HATFIELD MODEL VERSION 2.2, RELEASE 2
REFINEMENTS TO THE HATFIELD MODEL SINCE MAY 30, 1996

This document describe the refinements made to the Hatfield Model Version 2.2 Release 1 (as released publicly May 30, 1996) that are now incorporated into Version 2.2 Release 2. For convenience, the Hatfield Model Version 2.2 Release 1 will be referred to as HM 2.2.1, and the Hatfield Model Version 2.2 Release 2 will be referred to as HM 2.2.2.

While there have been significant improvements to the modeling logic and descriptive outputs of the HM 2.2.2 over the HM 2.2.1, there are also significant improvements from a user perspective. HM 2.2.1 used certain of the inputs and outputs of the December 1995 Benchmark Cost Model (BCM1) in its calculations. Because of infirmities in the BCM1 that limited the BCM1's speed, flexibility and effectiveness, HM 2.2.2 has chosen to incorporate a derivative work called the BCM Plus -- which has been developed for and copyrighted by MCI Telecommunications Corporation.I

The following describes the improvements to the modeling logic and descriptive outputs of the HM 2.2.2 over the HM 2.2.1.

BCM Plus Modules

Data module

- Input and output sheets include an additional column containing business line counts per census block group (CBG).

- In the presence of rocky terrain, feeder and distribution distances are increased by 20% to accommodate the routing of facilities around difficult placement conditions.

- Feeder length calculations are modified to place the Serving Area Interface (SAI) inside the CBG by a distance equal to one-fourth the length of a side of the CBG.

Loop module

- The distance at which fiber feeder is assumed is now user-adjustable. In the original BCM, the model assumed fiber feeder cables whenever total loop lengths were 12,000 ft or greater. In the HM 2.2.2, the calculation is based on total feeder length, and the threshold distance may be adjusted by the user to any value. The default setting is 9,000 ft.

Wire Center Investment Module

- The module removes a previous double-counting of the cost of trunk ports by reducing the previously assumed per-line switching investment (which had already incorporated these costs) by $16 per line.

- STP size is now scaled by the number of A links required in the LATA/study area; the model previously equipped maximum-capacity Signal Tranfer Points (STPs) in all cases.

- The module now computes the costs associated with SS7 C and D link investments in addition to A link investments -- whereas previously it calculated only SS7 A link investments.

- Transmission facilities investment per DS-0-mile, is now calculated separately and explicitly for each of the following types of interoffice transport routes:
  - Common (tandem)
  - Local direct
  - IntraLATA toll direct
  - IXC switched access direct
  - Special access

- Calculations now allow separate user assumptions related to optical patch panels, optical multiplexers, regenerator investment and spacing, installation costs, mix of buried/underground/aerial plant, manhole and pole spacing, and installation.

- The module now eliminates double counting of structure costs that typically are shared between interoffice transport and loop feeder facilities.

- The model now reconciles annual usage calculations in the Expense Module with busy hour usage calculation in the Wire Center Investment Module.

- Operator services positions may now be located remotely from the operator tandem. The user may select the distance, with zero as the default value.

- The module now includes tandem-to-POP switched access direct transport facilities.

- End office switches are now also limited by number of traffic minutes switched. Previously, switches were assumed only to be limited by number of line and processor real-time limits. There are separate holding time multipliers for business and residence lines to allow users to compute the effects of increased holding time on costs.

- End office trunk port costs are now estimated on a per DS-0 or per minute basis.

- Default user inputs for cost of debt, equity, and debt/equity ratio have been changed.

- There are now separate uncollectibles rates for retail services and carrier-to-carrier services.

- The module eliminates a triple counting of NID investment.

- Drops are now computed per household rather than per line.

- Dedicated trunking calculations have been reconciled between the Expense Module and the Wire Center Investment Module.

- IXC switched access and local interconnection unit costs have now been developed and added to a new "cost detail" worksheet.

- NID expenses are now based on ARMIS-reported regulated expense per line (from the ARMIS "Other Terminal Equipment" account). Previously these expenses were calculated based on both regulated and unregulated expenses in the "Other Terminal Equipment" account, thus overstating greatly NID maintenance expenses.

- A carrier-to-carrier customer service expense has been added. This expense is user definable, with the default value set at $1.56/line/year -- which is inferred from ARMIS 43-04 data concerning the LECs' costs of serving their interexchange carrier customers' access needs.

- The new version includes a NID monthly cost calculation in the "cost detail" worksheet.

- Structure sharing fractions have been expanded to allow the user to set independently parameters for the sharing of aerial, buried, and underground distribution and feeder structure. The default value is 0.33 for each category.

- The module now contains a Universal Service Module with the following features:
  - Network cost built up from unbundled network elements (UNEs)
  - Network Operations expenses factored to reflect local service costs only

Local number portability costs have been added as a user input. The default setting is $0.25 per line per month.

Appendix B

Instruction Manual

Hatfield Model Version 2.2, Release 2

Automated Interface

I. GETTING STARTED

SYSTEM REQUIREMENTS

The Hatfield Model (HM) Automated Interface requires the following minimum PC system components to run properly:

- Pentium 133 MHz processor or higher
- 128 MB RAM or more
- CD-ROM drive
- Microsoft Windows 95 or Windows NT operating system
- Microsoft Excel version 7.0

TERMINOLOGY

The following terminology is used in this documentation when referring to the Hatfield Model and its components:

HM Modules: The HM Modules are the six functional Excel files which comprise the HM. They are Line Converter, Data Master, Loop Master, Wire Center, Convergence, and Expense.

HM Interface: The user interface to the Hatfield model, which is contained in the Excel file HM_Interface.xls. (Figure 1 shows what the HM Interface looks like.)

Workfile: A workfile is an Excel file created by the HM which contains state-specific HM data and outputs, and can reflect user-specified input parameters. Although the workfile is created by the HM, the user must provide a filename.

Data Template: The data template is a special workfile which contains the default inputs for each state. Data templates use a filename convention which looks like: AZ_rboc__tmplt.xls. Data templates should not be modified by HM users.

DIRECTORY STRUCTURE

The HM Interface assumes a basic directory structure as follows:

- HM modules should be stored in C:\hatfield modules
- HM data templates should be stored in C:\hatfield templates

The HM Interface allows users to specify which directories the HM components reside in by selecting 'HM Tools/Set Up Paths and Directories', but it is recommended that the default settings be used.

CD-ROM users should ensure that the paths and filenames point to the appropriate CD-ROM drive (e.g., D:\).

II. RUNNING THE HATFIELD MODEL

CREATING A NEW WORKFILE

- Select 'HM Tools/New HM Workfile...'
- Select the appropriate state from the dialog box.
- Select 'HM Tools/Save HM Workfile...' to give the workfile a unique name.
- Press 'GO!'
- Save Expense Module when HM is done calculating
- Select 'HM Tools/Close HM Workfile...' when finished

MODIFYING AN EXISTING WORKFILE

Once a workfile has been created, it can be modified to reflect different input parameters. To modify an existing workfile:

- Select 'HM Tools/Open HM Workfile...'
- Modify inputs as necessary, using process described below
- Press 'GO!'
- Save Expense Module when HM is done calculating
- Select 'HM Tools/Close HM Workfile...' when finished

CHANGING USER INPUTS

The HM contains several hundred user-adjustable parameters, each of which can be easily modified using the'HM Interface. To change a user input, open the appropriate workfile, and select the desired category of inputs from the 'HM Inputs' menu. A dialog box will appear, in which alternative inputs may be specified. (See Figure 2.) If the workfile is saved, the alternative inputs will be saved with it. However, default inputs can always be restored by clicking the 'Reset Defaults' button on the input dialog box.

TROUBLESHOOTING

- If the HM Interface displays 'Cannot find file...' errors, ensure that the paths and filenames are correctly specified in the 'HM Tools/Set Paths and Filenames...' menu.
- In the unlikely event that the HM crashes, it is always best to restart.

Figure 1: HM Interface

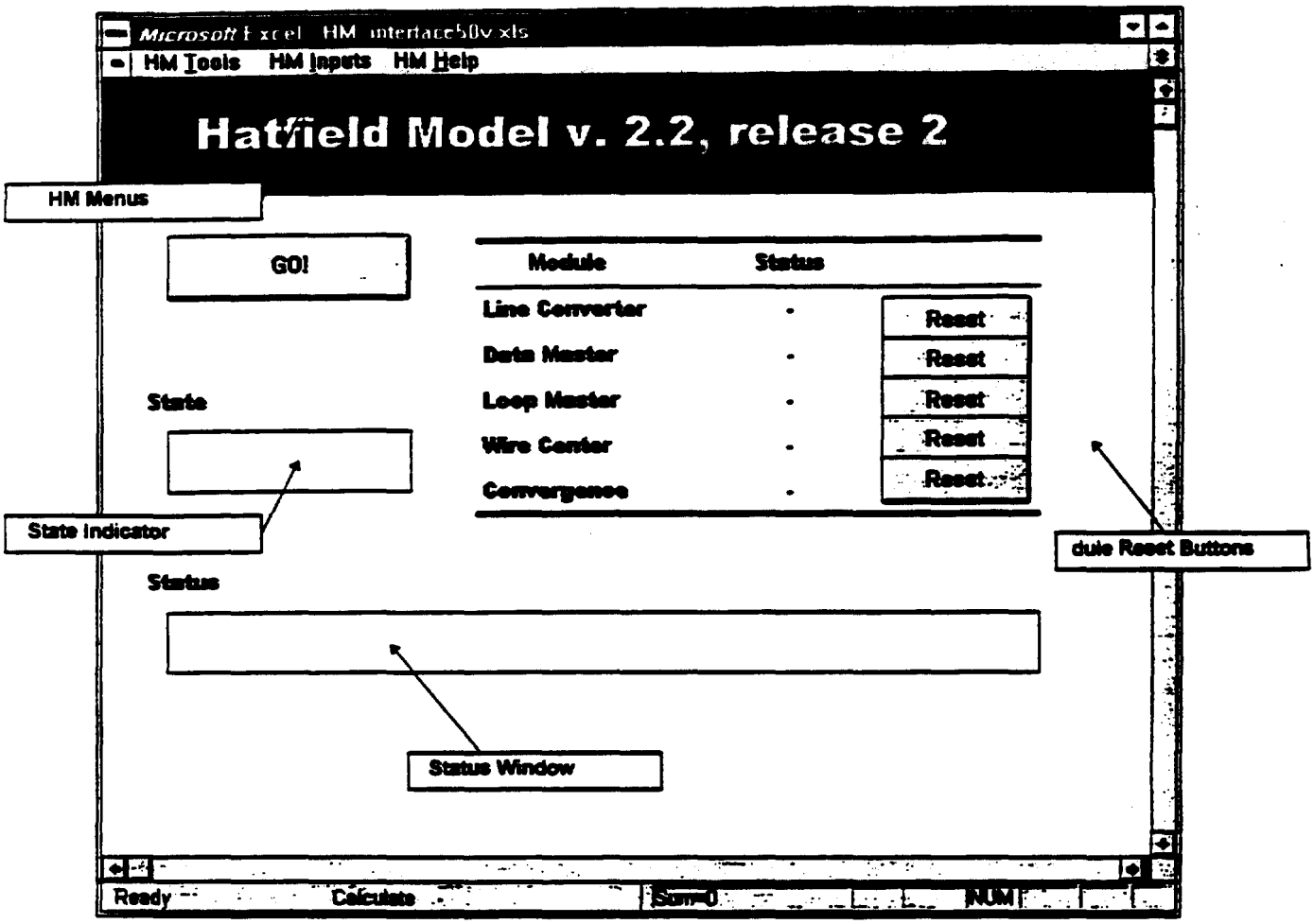
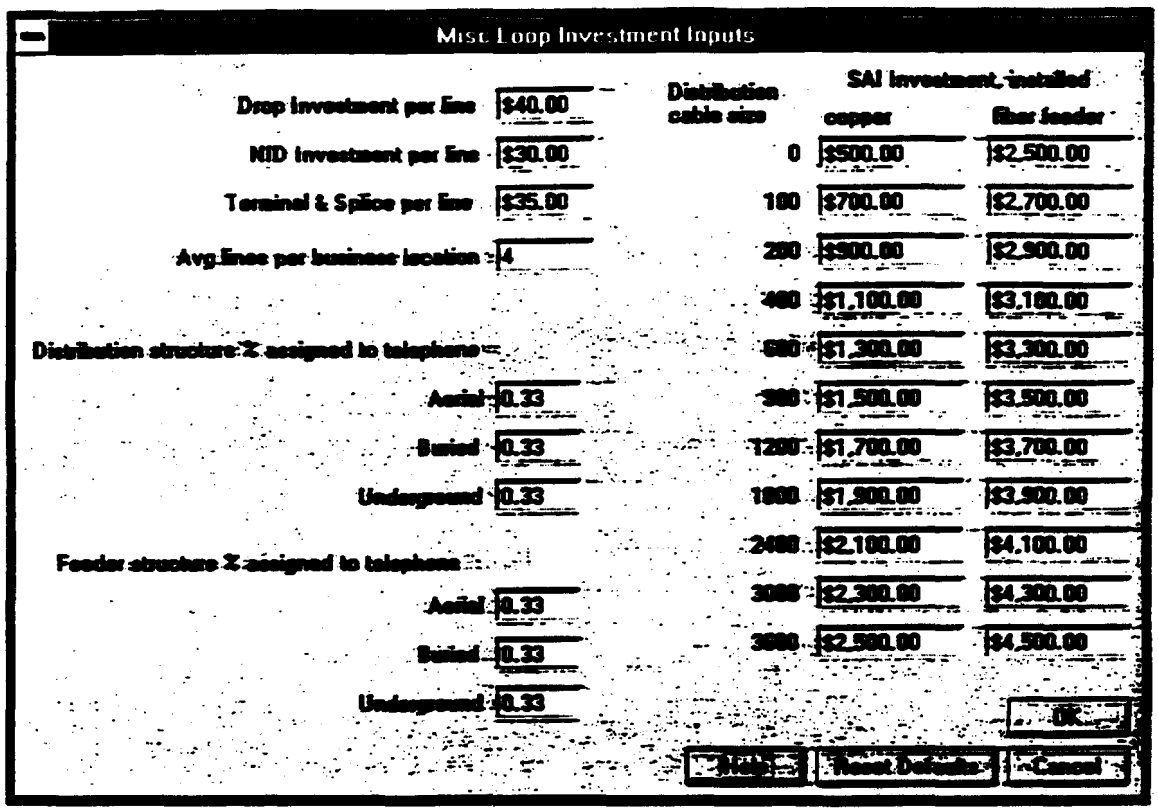


Figure 2: Sample User Input Dialog Box



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ECONOMIC EVALUATION OF VERSION 2.2 OF THE HATFIELD MODEL

by

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September 13, 1996

EXECUTIVE SUMMARY

Version 2.2 of the Hatfield Model is fundamentally flawed, and therefore does not provide reasonable estimates of the costs of incumbent local exchange carrier (ILEC) network elements. Particular shortcomings of the model fall into two major areas. First, the model has never been directly empirically validated. By this we mean that the predictions of the model have never been compared to actual observable data to see how well the model predictions comport with reality. Second, the model fails direct internal consistency checks of its validity, indirect comparisons of its validity by comparison of its results to cost models that do depend on real data, and is based on a set of restrictive assumptions whose lack of realism would try the confidence of even the most partisan proponent. Particular shortcomings of the model include the following.

- The model is based on static notions of cost rather than the dynamic notions that are relevant to regulations that seek to emulate the workings of dynamic competitive markets.
- There is no attempt at empirical validation of the model or its predictions.
- Its predictions fail explicit internal consistency requirements that are a necessary feature of structures capable of representing the minimum cost of producing telecommunications services using the most efficient forward-looking technology[1].
- Its predictions do not agree with other industry models that are based on firm specific data.
- The assumption that all volumes currently served by local exchange carriers will be served by a brand new entrant that instantly materializes is inconsistent with both reality and sound economics. Accordingly, costs based on such a model will *not* be

[1] By the most efficient forward looking technology, we mean the least cost technology taking the installed network as a base and building from that using the least cost technology available for producing the services required. Ignored in most "greenfield" or "scorched node" arguments is that to actually use them one would have to tear up useful plant. None of these methods take into account either the direct or indirect costs of such a strategy.

representative of the costs incumbent LECs incur providing services and unbundled networks components.

- The inputs (e.g., central office equipment prices) are consistently lower than what local exchange companies actually pay.

This report evaluates a number of additional, specific shortcomings of the model, including (1) the use of Census Block Groups to represent distribution plant, (2) the misuse of utilization (fill) factors, (3) the understatement of local switching costs, and (4) the understatement of the cost-of-capital and the rates of depreciation that will prevail under competitive conditions when network elements are offered on an unbundled basis. The cumulative impact of these various effects is that the Hatfield model understates the cost of loop plant and local switching by about one-third. Stated on a per line basis, the Hatfield model understates loop and local switching costs by about $9.00 per month.

Of course, the ultimate concern is how network elements are unbundled in a way that promotes competition. Basing prices on costs that no real-world provider could hope to meet is *anti-competitive*, because it would stifle, not promote, the most effective type of competition—facilities-based. In addition, requiring incumbent LECs to sell inputs at non-compensatory rates would have the deleterious effects of forcing whatever customers that may remain with the LEC to subsidize the below-cost input prices and/or severely handicapping firms that represent a substantial proportion of this dynamic industry.

I. INTRODUCTION

In its May 16, 1996 comments and May 30, 1996 reply comments in the Federal Communications Commission's (FCC) Local Competition Investigation, AT&T introduced Version 2.2 of the Hatfield model.[2] On June 14, 1996, AT&T and MCI filed the same model in the unbundling proceeding in California.[3] The purpose of this paper is to demonstrate that the Hatfield model does *not* provide reasonable estimates of the costs of local exchange company (LEC) network elements, either for LECs in general or any particular LEC, because the model (1) departs from fundamental economics in a number of significant ways, (2) contains a number of inaccuracies in execution that depart from reality, (3) produces results that are inconsistent with what can actually be observed, and (4) implies a fantasy version of both regulation and functioning markets.[4]

Particular shortcomings of the model include the following:

- The model is based on static notions of cost rather than the dynamic notions that are relevant to regulations that seek to emulate the workings of dynamic competitive markets.
- There is no attempt at empirical validation of the model or its predictions.
- Its predictions fail explicit internal consistency requirements that are a necessary feature of structures capable of representing the minimum cost of producing telecommunications services using the most efficient forward-looking technology.

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[2] The Hatfield model is somewhat of a moving target. For example, MCI introduced a different ("greenfield") version of the model in its May 16 comments (Hatfield Associates, Inc., "The Cost of Basic Network Elements: Theory, Modeling, and Policy Implications"). Versions of the model have received extensive attention in ongoing universal service and unbundling proceedings in California.

[3] We understand that the model has been filed in a number of other states as well.

[4] Given the recent release of the Hatfield model and the constant changes made by the proponents, our evaluation is preliminary in nature, and will undoubtedly uncover more errors. As we understand it, working versions of Version 2.2 Release 1 only became available in late June. We received a working version of Version 2.2 Release 2 on August 26. The model is extremely complex and has limited and incomplete documentation.. As a consequence, a thorough evaluation is necessarily time-consuming and so it was not possible within the time period available for our evaluation. One must also ask how many more releases are in the offing.

- Its predictions do not agree with other industry models that are based on firm specific data.

- The assumption that all volumes currently served by local exchange carriers will be served by a brand new entrant that instantly materializes is inconsistent with both reality and sound economics. Accordingly, costs based on such a model will *not* be representative of the costs incumbent LECs incur providing services and unbundled networks components.

- The inputs (e.g., central office equipment prices) are consistently lower than what local exchange companies actually pay.

II. EXTERNAL VALIDITY

We begin with the most vexing of the many problems accompanying the Hatfield Model. That is its lack of independent or external verification. Whether estimating costs using a pure econometric approach, a pure engineering approach or some hybrid approach, common practice requires validating a model by comparison to real world phenomena.

Ideally, a model such as the Hatfield Model would be calibrated or estimated using cost data from a source similar to those desired to be predicted. For example, the typical cost model would attempt to minimize differences in its predictions and real world data. If TS/TELRICs were readily available and observable for a number of firms over a period of time, then the model would be calibrated using all of the data from a subset of the firms, presumably a group of firms representative of the group whose TS/TELRICs we wish to predict. The model developed during this phase would then be subjected to a validation test, that being a comparison of the predictions of the model for firms left out of the calibration subset to the actual TS/TELRICs of those firms. For example if there were data on five or six firms one might hold out the data for two of them and calibrate the cost model on the basis of the other four. Then the model would be used to predict the TS/TELRICs for the two firms held out. The validity of the model would be judged by comparing the predictions of the model with the data that obtained in the real world for the firms in the validation data set using a variety of well known and widely accepted criteria.

This ideal procedure is not always followed, of course. Data are precious and expensive; so often other types of validation are used where the whole data set can be employed in the calibration or estimation phase. Again the methods are well known and need not concern us here because the Hatfield model is not based on sampling data nor has it ever been validated to our knowledge. Consequently, its validity or lack thereof must be judged on other grounds. These include the realism of the model's assumptions, comparison of the results to those produced by other models, and the extent to which the model satisfies internal validity checks. The model will be shown to fail miserably in these other criteria, leaving absolutely no basis supporting the model.

One particular feature of the structure of the Hatfield model needs special verification, that is its assumption that the cost function is additive in element cost components[5]. This assumption is particularly troublesome because it assumes away the existence of joint and common costs without testing to see whether or not there really are. Ordinarily, such features of a model are subjected to statistical testing to validate the structure. Indeed, Baumol, Willig and Ordover base their claim that pricing at TELRIC is economically valid on a mistaken belief that the Hatfield Model proves that the costs are indeed separable, whereas it merely assumes that fact as part of its construction so necessarily reproduces such a result when run. The fact of the matter is that this crucial aspect of the Hatfield Model has never been tested at all, neither have any other features of the model.

Another reason for needing formal external validation is the fact that the model is written in EXCEL which is a language ill suited for modeling. While easy to use, it is difficult to debug in the best of circumstances. Particularly disturbing here is there are thousands of lines of undocumented code. Moreover, the auditing feature that allows some minimal tracing of the code are turned off by the Hatfield authors and password protected preventing the feature

[5] If a cost function $C(y_1,...,y_n)$ can be written as $C(y_1,...,y_n)=C_1(y_1)+...+C_n(y_n)$ it is said to be additive. This is the only structure consistent with TELRIC pricing. This is because there are no joint or common costs. The TSLRICs are simply the components, e.g. $TSLRIC_1= C_1(y_1)$.

to be turned back on. Consequently, the only way to figure out if all the formulas are correct is to see if the model correctly comports with reality.

The rest of the paper is divided into two parts. The first part concentrates on the realism of the assumptions and comparison of Hatfield Model outputs to those of other cost models. The second part demonstrates that the Hatfield Model is theoretically incapable of representing the minimum cost of producing telecommunications services using the most efficient forward looking technology.

III. ECONOMIC THEORY

The Hatfield model documentation characterizes the model as "scorched node"—it starts with the existing locations of central offices, then builds a brand new system instantaneously from the ground up. While proponents of this approach claim that it approximates the textbook definition of long-run cost, it is grossly at odds with how real businesses incur costs, especially capital-intensive firms that expand their facilities by adding capacity in discrete modules.[6] Almost five years ago, Professor Alfred Kahn advised the FCC of the need to employ a realistic and practical perspective.

> In strict economic terms, the concept of long-run marginal costs relates to a hypothetical situation in which all inputs are variable, and a supplier confronts the possibility of installing entirely new facilities, in effect from the ground up. And the "marginal" relates to the incremental cost of a single unit of output. The concept of long-run incremental cost, in contrast, is more pragmatic: it takes a firm's past history as given, does not assume that it is writing on a blank slate, but recognizes that it will ordinarily be planning the installation of new capacity, at whatever that additional investment will cost given its current situation, and it spreads the costs over either the total output of that additional capacity—in that sense it is a kind of average incremental cost—or over the

[6] Even the theoretical definition must be conditioned by reality. For example, Professor Varian has noted: "Long run and short run are of course relative concepts. Which factors are considered variable and which are considered fixed depends on the particular problem being analyzed. You must consider over what time period you wish to analyze the firm's behavior and then ask what factors can the firm adjust during that time period." Hal R. Varian, *Microeconomic Analysis, Third Edition*, New York: Norton, 1992, p. 66.

> additional output that is likely to be induced by a price reduction under consideration (or curtailed in response to a price increase.)[7]

An additional difficulty with the Hatfield scorched view of the world is that it ignores the fact that in an industry with technological change, which clearly characterizes telecommunications, no company would set prices based upon such costs. The reason is that when technology advances, a new entrant taking advantage of latest technologies would drive prices down. Basing prices on the Hatfield view of the world would never recover costs. Professor Kahn and Dr. Tardiff recently noted this phenomenon as follows:

> In a world of continuous technological progress, it would be irrational for firms constantly to update their facilities in order completely to incorporate today's lowest-cost technology, as though starting from scratch: investments made today, totally embodying today's most modern technology, would instantaneously be outdated tomorrow and, in consequence, never earn a return sufficient to justify the investments in the first place. For this reason, as Professor William J. Fellner pointed out many years ago, firms even in competitive industries would systematically practice what he calls "anticipatory retardation," adopting the most modern technology only when the progressively declining real costs had fallen sufficiently below currently prevailing prices as to offer them a reasonable expectation of earning a return on those investments over their entire economic life. In consequence even perfectly competitive prices would not be set at the level of these (totally) current costs—unless, to put it another way, the calculated costs of the new plant included an extremely high rate of return and of depreciation, in reflection of the exposure of any such investments to costs and prices progressively declining in real terms over their life.[8]

The Hatfield model's scorched approach to cost modeling essentially assumes that a LEC's loses one hundred percent of its demand for telephone services on day one. In effect, the succession of incumbent LECs would hand over their entire business to the newcomer, which

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[7] Affidavit of Alfred E. Kahn, Before the Federal Communications Commission, In the Matter of Expanded Interconnection with Local Telephone Company Facilities, CC Docket No. 91-141, August 6, 1991.

[8] Declaration of Alfred E. Kahn and Timothy J. Tardiff, Before the Federal Communications Commission, In the Matter of Implementation of the Local Competition Provisions in the Telecommunications Act of 1996, CC Docket No. 96-98, May 30, 1996. (footnote omitted). Professor Jerry Hausman's reply affidavit, filed in this docket on the same day, makes a similar point in the context of depreciation. Professor Hausman's findings will be discussed later when depreciation issues are addressed.

in turn would instantly size its plant to perfectly accommodate this demand, taking advantage of all the economies that come with serving the demand with perfectly sized facilities obtained at the maximum volume discounts. It would be nice if the world worked this way, because we would all like to pay less for what we consume. Unfortunately, it does not. A real firm grows to meet demand as it materializes. As such, it adds capacity taking into account the trade-off between the lower per unit costs of bigger modules (e.g., larger cable sizes) and the costs of carrying the unused capacity that deploying larger modules would entail.

In short, the Hatfield model creates a contradictory world in which both full competition and the scale economies that would ordinarily dictate a monopoly structure coexist:

- Only a single firm can enjoy the economies of scale from deploying larger modules and the high capacity utilization from efficient inventory management.
- The firm is subject to the cost reducing effects of using the latest technology, while at the same time its equipment depreciates at regulatory-prescribed rates and its cost-of-capital is the same as for regulated utilities and it is guaranteed the full level of demand that a monopoly carrier would enjoy. Unfortunately, as discussed by Dr. Hausman, competitive markets are inconsistent low depreciation rates, guaranteed demand and guaranteed returns.

IV. SPECIFIC COMPONENTS OF HATFIELD MODEL

The Hatfield model reports results for several networks components: (1) loops, (2) local switching, (3) signaling, (4) transport, and (5) operator systems. Because the first two components constitute a substantial proportion of the total cost and have been subject to more extensive examination in the California proceedings than the other components, our review focuses on these components.

A. Loops

For the most part, the Hatfield model's development of loop costs relies on an incompletely documented revision to the Benchmark Cost Model (BCM Plus). The original model (BCM1) has been filed with the FCC by MCI, NYNEX, Sprint, and U.S. West. BCM1

identified geographic areas where costs of basic residential access service are relatively high or low cost. The sponsors describe their model as follows.

> The BCM does not define the actual cost of any telephone company, nor the embedded cost that a company might experience in providing telephone service today. Rather the BCM provides a benchmark measurement of the relative costs of serving customers residing in given areas, i.e., the CBGs [Census Block Groups].[9]

What is noteworthy about this description of purpose is that the costs that the BCM produces are not the actual costs of any particular company. Despite this acknowledgment by the BCM's sponsors, the proponents of the Hatfield model incorrectly propose to use parts of the BCM, albeit revised, to produce actual prices for the incumbent LEC's unbundled elements.

The BCM starts with the current locations of the LEC's central offices. The model constructs loop plant (feeder, distribution, and associated structures) from the central office locations to the households in the CBG by means of specific engineering rules, e.g., the lines served by a particular central office are the result of assigning CBGs to the closest wirecenters.

This assignment does not necessarily assign the households within the CBG to the wire center that actually serves them. For example, in California, Pacific Bell and GTE have found that the BCM assigns substantial percentages of households to the wrong wirecenter. As a result, the network represented by the BCM departs from the LEC's actual network. The Hatfield model's proponents may argue that the BCM has assigned households more efficiently than the LECs have. A more likely explanation is that the extremely abstract representation of the network—a featureless plain[10]—ignores real world constraints, such as physical barriers, e.g., rivers, lakes, and hills, between a CBG and its closest central office.

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[9] MCI Telecommunications Corporation, NYNEX Corporation, Sprint Corporation, and US West Inc., "Benchmark Cost Model," Submitted to the FCC, CC Docket No. 80-286, September 12, 1995, p. 3.

[10] The only distinguishing characteristics are a number of topological factors used to estimate the cost of installation and support structures.

Because the BCM assumes that loop facilities are installed instantaneously, the model selects the largest available cable sizes to serve a given static volume. In contrast, because real networks evolve as demand grows and changes, firms face a trade-off between deploying larger cable sizes (and enjoying the economies of scale that result at or near full capacity) versus using smaller sizes, thus reducing the carrying costs of the extra inventory that large cable sizes entail. In this regard, the BCM may underestimate loop cost, because it could assign larger/less costly facilities (on a per-unit basis) than an efficient firm would deploy. Such "savings" are illusory, not real. What has been left out of the BCM is the carrying charges on the unused capacity that the larger cable sizes would require for several years, until actual demand materializes.

A number of calculations built into the BCM can produce inaccurate estimates of efficient loop costs.

1. Installation and Structure Costs

For loop plant, both feeder and distribution, BCM1 calculates the investment costs of installation and structures by multiplying the cost of cable by factors that represent the installation labor cost and support structure investments. While properly developed factors can give reasonable representations of average installation and structure costs if current conditions are similar to those from which the factors were based, problems can arise when conditions change. In particular, changes in the cost of cable pass through directly into changes in the cost of installation and structures. In other words, the model would predict that two otherwise identical areas would have different installation and structure costs if they were served by companies that paid different amounts for their cable. Similarly, the model would predict that cost of installation and structures would decrease when a company is able to secure a better discount on the cost of the cable itself.

Hatfield's BCM Plus separately estimates the cost of structures, thus potentially overcoming the conceptual flaw in BCM1. Of course, the accuracy of the estimates depend heavily on the use of correct input prices for structures. We understand that for at least one

such structure—manhole structures—the default prices contained in the model are considerably lower than at least one LEC actually pays. This type of inaccuracy is of more than academic interest; installation and structures can account for upwards of 80 percent of loop costs. In fact, a reasonable sanity check on the structure cost inputs would be to ascertain whether the share of loop costs accounted for by structures reasonably approximates real world experience.

2. Modeling Distribution Facilities

The BCM constructs feeder plant from the central office to the edge of the CBG. All loop plant within a CBG is assumed to be distribution plant. The BCM assumes that CBGs are square in shape and that households are uniformly distributed over the area of the CBG, neither of which is true of real CBGs. The BCM also uses an abstract representation of the distribution plant within a CBG. CBGs in the same density class have the same number of distribution cables of length equal to 62.5 percent of the square-root of the area of the CBG.[11]

The abstract representation of distribution plant can produce results that differ from reality, i.e., loop lengths can be inaccurate, cable sizes can be incorrect, and the number of cables within a CBG can differ from the number of cables assigned by the BCM.

First, as the sponsors of the CBG acknowledge, in sparsely populated areas, the uniform distribution assumption can cause substantial errors in cost estimation.[12] The basic problem is that the average loop length depends on the distribution of households within an area. When the assumed distribution differs from the actual, an average based on the former will be inaccurate.

Second, although the BCM documentation describes CBGs as containing on average 400 households, there is, in fact, considerable variation in the number of households within a CBG. The consequence is that CBGs with a large number of households exceed the size of the distribution areas that at least one LEC, Pacific Bell, employs. In turn, the BCM allows larger

[11] The model assumes that CBGs are square. Therefore, the square root of the area is the side of the square.

[12] BCM, p. 38.

copper cable sizes than the LEC actually employs. In particular, Pacific's maximum feeder cable is 3,600 pairs (GTE's maximum size is 3,000 pairs), compared to the 4,200 maximum in the BCM. For distribution cable, the corresponding values are 1,800 and 3,600 for Pacific and the BCM, respectively. If support structure can accommodate larger cables, there are economies in larger cable sizes. Because Pacific has found that its support structures cannot accommodate the largest cables assumed by the BCM, the BCM's default assumptions would understate the true cost of Pacific's loop plant.

Third, the use of the same number of distribution cables in a density class can cause substantial bias.[13] In fact, GTE examined the impacts of doubling the number of distribution cables from four to eight, accounting for installation and structural costs the way they are actually incurred. The estimated increase in cost was 49 percent.

Finally, the representation of the interface between the distribution cable and the subscriber (the drop wire and subscriber terminal) is not described in the Hatfield model documentation. The cost assumed for drop wire may be inconsistent with drop wire lengths that are compatible with the number of distribution cables employed in the model. For example, under a particular geometric representation of the distribution cables and drop wire, four distribution cables (as used in BCM1) implies an average drop wire length would be about 25 percent of the distribution cable length. In contrast, GTE estimates that the cost employed in the Hatfield model implies a drop distance of only about 25 feet, which is considerably shorter than 25 percent of the average length of distribution cable. For example, for a low density CBG of one square mile, one-quarter of the BCM1's distribution cable length is 3/16 of a mile. GTE estimates that the drop wire investment for this length to be about $1,700 in California.[14]

[13] BCM1 used exactly four distribution cables per CBG. BCM Plus apparently varies the number of cables by density class, although no documentation on the actual numbers has been provided.

[14] Despite the likelihood that changing the number of distribution cables (as well as an apparent change in the average distribution cable length) would change the drop length, no change in the default values for drop wire have been made in the latest version of the Hatfield model.

This is equivalent to a monthly cost of $32, which is about 55 percent of the Hatfield model's loop cost in the lowest density group (0 - 5 households per square mile) in California.

The abstract nature of the BCM's distribution model has practical importance. In the network cost elements produced by Release 2, distribution plant accounted for 39 percent of the total cost of switched network elements in California. Percentages are similar in other states, e.g., distribution plant accounts for 42 percent of Hatfield's total cost for switched network elements in Texas.

3. Fill Factors[15]

Because telephone capacity is modular, i.e., it comes in sizes greater than a single unit, there is more capacity in place than volumes in service. Capacity exceeds volume even when the most efficient engineering practices are followed. The ratio of volume in service to capacity is the fill factor.

The spare capacity represented by a fill factor less than 1.0 is a *current* economic cost of providing service. In a previous evaluation of the BCM, Pacific Bell's cost experts in reviewed that model.[16] As part of that review of the BCM engineering rules, Pacific's experts compared the model's fill factors with the actual fill factors that would result from the best engineering practices. In general, the fill factors for feeder plant in the BCM were moderately higher than best practice and the fill factors for distribution plant in high density areas were substantially higher than best practice. Distribution fill factors are relatively low because of the high cost of adding capacity after the support structure has been built. Accordingly, capacity for an

[15] A theoretical discussion of these issues appears in Richard D. Emmerson, "Theoretical Foundation of Network Costs," in W. Pollard, editor, *Marginal Cost Techniques for Telephone Services*, National Regulatory Research Institute, 1991, pp. 145-189. See also Gregory M. Duncan, "The Effect of Probabilistic Demand Structures on The Structure of Cost Functions", *Journal of Risk and Uncertainty* (1990), 3, 3, 211-220.

[16] Timothy J. Tardiff, "Evaluation of the Benchmark Cost Model," prepared on behalf of Pacific Bell, for filing with the California Public Utilities Commission, Rulemaking/Investigation on the Commission's Own Motion into Universal Service and to Comply with Mandates of Assembly Bill 3643, R.95-01-020/I.95-01-021, December 1, 1995.

indefinitely long planning horizon is installed initially and utilization of that capacity is low as a result.

Unfortunately, Version 2.2 of the Hatfield model has increased the already somewhat high distribution fill factors in the original BCM, as shown in the table below. This would cause the underestimation of loop costs to be even greater.

	BCM		**Hatfield**	
Density Zone	Feeder	Distribution	Feeder	Distribution
1	0.65	0.25	0.65	0.50
2	0.75	0.35	0.75	0.55
3	0.80	0.45	0.80	0.60
4	0.80	0.55	0.80	0.65
5	0.80	0.65	0.80	0.70
6	0.80	0.75	0.80	0.75

The Hatfield model's use of unrealistically high fill factors causes costs to be understated because the fill factor, in part, determines how much cable is needed. The Hatfield model appears to be based on the belief that competitive firms would have minimal spare capacity. In this regard, the FCC's finding on spare capacity in interstate long-distance, which was one of the bases for granting AT&T non-dominant status, contradicts this apparent belief:

> AT&T asserts, and no one disputes, 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, LDDS/Wiltel, using their existing equipment, could absorb almost one-third of AT&T's total switched capacity; or that within twelve months, AT&T's largest competitors could absorb almost two thirds of total switched traffic for a combined investment of $660 million. Thus, AT&T's competitors possess the ability to accommodate a substantial number of new customers on their networks with

> little or no investment immediately, and relatively modest investment in the short term. We therefore conclude that AT&T's competitors have sufficient excess capacity available to constrain AT&T's pricing behavior.[17]

To cast the FCC findings in terms relevant to the current discussion, note that MCI and Sprint combined are roughly one-half of AT&T's size. Overnight they can absorb 15 percent of AT&T's capacity. This implies that MCI and Sprint have at least 30 percent spare capacity that could be deployed overnight.

The implication of these findings is that, if anything, competition may require more, rather than less spare capacity to be flexible enough to respond the to vicissitudes of the market. Failure to recover in current revenues the current cost of business caused by the spare capacity necessary to operate in the competitive environment would be detrimental to the shareholders of such companies, perhaps even forcing some of them out of business.

B. Switching

Version 2.2 of the Hatfield model systematically understates the cost of local switching. By selectively using heavily discounted prices for new switches and by assuming that a local service provider would instantly install all of the switching capacity it needs at once, the Hatfield model produces results that are substantially lower than the forward-looking local switching costs that real telephone providers actually incur.

Hatfield developed a relationship between switching cost per line and the size of the switch by piecing together information from various sources. In particular, the algorithm is driven by three data points constructed as follows.[18]

- Small switch: the cost per line ($241 for 1994) was taken from the Northern Business Information report on the average cost of *new* lines for independent companies. Hatfield associated the average *installed* switch size of 2,782 lines for small LECs (LEC

[17] Federal Communication Commission, In the Matter of Motion of AT&T Corp. to be Reclassified as a Non-Dominant Carrier, FCC 95-427, October 15, 1995, paragraph 59.

[18] The switching cost function is described in some detail in the documentation for Release 1. The prices for the three switch sizes appear to be lower in Release 2. No justification for the lower prices has been provided.