network.[61] In addition to the factors cited *supra*, locating remotes close to concentrations of customers improves network reliability, since calling among the customers served by the remote is still possible even if the link to the host is broken.

The *Staff Analysis* (at ¶ 21) also raises the possibility of incorporating other technologies, such as wireless, into the proxy cost models. The current models use rules of thumb based on the current ILEC wireline technology. As the analysis presented in these comments show, the models have enough difficulty representing the costs of existing technology accurately. Attempting to add additional technologies would only complicate the models further, and is not likely to improve the results.[62] In any event, the models should seek to estimate the market price using the current technology. If an entrant can perform at lower cost using some innovation not available to an incumbent, then the price level given by the current technology will provide that firm with the correct market signal to enter.

In the context of *D.96-45*, a firm using lower cost technology would benefit consumers even if the universal service support amount does not adjust immediately, because the entrant would be likely to pass along to consumers any reduction in cost in

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[61] Hausman, Jerry A., "Proliferation of Networks in Telecommunications: Technological and Economic Considerations," in Werner Sichel and Donald T. Alexander, Editors, Networks, Infrastructure, and the New Task for Regulation, University of Michigan Press, Ann Arbor, 1996, at 21.

[62] The *Staff Analysis*'s proposal at ¶ 21 to use a presumed wireless cost as a "cap" might be reasonable to limit outliers among the estimates. The earlier BCM model had such an upper bound. However, wireless may not be a feasible alternative in mountainous areas; it might be possible to link the use of this cap to the terrain variable in the model.

the form of lower prices. As for adjusting the universal support itself to reflect changes in the market price over time, this should be accomplished though a system of competitive bidding, rather than by attempting endlessly to update a cost model to accommodate new technologies and/or different network nodes. Indeed, all of this effort can be easily avoided by a competitive bidding mechanism. As Ameritech stated: "Under a bid model, it would be the serving entity's responsibility to determine its own costs, to bid accordingly, and then to live with the consequences."[63] That will reveal more actual cost information than years of adversarial regulatory proceedings.

B. A Hybrid Approach That Adopts Census Block Groups For Non-Rural Areas And Grid Squares For Rural Areas As The Geographic Unit Of Analysis May Prove Useful. (¶¶ 22-24)

GTE has consistently supported the use of a geographic unit at least as small as a CBG, because universal service support based upon a geographic unit with reasonably homogenous costs is essential to ensure competitive neutrality and the sustainability of a support plan. A study area, density zone, exchange, or wire center is simply too large.

Given the well-known problems associated with the use of CBGs in modeling rural areas, GTE has suggested that it may prove useful to adopt a hybrid approach -- grid cells in rural areas and CBGs elsewhere. Apart from their size, grid squares have the advantage of regular shape: the models assume that the small geographic units are

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[63] Comments of Ameritech on Joint Board Recommendation, *D.96-45*, page 11 (December 19, 1996).

square, and grid cells really are square.[64] Their disadvantages are that they may cross state and county boundaries, which CBGs do not. An alternative to the grid cell is the census block that lacks the advantage of regular shape, but for which household data are available from the Census Bureau.

Either of these smaller units could be used, not only to deal with very large rural CBGs, but also to address the problem of imprecise assignment of CBGs to wire centers where the same CBG may overlap two or more wire center serving areas.[65] Where the overlap is significant, it can create a source of error in the estimation of the costs of a given wire center. This can be minimized by using either grid squares or census blocks to subdivide a CBG to align more closely with a wire center boundary.[66]

For use in a universal service plan, GTE urges the Commission to estimate costs at the small area level (CBG), and to calculate support amounts at the same level. Because the models are already configured to run at the small area level, nothing is gained, and some accuracy is lost, by aggregating the data to zones before the support

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[64] Actually, because the dimensions of the grid cells are defined in terms of latitude and longitude, they are square only near the equator. The farther north from the equator, the more oblong the grid cell will be.

[65] This inherent problem of the use of CBGs is vastly exacerbated by the errors in the assignment of CBGs to wirecenters in the Hatfield 3 model. For example, Hatfield 3 overstates the GTE California service area by 85%. *See* Attachment B, at 5-6; Attachment B, Appendix H; and Attachment F for maps demonstrating this error.

[66] Another problem, related to the implementation of a universal service plan rather than to the cost model itself, is that ILECs do not have a good means available today to assign customers within a wire center to the appropriate CBG. A means for doing this will have to be found if ILECs are to report to a plan administrator the number of customers they serve in each CBG.

is calculated. For pricing purposes, aggregation to zones does serve a useful purpose, since ordering and billing systems must be able to operate at the geographic level of the prices. As the *Staff Analysis* notes (at ¶ 24) the issue with respect to pricing is whether the zone structure captures differences in cost closely enough to limit arbitrage opportunities. Since these variations in cost -- and system constraints -- will vary by company and by serving area, GTE suggests that the Commission should not adopt a standard level of disaggregation for pricing services like interstate access, but should adopt rules for access pricing that allow the LECs flexibility to select the appropriate level of deaveraging for their areas.[67]

C. A Cost Model Should Use Actual Line Quantity Data, and Should Consider Growth Over A Planning Horizon. (¶¶ 25-28)

As the *Staff Analysis* recognizes (at ¶ 25) the accuracy of the proxy cost estimates will depend on the accuracy of the demand estimate used to drive the model. The current proxy models rely on the number of households in each CBG, from census data, to estimate the number of residence lines. This fails to capture differences across CBGs in penetration rates and in the number of second lines. The models also determine the number of business lines by applying a simple ratio to an estimate of the number of employees in each CBG. As the *Staff Analysis* notes (at ¶ 26) the number of lines demanded per employee will vary sharply among different kinds of businesses.

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[67] In choosing how much to deaverage interstate rates, an ILEC would also have to consider possible arbitrage with state rates, and whether the state regulator has allowed those rates to be deaveraged.

GTE suggests that it is not necessary to estimate the number of lines in each wire center, since these data are maintained by the ILECs today.[68] Because the distribution of residence and business lines is not uniform across the CBGs in each wire center, GTE proposes that CBG data be combined with the wire center line counts to make the best possible use of the available information. Specifically, GTE proposes that the estimated number of residence lines in each wire center should be forced to equal the residence line count in that wire center. These lines should then be distributed among the CBGs in the wire center, based on the relative number of households in each CBG. Similarly, the total estimate of business lines in each wire center should equal the business line count in that wire center. These lines should then be distributed among the CBGs in the wire center, based on the relative employment in each CBG. Under this approach, the wire center line counts will pick up differences in employment per line at the wire center level; this will be more effective at picking up differences in lines per employee than any analysis of industry classifications. The employee count in each CBG will then capture differences in the concentration of business activity, such as between the center of a rural town and surrounding farms.

GTE agrees with the *Staff Analysis* (at ¶ 28) that the cost estimate should consider the growth in demand over the planning period. For reasons discussed *supra*,

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[68] As the *Staff Analysis* at ¶ 25 points out, the number of lines in each wire center may be regarded as proprietary by an ILEC. GTE submits that this information could be made available under a protective agreement. While it would not be available for inspection by all parties, there is little concern that the ILEC would be able somehow to manipulate data of this kind, and the Commission can check its validity through the use of an independent auditor.

the need to allow for growth and uncertainty in demand over time imposes certain costs on carriers which are not captured by the static models. It is not feasible, within the Commission's time and resource constraints, to develop a dynamic cost model that optimizes such growth in demand over time. However, it is possible to make some adjustments to the existing proxy models that would allow them to represent, at least in part, some of the costs real firms -- including a real entrant -- would incur. GTE summarizes these issues, and its proposals for dealing with them:

1. The cost model should assume realistic utilization rates which recognize the tradeoffs inherent in optimizing the network over time. The best source of this data is the actual utilization rates experienced by the industry today.

2. The model should use inputs for switching cost that include the average cost of the switch capacity over its life cycle, including both the initial cost and the cost of additional increments of capacity.[69] As GTE illustrated in earlier comments, switch vendors generally charge a lower price for capacity purchased when the switch is first installed, and much higher prices for subsequent additions to that switch.[70]

3. For reasons explained *supra*, the model should not assume that all network capacity is placed at once. Any firm solving the stair step problem will choose some optimal increment of capacity to place each time the design

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[69] Hatfield 3 uses three switch line investment data points just as Hatfield 2.2.2. Moreover, inadequate documentation is available to determine the origin of the data. *See* Attachment B, at 13-14.

[70] *See GTE Model Responses*, at 5.

capacity "trigger" is reached. Thus, as panelist Peter Martin from BellSouth pointed out at the Proxy Cost Model Workshop,[71] instead of placing a single 1200 pair feeder cable to provide, say, 1000 working lines, it is more likely that three 400 pair cables were placed over time as demand grew. In this example, the rules of thumb in the model should reflect this best industry practice, and should place three 400 pair cables instead of one 1200 pair cable. Implementing this modification to the model will change the cost estimate. First, three 400 pair cables will cost more than one 1200 pair cable. Second, in order to install three 400 pair cables over time, the carrier will incur placement costs three times rather than just once.[72] This modification will allow the model to more accurately reflect the manner in which the firm incurs costs. While it may appear that the proposed rule of thumb is less "efficient" than those currently used in the models, in fact placing cable in these optimal increments is the industry practice precisely because it minimizes cost over time. In contrast, placing a very large cable at one time is actually less efficient, and would be especially so for an "efficient entrant" whose demand started at zero. Only because the current models are not capable of comparing the tradeoffs involved in the "stair step" problem does the placement of a 1200 pair cable in this example appear to be efficient.

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[71] Public Notice, Federal-State Joint Board on Universal Service: Staff to Hold Workshops on Proxy Cost Models on January 14-15, 1997, *D.96-45*, DA 96-2091, (released December 12, 1996) ("Proxy Cost Model Workshop") .

[72] Whether the firm will incur structure costs more than once depends on the size of cable and the type of placement. It will also depend on the extent to which all of the demand could be predicted with certainty.

4. If the demand to be considered is that of an efficient entrant, then it is not reasonable to assume that this amount will be 100% of the total demand. While the total number of lines demanded may increase over time, each firm in a competitive market will achieve a market share less than 100%. Further, if the market shares are not assumed to be equal among the market participants, but are split in some fashion with a larger share to the incumbent, then it is the smaller share to which we must look in order to model an efficient entrant. GTE recognizes that it is difficult to develop a scenario with respect to expected market shares. However, the Commission should explore the effect of varying market share on the cost level estimated by the model. It would be arbitrary for the Commission to assume the circumstances of an "efficient entrant" wherever this would justify a lower cost, but to revert to the current demand level of the incumbent where use of a more likely view of the entrant's demand would produce a higher cost.[73]

D. Cost Models Must Accurately Estimate The Quantity Of Facilities Needed To Provide Service. (¶ 31-32)

It should be noted that the forward-looking investment figures generated by the three models (BCM2, CPM, and Hatfield 2.2.2) as cited by the Staff are not all comparable. As the Christensen Associates report for USTA points out, the Hatfield

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[73] In fact, for reasons explained *supra*, it is not clear why the forward-looking costs of an efficient entrant should be lower than the actual cost of an incumbent, if both are measured correctly. The difficulty of estimating the entrant's demand should, at a minimum, serve as a caution to the Commission against arbitrarily assuming a cost level significantly below the current actual cost level.

figure is for RBOC serving areas only, which omits most of the high-cost serving areas in the country.[74] Also, any comparison of models should take into account data filed by AT&T cited in the *Local Competition NPRM* (at n.15): $1,255 per line of local investment for only the first 20% of the RBOCs' switched access line customers. Presumably, AT&T's market entry strategy would not focus exclusively on the most-expensive-to-serve 20% of the RBOCs' customers, so the AT&T figure should by no means be taken as an upper bound.

The *Staff Analysis* (at ¶ 32) is incorrect in asserting that commenters on the models have not provided detailed analysis of the models' flaws. At the Proxy Cost Models Workshop on January 14-15, Mr. James Dunbar, from Sprint, recited in detail the deficiencies in the Hatfield 2.2.2 model's basic network. Moreover, a number of critical flaws in the Hatfield Model have been admitted by Hatfield proponents in various state arbitration proceedings.[75] These flaws are also tacitly conceded by Hatfield in the list of proposed improvements in Version 3 of the model.

1. Cost models must accurately estimate the amount of feeder and distribution loop plant needed to satisfy demand. (¶¶ 33-40)

The *Staff Analysis* (at ¶ 33) states that it is vitally important that "models estimate accurately the cost of loop plant sufficient to satisfy demand." GTE agrees. The Staff also notes that it would be helpful for model sponsors to "list and define the

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[74] *Christensen Evaluation* at 2.

[75] *See* GTE's *D.96-45* Comments, at Attachment 2 (December 19, 1996). *See also*, *GTE's D. 96-98 Opposition*, at 10-14 and Appendices B, C, D, E, F.

loop plant components derived by their models." *Id.* Again, GTE agrees that such information is critical to allow for a proper review of the accuracy of any model's estimate of loop plant costs. Further, in addition to a list of all the loop plant components included in a model, the physical quantities of those components, *e.g.*, miles of cable, must also be provided so that those amounts can be checked against what is actually on the ground or in the air.

To determine how accurately the Hatfield 2.2.2 model predicts the amount of needed loop plant, NERA performed two tests on GTE's behalf. The first test compares the sheath-miles of cable estimated by the Hatfield 2.2.2 model with the actual street miles in the same wire center area, which serves as a proxy for sheath-miles. The results shown in Attachment A (at Table 1) demonstrate that the Hatfield 2.2.2 model fails to incorporate sufficient loop investments -- placing at most only 40% of the needed facilities in several of the wire centers examined -- when estimating the amount of feeder and distribution loop facilities.[76] NERA was unable to prepare a similar comparison for Hatfield 3 in the amount of time available.

The second test compares the amount of dollar investments and expenses predicted by Hatfield 2.2.2 to those reported to ARMIS 43-08 by two ILECs -- GTE Northwest in Washington and GTE California. The results shown in Attachment A (at Table 2 and Table 3) demonstrate that the Hatfield 2.2.2 model grossly underestimates the necessary investment and expenses in the two states examined, estimating only

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[76] The lack of necessary structural investments in the loop, and possibly other network elements, explains, to a great extent, why model-predicted investments are much lower than investments reported in the ARMIS. See *Staff Analysis* at ¶ 13.

42% and 67%, respectively, of the total investment, and 33% and 60% respectively, of total expenses. The Hatfield 3 also seriously underestimates the needed investment and expenses in the one state examined, estimating only 59% of the total investment and 41% of the total expenses.[77]

Hatfield 3 designs far more distribution plant than Hatfield 2.2.2 -- in all California CBGs examined, on average, Hatfield 3 would place 17 times more cable.[78] However, this feat is somehow accomplished with a corresponding decrease in total cable investment, from $309 million in Hatfield 2.2.2 to $307 million in Hatfield 3 for the same serving area.

2. A loop plant fill factor must be used that represents utilization normally found in the industry. (¶¶ 41-43)

The Staff's dissatisfaction with the treatment of fill factors in both models is correct but somewhat misplaced: it is not simply a matter of what the numbers should be and how well they are justified by the model sponsors -- although those concerns are important, because some of the models are very sensitive to fill factors.[79] However,

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[77] Attachment A, at Table 4.

[78] Attachment B, at 7-9.

[79] Both BCPM and Hatfield 3 are less sensitive to fill assumptions than their predecessors, because they no longer develop structure cost by applying a factor to cable investment.

the basic issue is what fill factor concept should be used and how it takes growth, uncertainty and other factors into account, in the context of a static model.[80]

Design fill is essentially a trigger point for augmenting capacity; *e.g.*, when the feeder plant on a particular route reaches a trigger point such as 75% utilization, additional capacity has to be added. The 25% margin allows for defective facilities, for an administrative reserve, and for the fact that it often takes as much as a year to design and install a new increment. Over the planning horizon of the firm, the frequency with which capacity will have to be added depends directly on the rate of growth of demand and, in a given feeder route, on the total amount of facilities present. In the following diagram, that growth rate is reflected in the slope of the demand line -- the steeper the slope, the closer together are the steps in the capacity staircase, *i.e.*, the greater is the frequency of required additions to capacity.[81]

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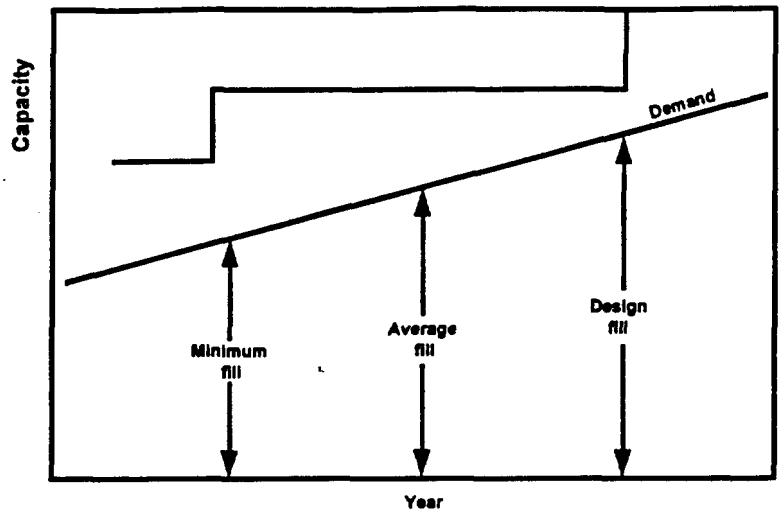
[80] One such approach to fill factors was demonstrated in the RAND Model several years ago. Mitchell used the design, or objective, fill factor and gave a cogent explanation of why that concept of capacity utilization was selected and how it worked in the model. "Incremental Costs of Telephone Access and Local Use," Bridger M. Mitchell, RAND, R-3909-ICTF, July, 1990. Park also undertook a separate analysis to determine the implications of the lumpy investment phenomenon for setting economically efficient prices. "Incremental Costs and Efficient Prices with Lumpy Capacity: The Two Product Case," Rolla Edward Park, RAND, MR-427-ICTF, 1994.

[81] As described *supra*, the solution to the "stair step" problem also depends on such factors as the uncertainty surrounding the firm's ability to forecast demand on each route, expectations regarding input prices over the planning horizon, and the feasibility and cost of rearrangements.

Figure 2
FEEDER CABLE UTILIZATION



Whenever additional capacity is created, the percent of utilization falls to a lower level than the design fill factor. Over time, the actual fill factor will increase until the design fill factor figure is reached again. Thus, actual fill factors do vary over the projected service life of the plant, as the Staff asserts they should. *Staff Analysis* at ¶ 41.

None of the available proxy models represents the tradeoffs involved in choosing utilization levels. They have no time dimension, nor do they optimize network design to minimize costs. Nor is it practical to add these features to the models. Since the models themselves do not generate any information about what level of fill would be optimal, it is particularly important that, when developing the fill assumptions, the Commission should choose numbers which incorporate information about the solution to the cost minimization problem. The only information the Commission has is the observable results of the optimization that existing firms have actually done. For this reason, the Commission should choose the fill factor assumptions that cause the

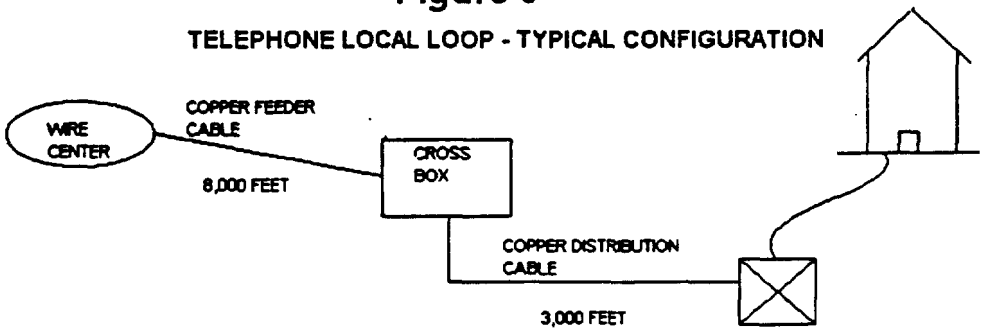
effective fills implemented by the cost model to approximate those actually realized in real-world local networks today.

a. Engineering standards and guidelines.

When an ILEC designs loop plant to provide local telephone service in a new development, it follows an accepted set of engineering standards. For engineering and planning purposes, new local loop plant is usually divided into two sections or segments: (1) feeder facilities, and (2) distribution facilities. Feeder facilities and distribution facilities are provisioned in fundamentally different ways. The differences in planning and sizing the two types of facilities are discussed below.

Figure 3

TELEPHONE LOCAL LOOP - TYPICAL CONFIGURATION



As Figure 3 illustrates, feeder facilities provide the backbone of the local telephone network, extending the network from the central office (or wire center) into the neighborhood where telephone service is provided. Feeder cables range from as small as a few hundred pairs to as large as 3,600 pairs.[82] Feeder cables are generally sized to provide sufficient capacity to accommodate growth along their routes for only a relatively short period of time, typically 3 to 5 years. They consist of either copper or

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[82] One pair equals two wires of a circuit, those which make up the subscriber's loop from the home or office to the central office. Newton's Telecom Dictionary at 444.

fiber optic materials. These cables are often placed in underground conduits, which facilitates the placement of additional feeder cables when necessary. Generally, feeder cables terminate at a passive physical device known as a cross-connect box. Thus, the dividing point between the feeder and distribution facilities is normally a cross-connect box.[83]

Distribution facilities, on the other hand, extend the telephone network to the individual streets and houses of the neighborhood being served. Distribution cables are typically buried directly in the ground, often in utility easements along property lines. They are typically much smaller than feeder cables, normally with a minimum size of 25 pairs.[84] To avoid customer inconvenience and the significant expense to the company of repeatedly digging up private property to accommodate growth, GTE often installs distribution facilities that are estimated to be sufficient to serve the demand for telecommunications services ultimately expected in that area. That is, the optimal solution to the "stair step" problem for distribution is often to place capacity only once. While this minimizes placement costs, it also means that the fill actually achieved in a minimum-cost distribution design may be quite low.

As the *Staff Analysis* (at ¶ 42) correctly notes, distribution cable is often provided on the assumption that some housing units will require more than one telephone line. In fact, GTE's engineering guidelines for distribution cables recommend that new

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[83] In the models this is also the location of DLCs.

[84] Distribution cable sizes generally used by GTE range in the following numbers of pairs: 25, 50, 100, 200, 300, 400, 600. Larger cable sizes, *e.g.*, 900, 1200, 1500, 1800, may be used in small amounts until the first distribution branch point.

distribution facilities normally be designed for a minimum of 1.25 pairs per housing unit, with 2 pairs per unit often placed in urban and high-income communities. Given the recent growth in the number of "teen lines," home offices, computer usage, facsimile machines and home alarm systems, the often used design guideline of two lines per household may be a conservative estimate.

b. Factors that affect fill rates.

1. Population density and growth.

Population density has a direct effect on fill factors. GTE's serving area is typically less dense than the RBOCs.' Therefore, GTE must place cables that are typically smaller in size, and thus more costly on an average, per-customer basis. For the same reason, GTE is more often affected by the indivisibility of the minimum size cable. The existing models generally associate higher fill factors with higher density zones, to reflect the fact that indivisibility will impose fewer cost in areas where the level of demand is greater.

A majority of GTE's network is designed to serve residential customers.[85] In order for the models to specify fill factors for business markets and residence markets separately,[86] fill factors would have to be variable by wire center or CBG, not merely by density zone, as is now the case in both models. It is not clear that there would be a

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[85] Of the approximately 20 million GTE access lines, about 13 million are residential and 7 million are business.

[86] *Staff Analysis* at ¶ 42.

reliable basis in the available data to develop different fill assumptions for business and residence.

For reasons described *supra*, growth is an important factor in choosing utilization. When growth is high, the increment of capacity placed must be larger, and hence the achieved fill over time will be lower. Alternatively, placements must be done at frequent intervals.

2. Network reliability standards.

Network reliability is generally measured by the amount of maintenance required, the number of held orders, scheduled and unscheduled downtime, and the number of customer complaints per 100 lines. There is an inverse relationship between the level of network reliability and the size of the fill factor for the network. That is, the higher the fill factor, the lower the expected network reliability. A network that has a relatively low fill factor is more reliable (holding other factors constant) because it has more capacity to handle maintenance and other administrative needs.[87] For similar reasons, high level of utilization will lead to high maintenance costs, and to greater expenditures for network rearrangements.

3. Uncertainty.

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[87] The Hatfield 2.2.2 model is further flawed because it fails to consider the need for network reliability. If fill rates are set on the basis of Hatfield, then one of two outcomes will occur. Either GTE will be forced to increase its fill factors, thereby reducing network reliability, or reliability will be maintained with the result that the users of unbundled network elements will receive a level of service that they are not paying for, placing GTE at a competitive disadvantage.

Variability in expected demand growth will oblige the firm to place more capacity, and hence to operate with lower fills, in order to meet any desired standard of service quality. On the other hand, uncertainty regarding future input prices or technology could create an incentive to defer investment, which might lead to higher utilization in the near term.

4. Competition.

The Hatfield 2.2.2 model claims to take account of anticipated competitive interactions among firms, asserting that competition will force LECs to become more efficient and causing fill factors to be higher than they traditionally have been. That is not a correct assumption. While competition will indeed compel all firms to become more efficient, it does not follow that fill factors will go up. In fact, competition will more likely lead to lower fill factors than have historically prevailed for ILECs. As the interexchange industry so amply demonstrates, when significant facilities-based entry occurs, spare capacity increases.[88] This is true *a fortiori* if the firm being modeled is an efficient entrant, because it must place equipment of some minimum size but will start with zero demand. Thus, it will certainly expect to have low utilization levels for some period of time.

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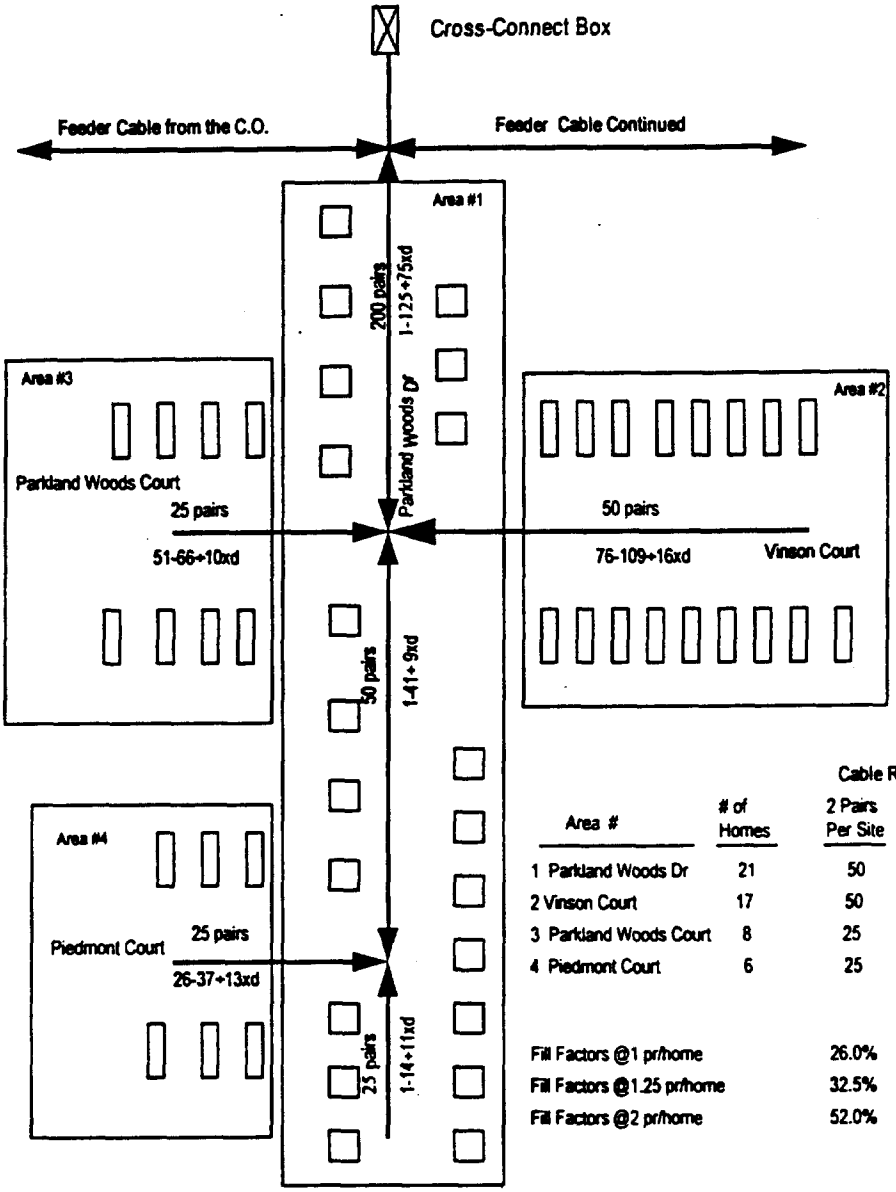
[88] Firms in competitive markets are likely to have low fill factors because they have either lost customers or have constructed sufficient capacity to allow them to capture a large number of new customers. For example, the Commission found that "MCI and Sprint alone can absorb overnight as much as fifteen percent of AT&T's total 1993 switched demand at no incremental capacity cost; that within 90 days MCI, Sprint, and LDDS/WilTel, using their existing equipment, could absorb almost one-third of AT&T's total switched capacity...." Motion of AT&T Corp. to be Reclassified as a Non-Dominant Carrier, 11 FCC Rcd 3271, 3303 (1995).

c. Calculation of fill factors.

Figure 4 illustrates how distribution cables are used to provide telephone service to a new development and how distribution fill factors are calculated. The impact of the need to build distribution plant to meet the expected ultimate demand on distribution fill factors is depicted in this example.

Figure 4

Calculation of Distribution Fill



Area #	# of Homes	Cable Required at 2 Pairs Per Site	Cable Required at 1.25 Pairs Per Site
1 Parkland Woods Dr	21	50	50
2 Vinson Court	17	50	25
3 Parkland Woods Court	8	25	25
4 Piedmont Court	6	25	25
Fill Factors @1 pr/home		26.0%	26.0%
Fill Factors @1.25 pr/home		32.5%	32.5%
Fill Factors @2 pr/home		52.0%	N/A

Figure 4 illustrates a 52-lot subdivision with four streets. From the feeder plant, a 200 pair distribution cable is laid along Parkland Woods Drive to the first cross street (Vinson Court). At that point, a 50 pair cable is placed to serve the 17 homes in Area 2 (Vinson Court), and a 25 pair cable is placed to serve the 8 homes in Area 3 (Parkland

Woods Court).[89] Below the first cross street, a 50 pair distribution cable extends to the next street (Piedmont Court). At that point, a 25 pair cable is used to serve the needs of the 6 homes in Area 4, and another 25 pair cable is used for the 6 homes along Parkland Woods Drive below Piedmont Court.

The drawing in this example assumes that GTE's typical design criterion of two pairs per site will be provisioned, subject to minimum cable sizes of 25, 50, 100, and 200 pairs. If each home actually demands two telephone lines, the fill factor across the 200 pair main distribution cable will be 52%.[90] However, if only one telephone line per home is actually used, and two pairs per site are provisioned, the fill factor across the 200 pair main distribution cable will equal 26% when the development is fully occupied. If the development were provisioned at 1.25 pairs per site rather than 2 pairs per site, the ultimate fill factor would be higher (*i.e.*, 52%) because a 100 pair cable could be used rather than a 200 pair. Obviously, in any development at any point in time, some homes may be vacant while others may have several lines, and actual fill rates at any point in time will vary substantially.

Note also that the ultimate fill factors shown will be only realized after the development is fully occupied. Distribution cable is placed as soon as the streets are completed, so that actual fill factors will range from zero to the levels that will ultimately

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[89] As noted *supra*, at n.84, GTE only installs distribution cable in standard cable sizes. In this case, the 25 pair and 50 pair cables are the smallest sizes available to provide the designed number of pairs per lot.

[90] Hatfield 2.2.2 uses this ratio of working lines to installed line capacity. Hatfield Associates 2.2.2 model, at 20, n.24 (September 4, 1996). This definition is substantially unchanged in Hatfield 3's Appendix B, at 3-4 (February 7, 1997).

be realized, at the end of the planning horizon. In some new developments, the maximum expected demand may be approached in only a few years, if the development is successful. More generally however, growth in total demand will continue throughout the planning period, as more developments, individual homes, and businesses are established. This is a particularly important factor for GTE because the company experiences a high rate of access-line growth -- last year, GTE gained approximately 1.5 million access lines -- and because a great proportion of the company's lines are represented by residential subscribers.[91]

The example shown in Figure 4 results in distribution fill factors in the range of 25% to 50%, depending on which distribution cable is examined. GTE's fill factors will necessarily fall in this range for the reasons illustrated by this example. First, cable is sized in discrete increments. Thus, GTE often has no option but to purchase cable that is larger than the needs required in a given situation. Second, GTE requires spare capacity to allow in order to quickly restore service when pairs suddenly become defective. However, even if no provision were made for administrative spare and for future growth, the fill factor would still be substantially less than 100 percent, simply because of the indivisibility of the cables.

d. Fill can be expressed in different ways.

The concept of capacity utilization can be expressed by different calculations of network fill, which are not directly comparable to one another.

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[91] *See* n.85 *supra*.

First, the design fill is the trigger point at which an additional increment of capacity is added, as shown in Figure 2. On a feeder route or for some distribution plant, it would take the form of a target percentage, such as 80%. This level is never actually realized over time, because as soon as it is approached, a new increment is added, and the actual level of utilization declines again. It is thus not reasonable to attempt to set fill factors in a proxy cost model equal to the design fill. On distribution plant, where the goal is to place capacity at the outset to meet all needs, the equivalent design objective is the amount placed at that time. In Figure 4, for example, this is 2 pairs per home.

Second, the actual fill achieved in the network will vary over time, as demand progresses along the "stair step." The average value will fall somewhere in the middle of the interval between the fill achieved just after the increment is installed and the design fill.

Third, even in a static model that does not represent the "stair step" pattern, the design fill is not achieved because cable comes in fixed sizes. This is illustrated by the fills calculated in Figure 4, that assume that the entire demand allowed for in the planning period is realized at once, just as the proxy cost models do. Because of the indivisibility of the cables, the fill realized, even on this static basis, is generally much less than 50%. To determine the number of pairs required, the models generally take the number of households to be served and divide by the fill factor supplied as an input

to the model. They then "round up" to the next cable size.[92] Because of this rounding effect, the fill realized in the model's output (which GTE will refer to as "static fill") will always be less than the input fill factor.

Note, however, that this does not correspond to the solution to the "stair step" dynamic optimization over time, nor does it consider all of the factors that go into that optimization, such as growth. Further, there is no reason why the increment of capacity that would be the solution to the "stair step" problem would be simply the difference between the number of pairs calculated in a static model and the next cable size. Thus, while it is true that the realized fill differs from the input value, it does not follow from this that the model output represents what a real, efficient firm would achieve as a result of its cost minimization.

e. The static fill result is determined largely by the model's own structure, not by any data.

Since the cost models are not dynamic, the only reason why the static fill would ever differ from the fill factor input to the model is the indivisibility of the cable. For this reason, the "static fill" in the output of the model depends primarily on how the model represents the tree and branch structure of the network. In a neighborhood such as the one illustrated in Figure 4, the number of miles of streets determines the length of cable that will be required. The number of small streets, and the distribution of homes along

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[92] In some cases a combination of cables may be selected. For example, if more than 1200 pairs are needed but less than 1300, a 1200 and 100 pair cable may be selected rather than the next available single cable size, a 1500 pair.

them, determines the number of houses that each cable can serve, and hence the fill that can be achieved on each cable.

Unfortunately, none of the models have any factual basis for developing this aspect of the model's structure. The models have data on the number of customers at the CBG level, while the details shown in Figure 4 are well below that level.[93] Therefore the output of the model, in terms of the total length of cable required, its capacity, and how that capacity is utilized, is largely determined by the structure each model builder has chosen to build into the distribution algorithm.

One source of the Hatfield model's consistent tendency to underestimate the amount of loop plant is the fact that its internal structure does not represent the actual way customers are likely to be distributed within a CBG. As Figure 4 illustrates, customers are generally located in such a way that only a limited number of customers can be served by a given cable. The distribution plant algorithm of the earlier BCM1 model, that was largely adopted by Hatfield, placed a limited number of distribution cables in each CBG.[94] By doing so, it implicitly assumed that customers in each CBG

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[93] Note that information on roads is used in the BCPM only to make an adjustment to the area assumed for a CBG. There are no data on the length of streets and roads along which distribution plant must be run, nor is there any other information below the CBG level about the disposition of customers within the square CBG area.

[94] The BCM2 uses a highway bounding approach to limit the area that must be modeled within large CBGs. This is a reasonable start on addressing the problem of the uniform distribution assumption. However, it does not eliminate inaccuracies caused by the assumption that the area is square, since the actual figure described by the road buffer might be quite irregular, and the length of cable required to serve it correspondingly greater than would be necessary to serve a square of the same area.