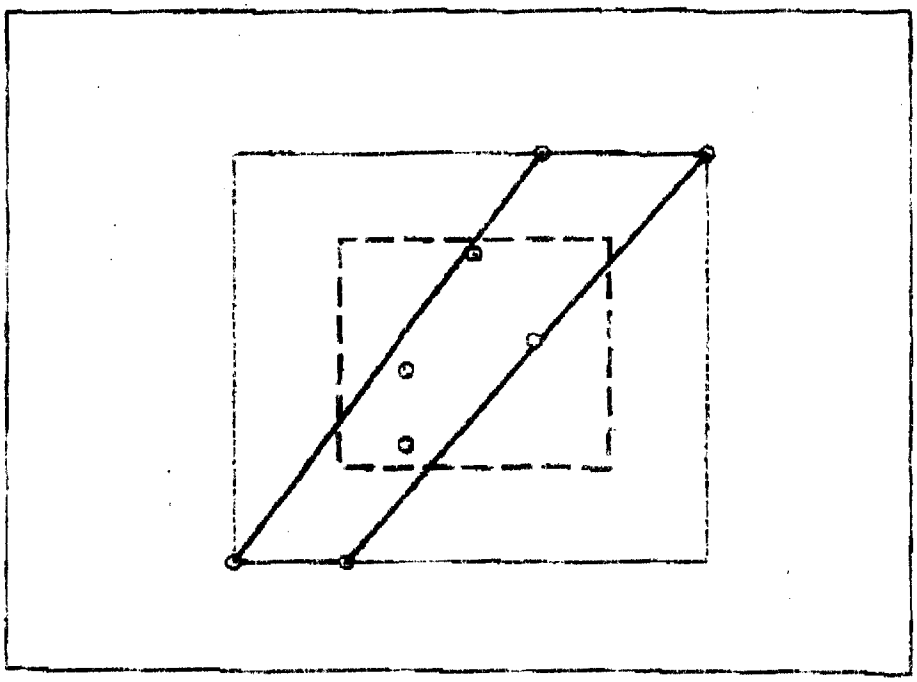
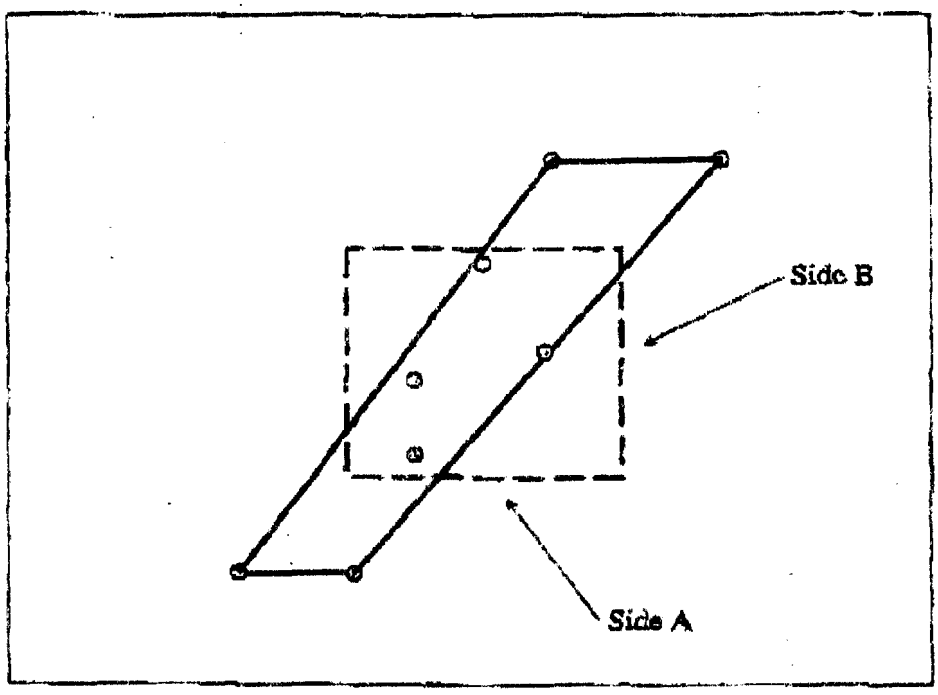


Facts Regarding the Hatfield Model's Preprocessing, Clustering and Loop Construction.

#4. The picture above displays the original polygon converted to a rectangle (the smaller rectangle with the dashed line.) This has the area of the original polygon, and the aspect ratio of the minimum bounding rectangle.

It is this smaller rectangle that actually enters the HAI Model, and will be discussed below. (For ease of exposition, the following pictures omit the larger, minimum bounding rectangle.)

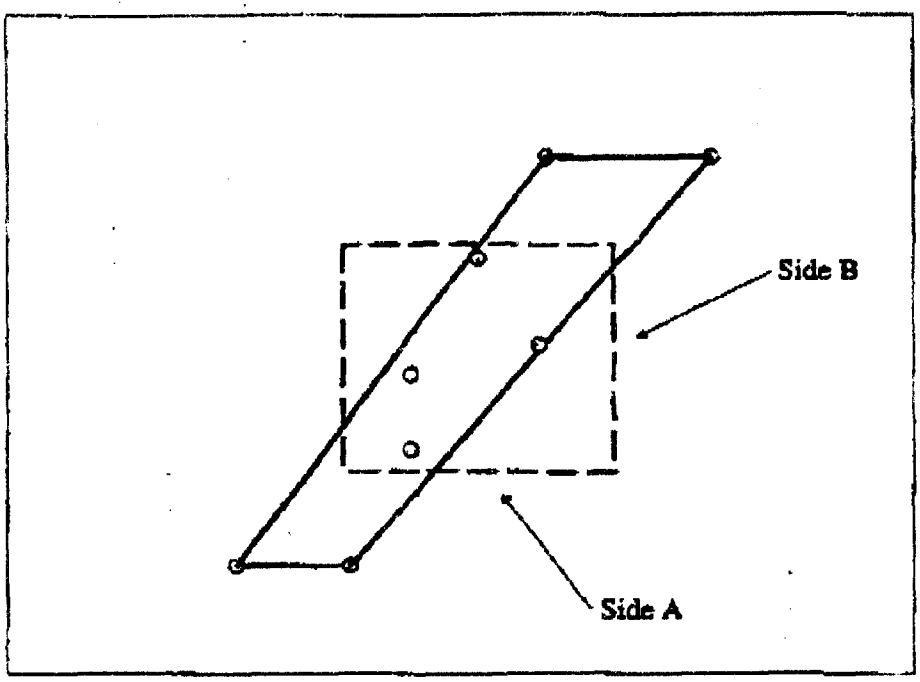
We will refer to the smaller rectangle as the "reduced rectangle".



Facts Regarding the Hatfield Model's Preprocessing, Clustering and Loop Construction.

#5. The HAI Model provides a user with the area of this reduced rectangle, as well as the aspect ratio. From these two pieces of information, it is straightforward to calculate the length of the rectangle's sides (shown above as Side A and Side B).

For the remainder of this discussion, the distance of Side A added to the distance of Side B will be referred to as the **height-plus-width,** measured in feet. This height-plus-width measure can be thought of as one half the perimeter of the reduced rectangle. It is this measure that is used in the following analysis.



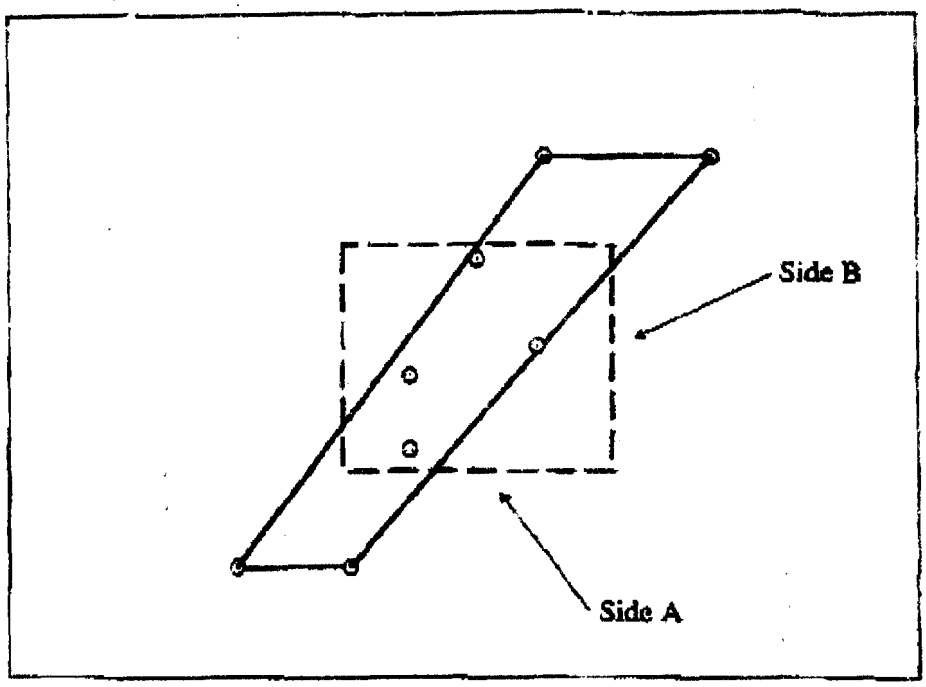
Facts Regarding the Hatfield Model (cont.)

#6. The HAI Model claims to build distribution cable to all locations in a cluster. However, initial analysis of the actual locations used in Nevada indicates that the HAI Model falls far short of building enough cable to connect all locations.

To measure the exact extent of this **underbuilding**, it is necessary to know actual point locations, in order to calculate the amount of required distribution cable (which is simply the shortest distance between all points).

To date, AT&T has not allowed these calculations to take place. In lieu of this analysis, it is still possible to obtain an imperfect measure (a grossly <u>understated</u> measure) of the degree to which the HAI Model underbuilds distribution plant.

This measure will use the **height-plus-width**, described earlier.



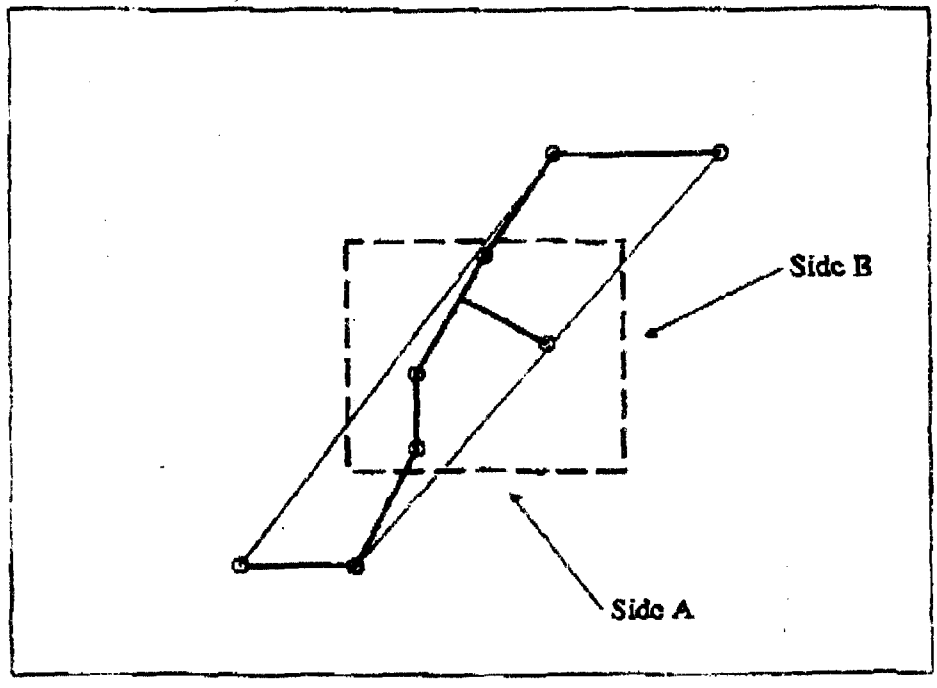
Facts Regarding the Hatfield Model (cont.)

#7. Simply stated, it is **mathematically impossible** for the distance connecting all points in a cluster to be less than the height-plus-width. (A detailed explanation of this fact follows in an Appendix.)

Therefore, it is also impossible for the actual required distribution cable in any cluster to be less than the height-plus-width.

Any cluster for which the HAI Model produces an amount of distribution cable that is less than the height-plus-width is a cluster that the HAI Model underbuilds.

IMPORTANT: **Height-plus-width does NOT represent the required amount of cable.** It represents a distance that is *less than* the required amount of cable. Therefore, a cluster with a distribution length greater than the height-plus-width distance is not necessarily a cluster with sufficient distribution cable.

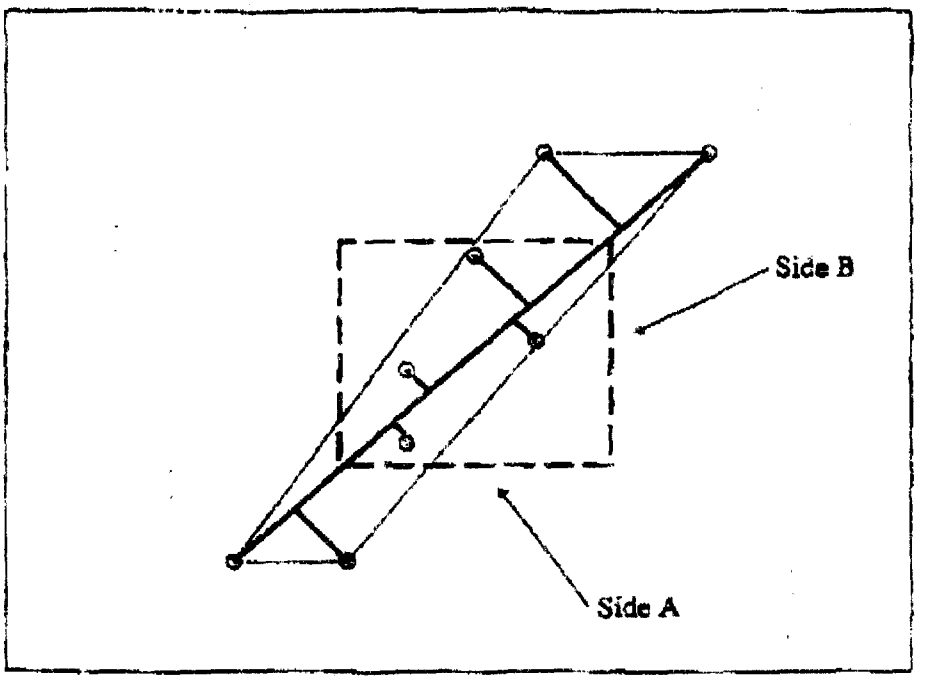


Facts Regarding the Hatfield Model (cont.)

Above, and on the following pages, for illustrative purposes only, are examples of potential distribution layouts. In every case, the amount of cable required to connect all customers dramatically exceeds the height-plus-width distance.

For example, in the picture above the total **height-plus-width** distance is less than 2.87 miles.

The distance connecting the points shown above (the solid lines) is over 4.25 miles.

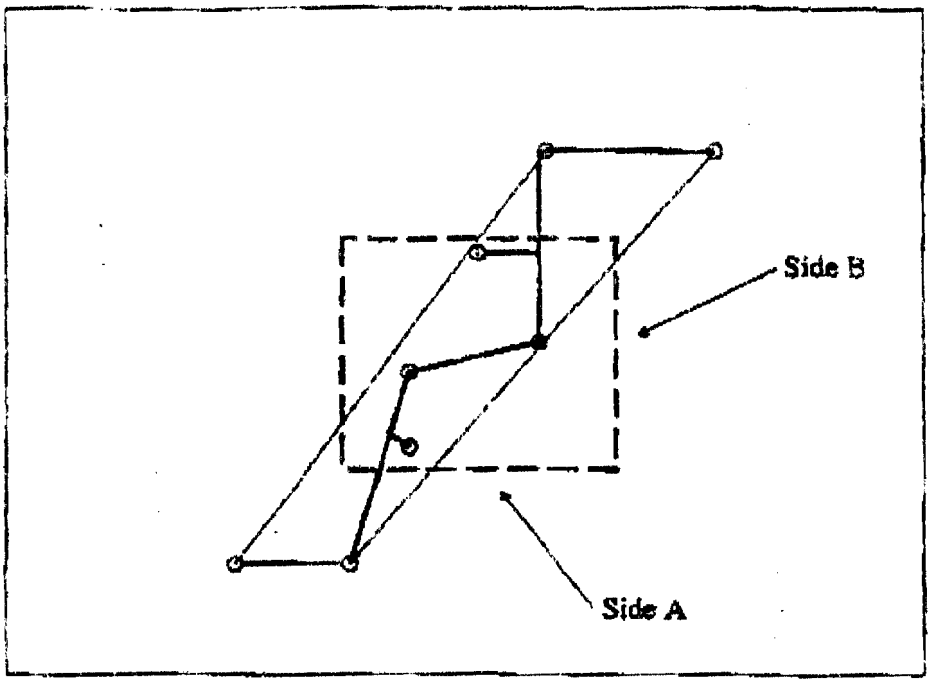


Facts Regarding the Hatfield Model (cont.)

example, for illustrative purposes only

In the picture above the total **height-plus-width** distance is less than 2.87 miles.

The distance connecting the points shown above (the solid lines) is over 5 miles.

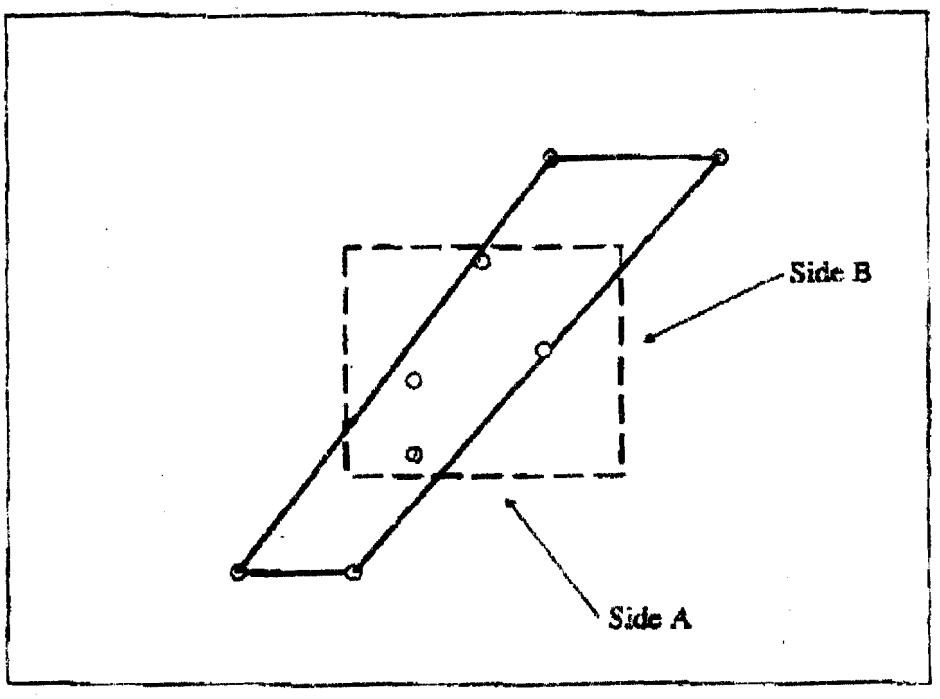


Facts Regarding the Hatfield Model (cont.)

example, for illustrative purposes only

In the picture above the total **height-plus-width** distance is less than 2.87 miles.

The distance connecting the points shown above (the solid lines) is over 4.25 miles.



In the tables that appear on the following pages, we list (by company) a sample of some of the clusters for which the HAI Model underbuilds distribution cable.

The tables are only samples, not a complete listing. For example, the Nevada Bell table lists only 25 clusters, but our analysis discovered over 200 clusters in Nevada Bell region that fell short.

Only main clusters are listed, to avoid any potential confusion caused by the treatment of outliers.

The tables list the total distribution the model builds as well as the height-plus-width distance.

Keep in mind that the height-plus-width distance measure is itself insufficient to connect all customers. So the cable shortages that appear on the following tables actually understate the amount by which HAI underbuilds.

SAMPLE OF NEVADA BELL MAIN CLUSTERS WITH DISTRIBUTION UNDER BUILT BY HAI 5.0

Note: Sum of height and width is less than the actual minimum amount of cable needed to connect points within the cluster.

WIRE CENTER	CLUSTER	TOTAL LINES	SUM HEIGHT AND WIDTH	ACTUAL MAIN CLUSTER DISTRIBUTION BUILT BY HAI
BTMTNV11	C019.	8	27,059	9,182
BTMTNV11	C018.	6	25,441	620
BTMTNV12	C001.	16	1,367	530
CSTVNV11	C003.	5	30,818	0
DKWRNV11	C001.	10	2,343	850
EMPRNV11	C002.	6	9,588	1,982
EMPRNV11	C016.	5	12,981	5,317
EMPRNV11	C014.	5	10,411	639
EMPRNV11	C015.	6	12,803	1,236
EMPRNV11	C012.	5	13,053	1,440
EMPRNV11	C008.	6	16,141	4,251
EMPRNV11	C010.	6	14,643	2,567
EMPRNV11	C004.	6	18,941	5,290
EMPRNV11	C013.	5	15,323	986
EMPRNV11	C001.	8	22,181	2,259
GABBNV11	C005.	8	17,712	6,009
GABBNV11	C002.	11	27,399	13,316
IMLYNV12	C021.	9	11,783	1,048
IMLYNV12	C030.	11	19,734	8,198
IMLYNV12	C023.	12	17,182	5,174
IMLYNV12	C022.	5	20,768	6,006
IMLYNV12	C018.	16	32,952	17,161
IMLYNV12	C029.	5	20,899	3,105
LVLCNV11	C008.	24	27,885	16,117
MCGLNV11	C003.	8	18,075	4,828

In total for Nevada Bell the HAI 5.0 model under builds distribution in 83% of the main clusters in the 0 – 5 density range, and 35% of the main clusters in the 6 – 100 density range. These two density zones represent the vast majority of clusters for which universal service funding is needed.

SAMPLE OF CITIZENS MAIN CLUSTERS WITH DISTRIBUTION UNDER BUILT BY HAI 5.0

Note: Sum of height and width is less than the actual minimum amount of cable needed to connect points within the cluster.

WIRE CENTER	CLUSTER	TOTAL LINES	SUM HEIGHT AND WIDTH	ACTUAL MAIN CLUSTER DISTRIBUTION BUILT BY HAI
ELKONVXF	C001.	5	5,523	0
GLFDNVXF	C001.	11	33,576	9,305
GLFDNVXF	C008.	10	38,877	9,579
JGGSNVXF	C001.	5	16,258	659
JGGSNVXF	C003.	5	19,747	6,062
MTLLNVXF	C002.	5	35,490	5,035
RBVYNVXG	C005.	5	11,018	221
RBVYNVXG	C006.	7	27,970	4,054
RBVYNVXG	C002.	10	14,381	6,135
RBVYNVXG	C001.	6	33,397	7,032
RBVYNVXG	C004.	5	27,976	8,820
RBVYNVXG	C003.	7	33,442	10,668
SLVPNVXF	C004.	8	30,863	1,632
SLVPNVXF	C003.	6	26,779	6,519
SLVPNVXF	C005.	6	31,660	7,026
SLVPNVXF	C001.	5	28,496	13,726
SLVPNVXF	C002.	15	30,798	14,813
TNPHNVXB	C004.	14	21,497	8,191
TNPHNVXB	C003.	18	31,784	12,272
WLLSNVXF	C005.	6	8,803	1,020
WLLSNVXF	C009.	6	11,280	1,469
WLLSNVXF	C008.	8	16,065	4,371
WLLSNVXF	C002.	7	21,066	4,722
WLLSNVXF	C012.	5	17,446	5,467
WLLSNVXF	C003.	8	23,745	6,288
WLLSNVXF	C010.	8	25,634	6,737
WLLSNVXF	C001.	8	25,616	6,981
WLLSNVXF	C004.	9	24,697	7,979

In total for Citizens the HAI 5.0 model under builds distribution in 78% of the main clusters in the 0 – 5 density range, and 25% of the main clusters in the 6 – 100 density range. These two density zones represent the vast majority of clusters for which universal service funding is needed.

SAMPLE OF CONTEL MAIN CLUSTERS WITH DISTRIBUTION UNDER BUILT BY HAI 5.0

Note: Sum of height and width is less than the actual minimum amount of cable needed to connect points within the cluster.

WIRE CENTER	CLUSTER	TOTAL LINES	SUM HEIGHT AND WIDTH	ACTUAL MAIN CLUSTER DISTRIBUTION BUILT BY HAI
GVRSNVXF	C001.	25	30,872	25,385
GVRSNVXF	C006.	38	20,123	13,681
GVRSNVXF	C002.	6	15,953	3,502
JKVYNVXF	C003.	6	600	0
JKVYNVXF	C004.	22	22,777	12,399
SMTHNVXF	C004.	9	17,151	4,992
SMTHNVXF	C001.	24	31,387	24,897
SMTHNVXF	C002.	21	34,399	27,494
SMTHNVXF	C009.	5	15,402	2,077
SMTHNVXF	C005.	23	33,701	26,637
SMTHNVXF	C010.	30	36,630	30,824
STLNNVXF	C002.	5	1,825	340
TPLKNVXA	C005.	8	16,421	2,611
TPLKNVXA	C001.	11	17,934	9,144
TPLKNVXA	C004.	14	23,843	8,404
TPLKNVXA	C007.	36	29,123	25,056
YRTNNVXA	C002.	12	10,374	1,278
YRTNNVXA	C001.	7	24,736	5,534
YRTNNVXA	C004.	11	13,555	6,252
YRTNNVXA	C007.	24	16,328	12,728
YRTNNVXA	C003.	25	33,717	31,535
YRTNNVXA	C015.	15	13,756	4,873
YRTNNVXA	C014.	21	31,737	18,940

In total for Contel the HAI 5.0 model under builds distribution in 59% of the main clusters in the 0 – 5 density range, and 28% of the main clusters in the 6 – 100 density range. These two density zones represent the vast majority of clusters for which universal service funding is needed.

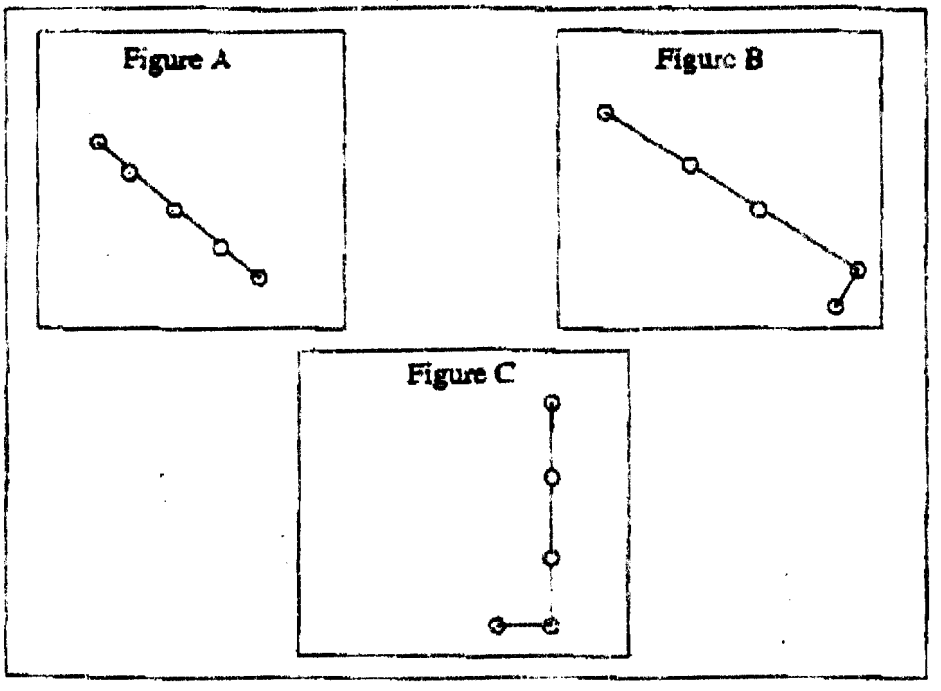
SAMPLE OF CENTEL MAIN CLUSTERS WITH DISTRIBUTION UNDER BUILT BY HAI 5.0

Note: Sum of height and width is less than the actual minimum amount of cable needed to connect points within the cluster.

WIRE CENTER	CLUSTER	TOT LINES	SUM HEIGHT AND WIDTH	ACTUAL MAIN CLUSTER DISTRIBUTION BUILT BY HAI
JEANNVXF	C005.	7	7,304	156
JEANNVXF	C007.	7	5,161	415
JEANNVXF	C003.	12	19,474	5,045
JEANNVXF	C004.	9	21,503	6,871
JEANNVXF	C012.	8	20,443	8,105
JEANNVXF	C008.	25	28,052	9,196
JEANNVXF	C006.	9	27,534	10,076
JEANNVXF	C001.	14	28,806	10,456
JEANNVXF	C013.	9	27,206	16,637
MTCHNVXF	C015.	5	2,407	605
MTCHNVXF	C001.	9	17,683	5,234
MTCHNVXF	C005.	9	14,125	6,001
MTCHNVXF	C009.	9	13,076	6,140
MTCHNVXF	C002.	8	12,828	6,407
MTCHNVXF	C010.	10	15,741	7,901
MTCHNVXF	C016.	9	17,126	8,918
MTCHNVXF	C008.	11	23,719	13,094
MTCHNVXF	C013.	12	27,597	14,784
NLSNNVXB	C002.	7	23,230	8,741
SRCHNVXF	C003.	7	10,607	2,338
SRCHNVXF	C002.	7	10,567	3,491
SRCHNVXF	C006.	14	29,717	9,897
SRCHNVXF	C011.	13	35,069	12,499
SRCHNVXF	C010.	11	30,164	15,558
SRCHNVXF	C009.	22	30,094	16,373

In total for Centel the HAI 5.0 model under builds distribution in 78% of the main clusters in the 0 – 5 density range, and 28% of the main clusters in the 6 – 100 density range. These two density zones represent the vast majority of clusters for which universal service funding is needed.

Appendix: Why it is Mathematically Impossible for the Distance Connecting All Points in a Cluster to be Less than the Height-Plus-Width of the Reduced Rectangle.



Facts Regarding the Hatfield Model (cont.)

All main clusters must have 5 points (see HAI Documentation).

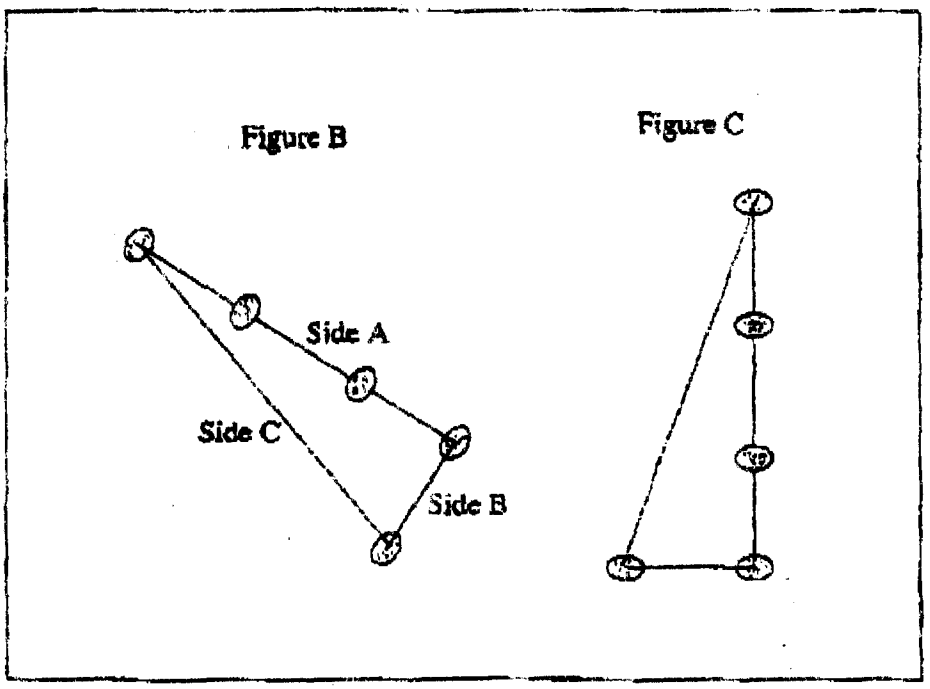
In Figure A, all points fall into direct line. By definition this cluster has no area. Impossible to create convex hull.

In Figures B and C, it is possible to create polygons having convex hull and area.

Although original polygons in Figures B and C will be identical, minimum bounding rectangles will be dramatically different (see following pages).

These two figures (B&C) will be used to illustrate fact that height-plus-width of reduced rectangle can only be less than minimum distance required to connect all points.

All other polygons can be viewed as variations of Figures B and C.



Facts Regarding the Hatfield Model (cont.)

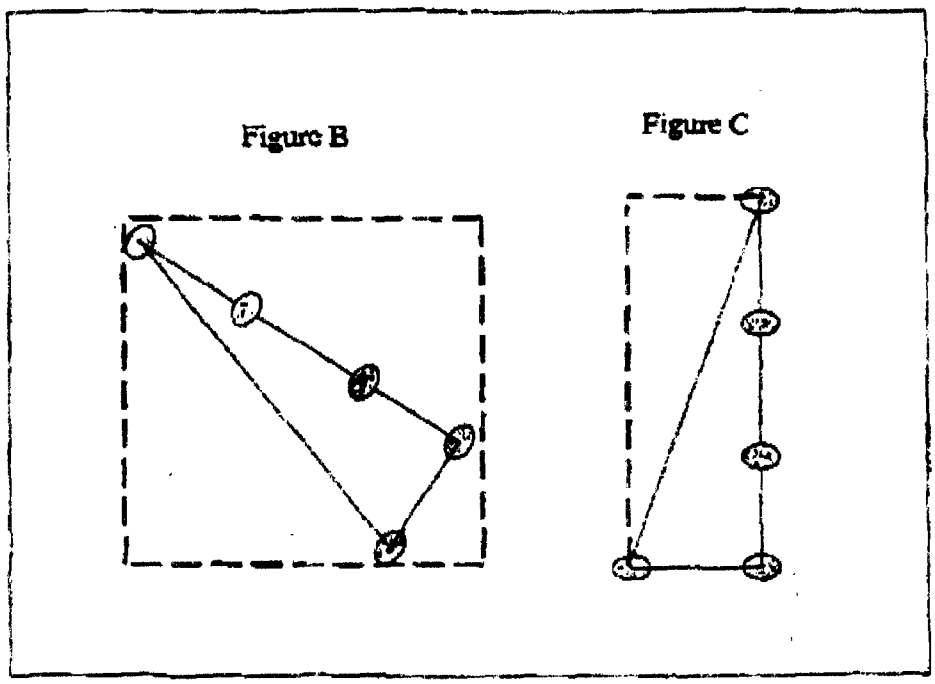
Area of both polygons is identical, approximately 0.71 square miles (where 1 inch = 1 mile).

Approximate Lengths of Sides (for future reference)-

Side A: 2.06 miles (10,900 feet)

Side B: 0.69 miles (3,630 feet)

Side C: 2.19 miles (11,550 feet)



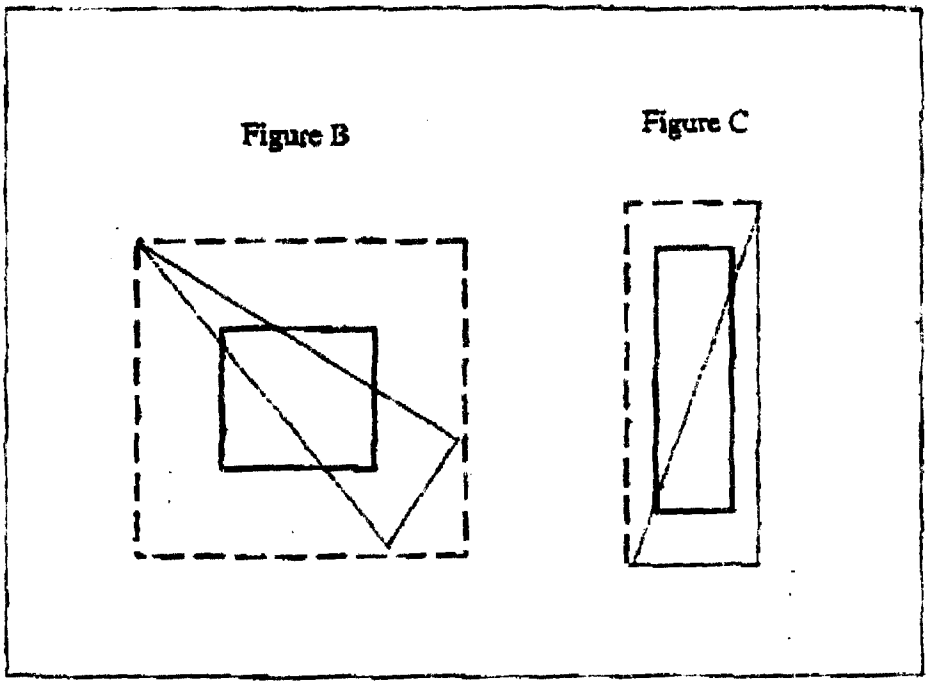
Facts Regarding the Hatfield Model (cont.)

Minimum bounding rectangles for each polygon are dramatically different. Each will produce a different aspect ratio, and a differently shaped reduced rectangle.

Recall, aspect ratio is height over width.

Aspect Ratio of Figure B is approximately 1.

Aspect Ratio of Figure C is approximately 3.



Facts Regarding the Hatfield Model (cont.)

(points removed for ease of exposition)

Picture above shows the corresponding reduced rectangle (heavier lines) for each of the original polygons.

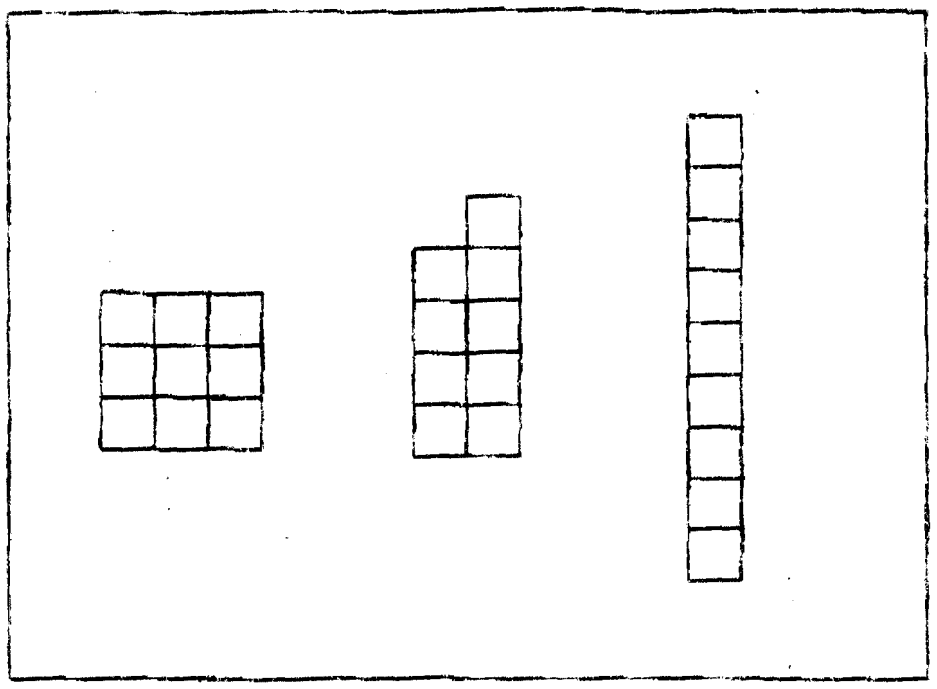
Each reduced rectangle has the same exact area, which is exactly equal to the area of the original polygon, 0.71 square miles.

However the distance figures "height-plus-width" can differ significantly.

Figure B, the reduced rectangle that appears more square-like, has height-plus-width distance of 1.68 miles.

Figure C, the more elongated figure, has a height-plus-width distance of 1.94 miles.

This illustrates a basic tenet of geometry discussed on the following page...



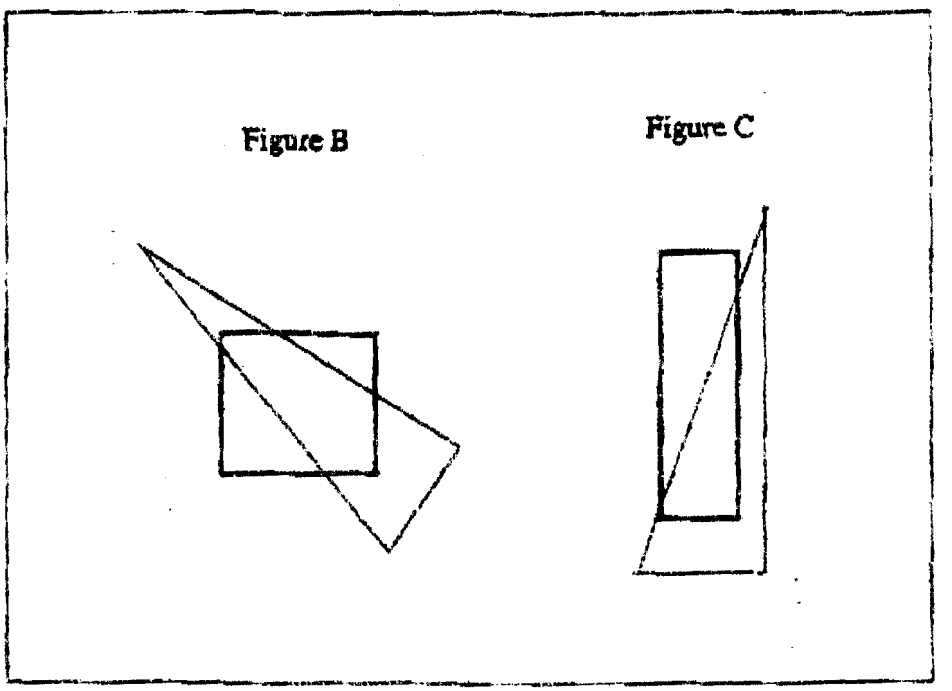
If two polygons have the same area, the measure of the perimeter will be shortest for the polygon which most closely approaches the shape of a square.

This is illustrated above using three polygons with identical area (9 square miles if 1 box = 1 square mile).

The figure on the far left has a perimeter distance of 12 miles.
The figure on the far right has a perimeter distance of 20 miles.
The figure in the center has a perimeter distance of 14 miles.

Implications for the HAI Model:

Whenever the convex hull of an original cluster is converted to the reduced rectangle (with identical area), it becomes relatively more square-shaped. Consequently, the perimeter measure decreases in every case.

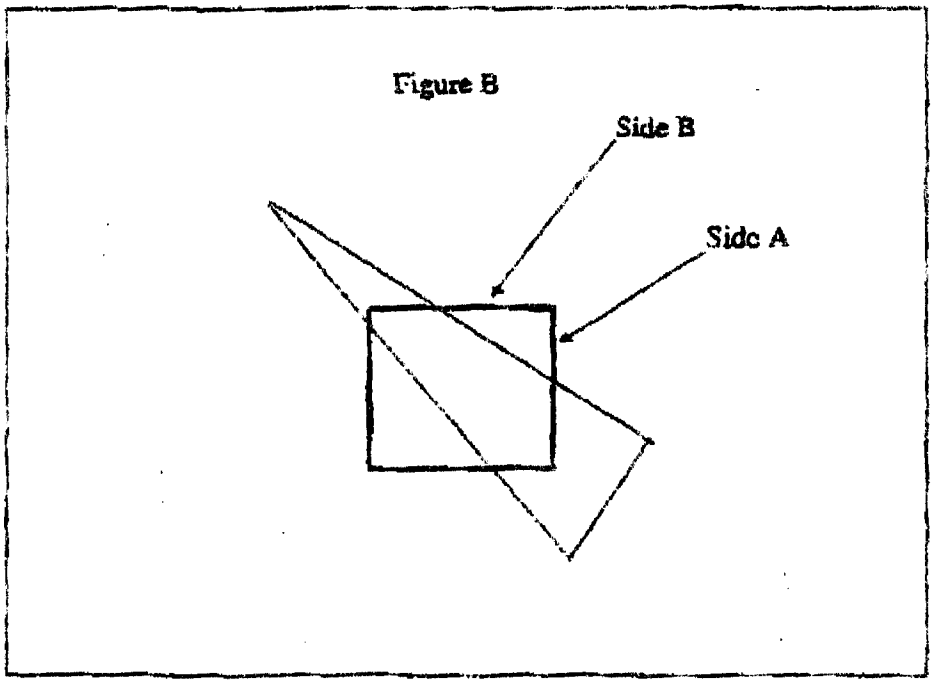


Facts Regarding the Hatfield Model (cont.)

In the figures above, the perimeter of reduced rectangle B is less than the perimeter of reduced rectangle C. But the perimeters of **both** reduced rectangles are less than the perimeters of the original polygons (which are identical).

The distance measure **height-plus-width** represents exactly one half the perimeter of (any) reduced rectangle. By definition and the result above, this is less than one half the perimeter of the original polygon.

<u>It is geometrically impossible to connect the bounding points of any polygon (not to mention any interior points) with only one half the distance of the perimeter. Consequently, it is also impossible to connect the same points with less than one half the perimeter distance.</u>

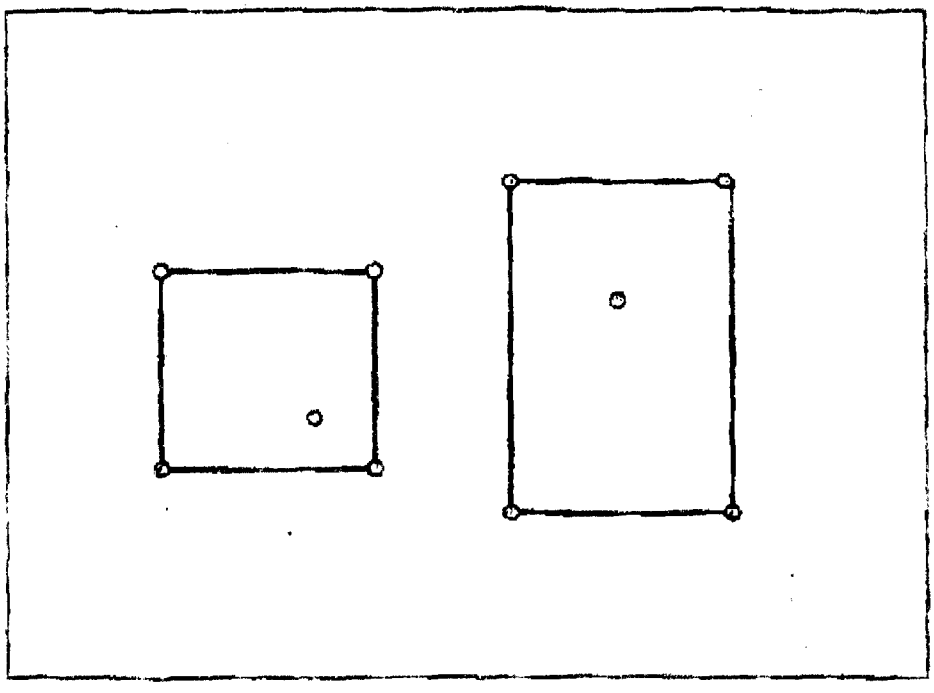


Implication of Hatfield Model Results:

Any main cluster in which the Total Distribution built falls short of the distance of side A plus side B is a cluster in which the model falls short of building a functioning, operable network. Total Distribution is measured: [(Hatfield Distribution Module, Calculations Worksheet Cell BU minus Cell CQ (outlier road distance)]

There is no exception to the rule that it is geometrically impossible to connect the bounding points of any polygon with only one half the distance of the perimeter.

There is, however, one rare exception to the rule that the polygon perimeter is reduced when it is converted to the reduced rectangle. This occurs when the polygon is exactly the size and shape of the minimum bounding rectangle. This is discussed below...



Implication of Hatfield Model Results:

There is one unique case, pictured above, where not only the area but also the perimeter of the original polygon is maintained: the case where the original polygon is a perfect rectangle (or square.)

In this case, even though the perimeter is not reduced, the distance **height-plus-width** is still massively insufficient to connect all points in the cluster.

Therefore, any cluster at all in which the amount of distribution built is less than the height-plus-width remains an "underbuilt" cluster in the HAI Model.

BCPM CUSTOMER LOCATION & OUTSIDE PLANT DISTRIBUTION DESIGN METHODOLOGY[1]

Overview

BCPM 3.1 integrates precise information regarding customer location with a customer location algorithm that establishes an optimal grid size based on an efficient network design.[2] The optimal grid size is determined by adhering to sound engineering practices that reflect forward looking, least cost technology for providing basic service. The algorithm establishes "ultimate grids" that are sized to comply with the technical requirements of a Carrier Serving Area (CSA). Thus, BCPM 3.1's customer location algorithm selects the appropriate granularity of analysis to assure that customers are accurately located and moreover, that the cost outputs are representative of the network design necessary to serve those customers.

BCPM 3.1's customer location algorithm uses housing and business line data at the Census Block (CB) level combined with information regarding the road network to more precisely locate customers. Utilizing all of this data, BCPM 3.1 models clusters of customers where they are indeed clustered and models sparsely populated areas where customers are, in fact, dispersed.

Additionally, BCPM 3.1 uses wire center boundaries provided by Business Location Research (BLR) increases the accuracy in assigning customers to their actual serving wire center.

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[1] Selected excerpts from the Benchmark Cost Proxy Model Release 3.1 Model Methodology, January 13, 1998 Edition , Developed by BellSouth, *INDETEC* International, Sprint and US West.

[2] See "Joint Comments of BellSouth Corporation, BellSouth Telecommunications Inc., U S WEST Inc., and Sprint Local Telephone Companies to Further Notice of Proposed Rulemaking Sections III.C.1", CC Docket 96-45 and CC Docket 97-160, filed Sept. 2, 1997.

By overlaying wire centers with grids, BCPM 3.1 constructs a network that avoids building to areas where people are unlikely to reside, concentrating instead, on road miles where people are more likely to be located.

BCPM 3.1 recognizes that telephone plant engineers do not typically build plant on a customer by customer basis. Rather, they plan and build plant based on Carrier Serving Areas (CSAs)[3] and Distribution Areas (DAs).

To accomplish this, BCPM 3.1 uses a reformulated geographic entity - the dynamic grid which varies in size to ensure that the number of customers included in a grid takes into account CSA guidelines. Furthermore, the maximum grid size is constrained so that the limitations of copper distribution are not exceeded.

The customer location algorithm performs a series of reaggregation steps that combine grids into various sizes, consistent with an efficient network design. Each grid's size, cost characteristics, and number of lines is integrally linked to telephone engineering CSAs and DAs. In addition, the construction of these grids takes into account the actual road network to more accurately reflect the location of customers within a CB.

Process Description

I. Establish Wire Center Boundaries

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[3] A CSA encompasses the entire design area potentially served from a particular digital loop carrier (DLC) site, including the feeder distribution interface, vertical and horizontal connecting cables, backbone cable and branch cables.

The first step in accurately establishing customer location is the specification of the appropriate wire center boundaries. BCPM 3.1 relies on wire center data obtained from BLR.

II. Locate Customers

The second step is to use the CB level of data that falls within the corresponding wire center boundary. For the occasional CB that crosses a wire center boundary, housing and business data is apportioned to the respective wire center based either on the proportion of land area, if the CB is less than 1/4 of a square mile, or the proportion of roads, if the CB is greater than 1/4 of a square mile.

III. Establish Serving Areas

The final step is the creation of the variable size grids from the CB data within the wire center boundaries. The purpose of developing variable size grids is to simulate the basic telephone plant engineering units of a CSA and DA. This process entails the establishment of microgrids and the reaggregation of these microgrids into ultimate grids.

A. Establishing Microgrids

It is necessary to establish microgrids so that populated areas can be aggregated appropriately into telephone engineering CSAs and DAs. There are two phases of the grid process. The first phase entails assigning CB data to microgrids. "Microgrid" refers to the smallest grid size used in the grid process. A microgrid is 1/200th of a degree latitude and longitude. This corresponds to approximately 1,500 feet by 1,700 feet latitude and longitude.[4] The entire serving wire center is partitioned into microgrids. Thus, each CB within the serving wire center is overlayed with microgrids (unless the entire CB falls within a single microgrid). Smaller CBs, typically located in the denser,

[4] Due to the curvature of the earth, these dimensions vary depending on the latitude and longitude where they are derived. These measurements are used only to give the reader a sense of relative size.

urban areas, are aggregated into microgrids while larger CBs located in the rural areas may span multiple microgrids.

Since household and business line data[5] are assigned at the CB level, this process requires apportioning CB line data to the corresponding microgrids. Two approaches are used to apportion this data to the microgrids, depending on the size of the CB. For CBs whose area is less than 1/4 of a square mile, (2,640 feet by 2,640 feet), encompassing approximately three to four microgrids, household and business line data is apportioned based on the land area of the microgrid used relative to the CB's total area.[6]

For CBs with an area greater than 1/4 of a square mile, household and business line data is apportioned based on relative road lengths using actual road data obtained from TIGER/Line files [Topologically Integrated Geographic Encoding and Referencing from the US Census Bureau]. That is to say, the line data is apportioned based on the road length contained within a microgrid that traverses that CB, relative to the total road length within that CB. Since roads are used to locate customers, certain roads where customers are unlikely to reside, have been excluded from the road data.[7] To illustrate the apportionment of household and business line data to microgrids based on relative road lengths, assume that the total road length associated with a particular CB is 60 miles

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[5] Household data includes housing unit and household information from the Census Bureau. Business line counts are obtained from PNR.

[6] For a microgrid that is fully encompassed by a CB, i.e. 100% of the microgrid's area is encompassed within the CB, the area covered by that one microgrid is (1,500ft. x 1,700 ft) = 2,550,000 sq. ft. If the total area of the CB is 5,100,000 sq. feet, then the fraction of land area of the CB encompassed by that microgrid is(2,550,000sq ft. /5,100,000sq. ft.) = .5 of the area. Thus, 50% of the household and business line data is apportioned to that microgrid.
If only a portion of a microgrid is encompassed by the CB, e.g. 80% of the microgrid is encompassed by the CB, then the area covered by that one microgrid is .8x(1,500ftx1,700ft) = 2,040,000 sq. ft. If the area of the CB is 5,100,000sq. ft., then (2,040,000 sq. ft./5,100,000 sq. ft.) =.40 In this case, .4 or 2/5ths of the household and business line data is apportioned to the microgrid.

[7] Road data used in BCPM 3.1 exclude all limited access highway segments; all highway and road segments that are in a tunnel or in an underpass; vehicular "trails" and roads passable only by 4 wheel drive vehicles; highway access ramps; ferry crossings; pedestrian walkways and stairways; alleys for service vehicles; and driveways and private roads.