLE COST INCLUDED IN THE MODEL. 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 CALLING RATES 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, MULTI-LINE BUSINESS LINES, OR PUBLIC LINES BY DENSITY ZONE, WIRE CENTER, CBG OR CLUSTER (DEPENDING ON THE UNIT OF ANALYSIS SELECTED).

THE DENSITY ZONE USF SHEET 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.

#### *6.6.4.4. 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 END OFFICE SWITCHING, DEDICATED TRANSPORT, COMMON TRANSPORT, TANDEM SWITCHING AND ISUP SIGNALING

[76] ON AN OPTIONAL BASIS, THE USAGE SENSITIVE COST OF SWITCHED ACCESS USE CAN BE INCLUDED AS WELL.

MESSAGES. IN ADDITION, THE SHEET ALSO DISPLAYS BUILT UP COSTS OF VARIOUS SIGNALING SERVICES THAT MIGHT BE USED BY IXCS OR COMPETITIVE LOCAL EXCHANGE CARRIERS (“CLECS”), AS WELL AS THE COSTS OF SEVERAL FORMS OF DEDICATED TRANSPORT.

## 7. SUMMARY

HM 5.2A-MA 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, THE HM 5.2A-MA 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 PREDECESSORS, THE HM 5.2A-MA METHODOLOGY IS OPEN TO PUBLIC SCRUTINY. TO THE EXTENT POSSIBLE, IT USES PUBLIC SOURCE DATA FOR ITS INPUTS. WHEN DOCUMENTED 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 5.2A-MA CAN USE THE MODEL’S AUTOMATED INTERFACE TO MODEL DIRECTLY AND SIMPLY ANY DESIRED ALTERNATIVE.

BY AND LARGE, HM 5.2A-MA IS QUITE SIMILAR IN STRUCTURE, OPERATION AND INPUTS TO PREVIOUS RELEASE 5 VERSIONS OF THE MODEL. HOWEVER, THE PROCESS OF REVIEWING AND REFINING DEFAULT VALUES FOR THE INPUTS TO THE MODEL HAS CONTINUED, AND THE VALUES SHOWN IN APPENDIX B REFLECT THE RESULT OF THIS PROCESS.

#### *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. The number of pairs resulting from this calculation for a given cluster is maintained all the way back to the wire center, even if the cable subsequently passes through an area with a higher sizing factor that might otherwise allow fewer pairs. In this way, the model ensures the number of pairs required to serve a given cluster does not vary along a cable route. 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, which is a user-adjustable quantity with a default value of four.
0.0.

Because a DLC terminal requires a minimum of two fibers, one for each direction of transmission, the HM 5.2a default of four fibers provides complete redundancy.

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 the user-adjustable fiber strand fill factor into account.

#### *6.4.2.3. Main Feeder Segment Sizing*

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

**Figure 22 Main Feeder Segmentation**

FIELD(KEYBOARD()KS USING ERLANG B ASSUMPTIONS AND 1% BLOCKING FROM A LOOKUP TABLE.THE TRAFFIC ENGINEERING THRESHOLD VALUE IS DETERMINED FROM THE USERSPECIFIED 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.THE MODEL ASSUMES THAT, WITH SOME EXCEPTIONS, ALL INTEROFFICE FACILITIES TAKE THE FORM OF A SET OF INTERCONNECTED SONET FOURFIBER BIDIRECTIONAL LINE SWITCHED RINGS, WITH AS MANY LOGICAL OR COINCIDENT RINGS ASSOCIATED WITH EACH PHYSICAL RING AS ARE NECESSARY TO PROVIDE THE REQUIRED CIRCUIT CAPACITY OF THAT RING. IT USES A PROGRAM WRITTEN IN VISUAL BASIC FOR APPLICATIONS (VBA) AND THE WIRE CENTER LOCATIONS SPECIFIED AS V&H COORDINATES TO CONFIGURE A SET OF RINGS CONSTITUTING THE INTEROFFICE NETWORK AND TO COMPUTE THE ASSOCIATED INTEROFFICE DISTANCES.FOR BOC AND ICOS WITH THEIR OWN TANDEM SWITCHES, THE INTEROFFICE RING NETWORK MAY CONSIST OF TWO RING CLASSES: TANDEM/HOST/STANDALONE AND HOST/REMOTE. 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. FOR EACH ILEC THAT DOES NOT OPERATE ITS OWN TANDEM SWITCHES, THE HM 5.2AMA DISTANCE FILE DESIGNATES A SET OF GATEWAY WIRE CENTERS FOR THAT ILEC. GATEWAY WIRE CENTERS MAY ALSO BE SELECTED FOR ILECS THAT DO OPERATE THEIR OWN TANDEMS WHEN DOING SO SERVES TO REDUCE OVERALL TRANSPORT DISTANCES. EACH GATEWAY SERVES AS THE HOMING POINT FOR A SET OF WIRE CENTERS ASSOCIATED WITH THIS ILEC. THE PURPOSE OF A GATEWAY SWITCH IS TO AVOID THE NEED FOR MULTIPLE LINKS FROM A SET OF PROXIMATE SWITCHES TO A DISTANT TANDEM SWITCH. THE MODEL FORMS GATEWAY RINGS TO CONNECT EACH GATEWAY WIRE CENTER WITH THE WIRE CENTE)