Hatfield Model 3.0 Analysis
Executive Summary

Overview

The purpose of this document is to provide an analysis of Hatfield Model 3.0 (HM 3.0), using Hatfield Model 2.2.2 (HM 2.2.2) as a frame of reference, that enables policymakers to assess the degree of confidence that they can have in the reasonableness of the results provided by this model. Such an assessment is crucial if this model is to be relied upon for guidance in establishing universal service policy and/or prices for unbundled elements. After extensive analysis of the Model, INDETEC International concludes that HM 3.0 is grossly inadequate for a variety of reasons. These reasons are subsumed in the following: 1) Network Modeling Deficiencies; 2) Inappropriate Methodology for Converting Investments into Annual Costs; 3) High Degree of Inaccessibility of the Model; 4) Limited Value of Reported Outputs; and 5) Inaccuracy of Raw Data Inputs. This Executive Summary merely highlights some of the salient findings. In general, the core of the model is unchanged from HM 2.2.2. Thus, fundamental criticisms of HM 2.2.2 apply here as well, rendering HM 3.0 a model that still produces unrealistically low costs for telephone service. The ensuing report and supporting appendices elaborate on the shortcomings of HM 3.0. These shortcomings yield results that are frequently counterintuitive, i.e. changes in inputs and assumptions that according to sound economic principles and engineering practices should result in significant cost increases result in minor cost increases and in some cases, decreases in cost. Such outcomes raise fundamental concerns about the reliability of such a model. Furthermore, INDETEC International is gravely troubled by the fact that hard coding certain assumptions regarding the network results in situations where the network fails, i.e. customers can't talk to each other. Finally, some of the assumptions and parameters in the Model are blatantly inconsistent with current engineering practices, practices not likely to change in the foreseeable future. These deficiencies result in a model that systematically, substantially understates the cost of the network. Therefore, INDETEC International contends that basing public policy on HM 3.0 will have deleterious consequences for attaining universal service objectives and maintaining the integrity of the ubiquitous network. Given the magnitude of these shortcomings, we do not recommend that the FCC and State Commissions base regulatory policy on the outputs of this model.

I. Network Modeling Deficiencies

The Hatfield Model appears to systematically produce low costs, despite economic and engineering intuition to the contrary. From a high level perspective, on average HM 3.0 develops the Total Cost of Switched Network Elements that is only slightly higher than the costs developed in HM 2.2.2. Yet, the Model develops loop lengths that are 17 times longer than in HM 2.2.2. <u>It is inconceivable that such a dramatic increase in loop length would result in such a small increase in costs.</u> While this is one of the most glaring discrepancies in the

Model, the Report provides numerous additional examples of such counter-intuitive phenomena.

The high level of structure sharing incorporated in the model is also a significant problem. It is unrealistic to assume that 25% of all poles and 33% of trenching would be attributed to the Incumbent Local Exchange Carrier (ILEC). Loop costs are highly sensitive to assumptions about the proportion of sharing. Furthermore, the Model underestimates structure investment for both poles and conduit, compounding the problem of underestimating those costs. The Model still underestimates, though to a lesser degree, the appropriate loop length to serve customers. In addition, where long loops occur they are designed so poorly, that they could not realistically be used to communicate. For example, the model does not recognize that, for longer loops, 19 and 22 gauge cable does not come in all cable sizes and for higher density areas a second sheath (and its related costs) will be needed. Drop and Network Interface Device (NID) costs are also understated. This is caused by understating the cost of the drop cable and widespread use of six pair NIDs.

The Model does not limit inappropriate assumptions regarding structure sharing to outside plant. HM 3.0 also assumes significant structure sharing of interoffice facilities. Thus, interoffice costs are also significantly underestimated due, in part, to an assumed 33% sharing of all interoffice structures.

In addition, switch costs are still vastly understated in HM 3.0. The input data continues to be suspect because of the flawed methodology upon which it is derived. The data lacks documentation and grossly under represents the cost of switching. Most importantly, the use of only a few data points to construct the switch curve is statistically inaccurate and at a minimum, certainly misrepresents the actual costs at the tails of the curve (i.e., extremely small or large switches).

II. Conversion of Investments into Annual Costs

HM 3.0 substantially underestimates the annual cost. It does so by: 1) using excessively long depreciation lives, 2) incorrectly applying ARMIS ratios, and 3) inappropriately using investment (not activities) to drive expense levels. HM 3.0 proposes depreciation lives for buried cable that are 5 to 6 times greater that that proposed by AT&T in a 1994 proceeding. Lengthening the life of the buried cable account as such, dramatically reduces loop costs. HM 3.0 continues to use embedded plant in calculating ARMIS ratios, while using forward looking plant investments in its application in the Model. These forward looking investments are about 1/2 the level of the their embedded counterparts, which results in inappropriately assigning only 1/2 the relevant expenses. Finally, INDETEC International maintains that there is no correlation between loop investment level and maintenance. Yet, for example, HM 3.0 applies higher maintenance to longer loops than shorter loops since it inappropriately drives expenses with investment levels.

HM 3.0 also escalates the highly suspect assumption that network efficiency will improve, not by the dubious 30% Hatfield proposed in HM 2.2.2, but by an even greater 50%. No foundation is provided for justifying HM 3.0's assumed 50% reduction in costs.

III. Inaccessibility of the Model

Significant changes have been made to HM 3.0. These changes include modifications to the architecture, algorithms, and inputs. In stark contrast to HM 2.2.2 which was written in a single Excel spreadsheet, HM 3.0 is a complex combination of Visual Basic, Excel, and Access software. It is difficult to follow and trace the algorithms through the model. Although the underpinnings of the Hatfield Model, as recently as version 2.2.2, may have appeared to be fairly accessible to external analysts, that accessibility drastically diminished with version 3.0. Using nonproprietary data in proxy models is only one step in facilitating widespread accessibility of cost proxy models. Enhancing accessibility by ensuring an understanding of the algorithms in a model is crucial.

IV. Limited Value of Reported Outputs

HM 3.0 continues to be severely limited in its ability to provide output that is of keen interest to policymakers, given the potential policy settings in which this model may be used. It can only produce results for a particular company in a particular state, e.g. GTE in CA. That is to say, it cannot analyze an entire state, an entire company in multiple states, multiple states, or run in batch mode to load multiple items. Additionally, the Model can produce only density zone and/or wire center reports, not Census Block Group (CBG) level reports. This limits the usefulness of disaggregating the data to a CBG level when output must subsequently be aggregated according to density zones or wire centers.

V. Inaccuracy of Raw Data Inputs

An external validity check of raw data inputs indicates that there are data problems that cause costs to be understated. Household counts do not match Census based numbers. There are major differences between the Census data and the data used in HM 3.0 that cannot be explained by any reasonable estimation of second access line penetration. Additionally, the model grossly misrepresents the actual square miles and the actual territories served by GTE.

In summary, by utilizing inappropriate methodology, modeling, inputs, and assumptions, HM 3.0 exacerbates the trend established by previous releases to underestimate the cost of the telephone network.

Analysis of Hatfield Model 3.0

Introduction

The purpose of this report is to provide an extensive analysis of Hatfield Model 3.0 (HM 3.0), using Hatfield Model 2.2.2 (HM 2.2.2) as a frame of reference . Such an analysis is crucial in facilitating policymakers determination of the reasonableness of the results provided by HM 3.0. It is essential that policymakers utilize reasonable cost proxy models because if policy is established based on a model that systematically, unreasonably understates the costs of the network, there will be deleterious consequences for attaining universal service objectives and maintaining the integrity of the ubiquitous telecommunications network.

After analyzing the Model, INDETEC International concludes that HM 3.0 is grossly inadequate and systematically, substantially understates the costs of the network for a wide variety of reasons. The reasons are subsumed in the following categories as outlined below: I) Network Modeling Deficiencies; II) Inappropriate Methodology for Converting Investments into Annual Costs; III) High Degree of Inaccessibility of the Model; IV) Limited Value of Reported Outputs; and 5) Inaccuracy of Raw Data Inputs. Since the number of deficiencies is so extensive, the Report highlights topics within each of the five categories with capital letters and a brief description in bold italics.

Statements have been underlined in the Report to emphasize a genre of problems that are pervasive throughout the Report. These problems can be summarized as follows. Deficiencies in the Model yield results that are counterintuitive, e.g. changes in inputs and assumptions that according to sound economic principles and engineering practices should result in significant cost increases result in minor cost increases and in some cases, decreases in costs. In addition, hard coding certain assumptions regarding the network results in situations where the network fails, i.e. customers can't talk to each other. Finally, some of the assumptions and parameters in the Model are blatantly inconsistent with current engineering practices.

I. Network Modeling Deficiencies

A. Structure sharing proposed in HM 3.0 is even more unrealistic than in HM 2.2.2.

The most significant problem with the loop assumptions is the amount of sharing proposed by the Hatfield Models. HM 2.2.2 sharing assumptions were unrealistic. HM 2.2.2 assumed that 33% of the cost of aerial structure (poles) was assigned to the Incumbent Local Exchange Carrier (ILEC). HM 3.0 assumes an even more unrealistic level of sharing. HM 3.0 assumes that 25% of the cost of aerial structure is assigned to the

ILEC. In effect, HM 3.0 assumes that 100% of the time, a 40 foot pole will have four utilities/carriers attached (Power, CATV ILEC, and Competitive Local Exchange Carrier (CLEC)). It assumes that 100% of the time all of these companies will be present, which is highly improbable. It also assumes that there will always be enough space on the pole to accommodate all four utilities. Appendix A, scenario 8, shows that by increasing the fraction of distribution and feeder structure assigned to telephone from 33% to 66%, HM 2..2.2's cost increased by 16.25% while HM 3.0's cost surprisingly increased by only 9.93%.

Furthermore, HM 3.0 assumes that each company will share equally in the cost of the pole. In fact, CATV does not pay an equal share of the pole cost with power companies and ILECs. They lease space for substantially less than their proportionate share.

Another important factor to consider when considering the feasibility for sharing is trench depth. Neither HM 2.2.2 nor HM 3.0 indicates a depth of trench nor includes a user table for input of trench depth. Therefore, it is impossible to determine if trench depth is sufficient to allow for sharing of the trench. Assuming that the trench depth is as it was in BCM1 (24 inches for copper and 36 inches for fiber), no sharing of trench can be assumed as trench depth and width would have to increase. The cost of trench would also increase and may eliminate any savings associated with sharing of trench.

Hatfield exacerbates the structure sharing problems by applying a portion of the interoffice to feeder 100% of the time. Interoffice facilities do not occupy the same feeder structure in every section in every feeder route of a wire center.

B. While distribution calculations are considerably different from HM 2.2.2, they still result in underestimating the cost of distribution.

First, HM 3.0 reduced each quadrant's area uniformly by the percentage of the CBG that is empty. Second, for low density areas, clusters were used to size the distribution grid. Third, HM 3.0 imposed a restriction on the maximum size lot to be 3 acres or about 361.5 feet by 361.5 feet. The impacts from the first two manipulations in reducing the amount of distribution grid needed are relatively easy to see, but the impact from the last is harder to ascertain. Furthermore, given that the last manipulation has the greatest effect on low density areas, the magnitude of the impact may be much greater, especially for GTE who serves mostly lower density areas.

To give some perspective, three acre lots per housing unit correspond to a density of about 214 housing units per square mile. The quadrant and clusters (if applicable) are calculated by multiplying the average lot size with that maximum lot size by the number of housing units in the quadrant or cluster. For Central Office (CO) areas with densities less than 214 housing units per square mile, HM 3.0's calculation of distribution grid involved "relocating" the housing units in the areas into the three acre lots located adjacent to each other. The distribution grid based on the "newly created Hatfield community" are sized using straight airline miles. As a

result, the number of grids needed is substantially underestimated.[1]

More specifically, Caliper Corp. provided a comparison of total street segment lengths to the corresponding HM 3.0 and HM 2.2.2 distribution cable distances in a selection of 29 California CBGs. The results of this analysis show a substantial increase in the amount of distribution loop from HM 2.2.2 to HM 3.0 *without a corresponding increase in distribution expense or investment.* This counterintuitive result remains inexplicable at this time because it is unclear what other changes may have offset the anticipated substantial increase in cost.

All 29 CBGs are contained entirely within GTE wire centers, and are assigned by both versions of the model to GTE. Street segments that cross over wire center boundaries are excluded. The analysis was restricted due to the enormous data and computational requirements of determining the physical location of streets within CBGs, and to the strict time constraints. Appendix B provides examples that illustrate the disparity between distribution distances and street segment lengths. This exercise compared actual street lengths to the sum of underground, buried & aerial cable columns, and to the "total distribution distance" column, in the "distribution output by CBG" tab of the GTE California default HM 3.0 workfile, as well as to the "Distr Distnc" column in the HM 2.2.2 GTE California default input file.

It is unclear whether HM 3.0 operates on the cable values (e.g., with the "empty fraction") to generate distribution distances to which expense and investment figures are applied, or vice versa. However, where the distribution distances generated by HM 2.2.2 failed to come anywhere close to the corresponding sums of street segment lengths, the observed HM 3.0 distribution distances sum to about 75% of the amount necessary to cover the roads.

Obviously, then, if distribution distance is equivalent to the eventual mileage of cable proposed by HM 3.0, it seriously understates the cable needs. Moreover, it represents a significant departure from HM 2.2.2 without a commensurate increase in expense and investment. If, however, the HM 3.0 *cable* data is the relevant measure, it may or may not be sufficient in reach, and it represents a *vastly* significant departure from HM 2.2.2 without the commensurate cost increases.

For the 29 observed GTE California CBGs, the total HM 3.0 distribution distance mileage for the 29 CBGs is 351. The total HM 2.2.2 distance is 28. The total length of street segments is 470. Preliminary estimates show that the amounts in the HM 3.0 distribution distances range from 4 to 33 times as large as the HM 2.2.2 distances. The sums of the HM 3.0 cable data range from 8 to 108 times as large. On average, the HM 3.0

[1] But even the network in the "newly created Hatfield community" may not function. Because for housing units with densities less than 214 units per square mile, the average shortest distance of the housing unit to the closest distribution branch would have to be at least 180.7 feet (one half of the side length of a 3 acres lot), but the drop in the Hatfield model is limited to 150 feet.

distances are 17 times larger than in HM 2.2.2, and the cable sums are 36 times larger. Thus, the insignificant cost increase is inconsistent with these substantially greater distribution distances and cable sums.

There is some additional evidence of a systematic approach to "correcting" the reprehensible distribution deficiency by adding cable in such a way as to minimize the resulting cost increases. In general, the larger the size of the observed CBG, the larger the difference between actual street length sums and the observed Hatfield 3 and 222 distribution cable length sums and distances. For HM 3.0, that percentage difference systematically increases, the larger the size of the observed CBG, while no significant correlation was observed between CBG size and percent difference with HM 2.2.2.

Distribution cable costs for the default California runs in HM 2.2.2 are $309,954,511. In HM 3.0, despite: 1) total distance of selected CBGs more than 12 times greater than that in HM 2.2.2; 2) total "cable" over 27 times greater; and 3) total distance of all CBGs more than 17 times greater, distribution cable costs only total to $307,511,968, ($2,442,543 less than the HM 2.2.2 run). For more information see Appendix F.

C. HM 3.0 loop designs result in a network that can't talk.

While HM 3.0 provides some improvement over HM 2.2.2 in how it designs loops, it still creates loops that will not transmit an acceptable signal. In HM 2.2.2, extremely long loops were engineered but no additional provisioning to account for the problems of long loops took place. In HM 3.0, the attempt to account for long loops falls short in accounting for provisioning cost. The additional cost for loading is understated. Also, the loop lengths assumed to be served from a Digital Loop Carrier (DLC) are too long. A DLC system can not power 178,000 foot loops (a specified lookup value in the Hatfield table), even with the extended range plug-ins. The extended range plug-in can power up to 1500 ohms. The maximum distance that a plug-in can handle is approximately 85,000 feet of copper and that is with an all 19 gauge (16.3 ohms per 1000 ft.) loop including loading (14 load points at 9 ohms each). In reality, copper distribution beyond 85,000 feet (beyond the DLC point) simply won't work.

In HM 2.2.2, the provisioning of extremely long loops used 26 and 24 gauge cables with no loading, gain, or extended range DLC plug-ins. Using these facilities, long distribution loops over 18,000 feet would not talk with either an all copper network or a network derived from a DLC. HM 3.0 corrects some of the problems. At least the network may work out to 85,000 feet on an all copper distribution loop or on a fiber/DLC derived network. However, the network will not work out to the limits that have been set by HM 3.0. Additional problems have arisen now that 22 and 19 gauge cables are being used. Those coarse gauge cables do not come in all of the sizes that are in the cable tables. For example, the standard cable in 19 gauge ranges in size from 25 - 300. This means that when a 600 pair 19 gauge is required, 2 separate cables plus 2 ducts or 2 spaces on a pole must also be accounted for. None of this has been incorporated into HM 3.0.

Assumptions about cable gauge could not be found in the documentation, but if HM 3.0's assumption is that large size cables (2400 to 4200) are 26 gauge and the remainder are 24 gauge as it was in HM 2.2.2, then HM 3.0's cost tables reflect that cost per foot installed. In HM 3.0 they add a multiplier for coarser gauge cable. (The multiplier is not explained fully, except that it is a uniform multiplier of the material cost of the per foot cable investment.) As stated above, 22 and 19 gauge do not come in all cables sizes so that in reality more than one sheath may be required. This will result in HM 3.0 understating cable and structure cost.

The DLC Channel Unit Adjustment table is, first of all mislabeled as Cable Gauge Multiplier, and also very confusing. Apparently, DLC plug-ins costs are: 1) increased 25% for loops 55,000 feet to 98,999 feet; 2) not increased for loops 99,000 feet to 177,999; and 3)increased again by 25% for loops over 178,000 feet. A plug-in adjustment is required for loops exceeding 900 ohms. The adjustment is necessary to increase cost for the placement of extended range plug-ins. The extended range plug-ins increase powering to 1500 ohms. Two major problems exist with the HM 3.0 model. One is the cost increase of the extended range plug-in. The increase is more like 2 times the cost of the 900 ohm plug-in rather than the .25 increase that Hatfield chose for loops between 55,000 feet and 89,999 feet. The second problem is that the increase does not occur until 55,000 feet, so the loop won't talk between 50,500 and 55,000 feet. At 55,000 feet there would be 9 points of load (9 ohms per load), assuming an all 19 gauge loop (16.3 ohms per 1000 ft.), the total ohms would be 977.5 ohms.

D. Fill factors are unreasonably high in HM 3.0.

Fill factors generally are too high and have not changed from HM 2.2.2. Furthermore, HM 3.0 now unreasonably assumes that fiber feeder has a fill factor of 100%. Recall that HM 2.2.2 assumed a feeder fill factor in the 65% - 80%. No network engineer would ever build a network without any excess capacity built into the feeder. To do so would make the network unable to handle short term demand fluctuations caused by competition and the ILECs requirement to provide service on demand.

E. Derivation of cable fill factors remains inappropriate.

There is no difference between HM 2.2.2 and HM 3.0 in the way cable fills are derived. HM 3.0 claims fills are a main distribution frame (MDF) fill meaning that the fill is the relationship of the total working lines at the wire center and the total number of pairs (all routes/quadrants combined) terminated on the MDF. Assuming an MDF fill and then applying that fill for sizing of section of plant is incorrect, especially with a fill factor as high as the one used. In reality, the MDF fill is lower than any of the cable sections as an accumulation of all breakage and spare occur here. Typically the further out in a route the higher the fill. An 80% fill factor at the MDF yields nearly a 100% fill factor in the last section of a route. Clearly, this unreasonable assumption is inconsistent with engineering practices. A reasonable MDF fill would be approximately 68% to 70% fill to avoid problems such as held orders and missed appointments.

F. HM3.0 violates outside plant engineering practices.

Although HM 3.0 claims that its general outside plant configuration simulates outside plant procedures followed by outside plant planning engineers, INDETEC International maintains that this is not the case. HM 3.0 violates planning engineer's practices because: 1) it permits copper loops longer than 12,000 feet (see 1994 AT&T Outside Plant Engineering Handbook); 2) places multiple gauges in the distribution; and 3) calls for placement of load coils in the distribution under certain circumstances.

G. HM 3.0 is inconsistent and inappropriate in its designation of % aerial and % buried outside plant.

HM 3.0 contradicts itself when assigning a percent to each mixture of plant (aerial. underground, or buried). On page 27 of the documentation, HM 3.0 states that ..."in downtown urban areas it is frequently necessary to install cable in underground conduit systems, while rural areas may accommodate less expensive aerial or direct-buried plant". Yet the input table (page 30 of documentation) assigns 85% of "downtown urban" areas plant to aerial and only 25% of rural areas to aerial, dramatically decreasing costs. In reality, placing more underground/buried plant in urban areas is the norm due to municipal regulations requiring "out-of-sight" plant, irrespective of whether the plant is feeder or distribution.

H. SAI Investment has changed considerably from HM 2.2.2 to HM 3.0, introducing another source of underestimated costs.

HM 2.2.2 has two tables for SAIs. One for copper feeder and one for fiber feeder. Costs ranged from $500.00 to $2,500 for a copper feeder SAI and $2,500 to $4,500 for a fiber feeder SAI. HM 3.0 costs and tables have changed considerably. Two tables are still used but the types of SAIs have changed. Now they are called "Indoor SAI" and "Outdoor SAI". The documentation still refers to electronics associated with SAIs with fiber feeder but that is the extent of any description. There is no documentation on how costs associated with fiber feeder are incorporated into the table costs. It is unclear what an indoor SAI is. The indoor SAI cost must assume a building terminal where feeder is cross-connected to house cable. Page 42 of the documentation refers to SAIs in large buildings as requiring only inexpensive "punch down blocks", thereby assuming cheap costs associated with "Indoor SAIs. While these types of cross-connects do have punch down blocks, they must also include protector blocks that are not inexpensive (190A1-100 installed cost is approximately $572 per block per 100 pair). These protectors are required to stop foreign power from entering buildings and causing fires (among other problems). HM 3.0's method of placing "Indoor SAIs" can result in burning down the businesses it wishes to serve. To include the cost of protection changes HM 3.0s cost for a 100 pair Indoor SAI from $48 to a minimum cost of $620. SAIs associated with fiber/DLC sites are assumed to be housed in the same cabinet (page 41). For "Low Density DLC" sites this may not be a problem but for large ("TR-303 DLC") DLC sites this would be a major problem. There is no cabinet manufactured that will house a 2016 Fiber DLC system plus 3-1200 or 6-600 connecting blocks, a splice chamber that can handle a total of 7200 copper wires, and 144 "710" splice connectors (assuming 1800 working lines @ 89% fill of DLC and 100% fill

of SAI). This arrangement of combining a large DLC system with the SAI would be more suitably housed in a hut or a controlled environmental vault (CEV), both of which would add enormous costs to the facilities. In HM 3.0, current costs range from $250 to $4,469 for "Outdoor SAIs" and $48 to $1,052 for "Indoor SAIs".

I. The terrain multiplier in HM 3.0 not only has the same flaw as in HM 2.2.2, that flaw has been compounded by a contradictory additional multiplier.

HM 2.2.2 increases distance by 20% to go around difficult terrain. It even went so far as to decrease trench depth to avoid rock. HM 3.0 still applies a 20% increase in distance to go around difficult terrain just as HM 2.2.2 does. Moreover, HM 3.0 adds multipliers to account for HARD and SOFT ROCK. This seems to be a contradiction. If difficult terrain is by-passed, then it seems inappropriate to increase cost for difficult trenching.

J. The structure investments are grossly understated in HM 3.0.

With respect to aerial facilities, both versions of Hatfield do not include costs for messengers, guys, and anchors in their costs. In addition, pole costs are too low in both versions. In fact, Hatfield developers have somehow determined that a larger size pole costs less. HM 2.2.2 placed a 35 foot pole for $450 and HM 3.0 places a 40 foot pole for a cheaper cost of $417.

With respect to Conduit, HM 2.2.2 placed only one duct no matter how many cables it placed. <u>This was a major flaw.</u> Hatfield manhole investment in the feeder was $3,000. In reality, this amount is about what it would cost for a small handhole (3X5 with a traffic lid) with a capability of 2 cable placements. Accordingly, these cost severely underrepresent the costs for larger systems. In addition to the undercosting, manholes were suppose to be placed in the distribution at a default cost of $3,000 However, there was no spacing table for distribution. Therefore, no manholes would have been placed even though the default cost is approximately correct. To address this flaw, Hatfield revised its methodology in a manner which introduced significant errors of its own, resulting in further underestimation of costs. In HM 3.0 the same size manhole is used in all density zones. The investment used ($1,865 for material) indicates that the size of the precast manhole is the 4X8X6 size that will accommodate 4 ducts. Assuming one duct as spare for maintenance and restoration, that leaves 3 spaces for cable. High density areas will require more than 3 cables or 12,600 cable pairs in the feeder. Each 10,000 + CBG will require 3 full size copper cables (allowing for fill adjustment) to serve it if the CBG is within the copper breakpoint. <u>Therefore, manhole assumptions and costs are grossly underestimated</u>. To add to the understatement of cost, Hatfield does not place manholes in the distribution even though the model places conduit there. Furthermore, on page 27 of the documentation, HM 3.0 states that "underground cable is always housed in conduit facilities that extend between manholes or pullboxes". It is typical to place small manholes (pullboxes or handholes) when placing conduit in the distribution at points where splicing, pulling, or terminating drop wire is needed. It is also possible that conduit can be terminated in pedestals, but there is no

indication that pedestal costs were included.[2]

K. Cable costs in HM 3.0 are underestimated.

The costs of cables remain the same as those with the corresponding size in HM 2.2.2. HM 2.2.2 developed cable costs from four tables used to account for feeder underground, feeder aerial, distribution underground, and distribution aerial cable costs. The problem is that the costs were the same in all tables for the same size cable assuming that there was no difference in labor cost between them. This is a completely false assumption. For example, the cost of laying cable in a trench is a lot less than climbing poles, placing messenger (which none of the Hatfield models accounts for), and lashing the cable to the messenger. HM 3.0 offers no improvement since it falsely assumes that labor is the same for all types of plant and that the basic cost of material is the same. (They apply multipliers for dual sheath and "jelly" filled cable).[3] Due to this assumption, the number of tables can be reduced to two for feeder and distribution with the cost per cable size remaining constant. (An additional table is added for riser cables).

L. DLC investments remain understated.

While HM 3.0 attempts to address concerns raised regarding HM 2.2.2. investments, costs are still understated. Recall that HM 2.2.2's costs are grossly understated. A 672 basic system without plug-ins costs $47,000. The HM 2.2.2 model apparently did not include some equipment because the cost dramatically increased in HM 3.0. HM 2.2.2 decided that Lucent's TR303 SLC 2000 and AFC' DLC systems were the systems of choice and that all ILECs should utilize those systems. The maximum size of a DLC system in HM 2.2.2 was 672 and required additional sites when going over that limit. For each additional system another $47,000 was added. However, DLC costs are still understated.

In HM 3.0 a 672 basic system without plug-ins is now $69,000 in HM 3.0. Costs for rights of way and DS1 plug-ins appear to not have been included. Other costs, such as cabinet costs, are grossly understated. To compensate for the additional cost of a 672 system, HM 3.0 adds only $18,000 for an additional 672 channels of capacity instead of doubling the costs as in HM 2.2.2. In addition, TR-303 has been inappropriately modeled in situations where it is not feasible to use a TR-303. TR-303 is currently proprietary to vender specific equipment. For example, only SLC 2000 (Lucent) can talk to an AT&T(Lucent) switch via TR-303. The predominate savings is in the switch and not the DLC equipment. Hatfield is confusing TR-08 with TR-303,

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2 Note: An error was found in the HM 3.0 model. In the R3_distribution.xls file found in the modules folder, column AP (conduit replacement) looks at density_inputs column 7 (buried cost per foot). There is a big difference in the cost per foot between these two columns (i.e., density zone 5000 column 6 = $50.10 per foot and column 7 = $13.00 per foot).

3 The cost for filled cable is not a single cost per foot ($.04 per default table) for all types and sizes of cable. For example, the material cost difference between a BKMA-100 air core pic cable and a GFMW -100 filled pic cable is $0.12 per foot. The material cost difference between BKMA-900 air core pic cable and a GFMW-900 filled pic cable is $1.02 per foot.

both integrated systems.

Actually, TR-303 can be more expensive than TR-08 or TR-57 (universal) when handing off loop elements to Competitive Local Exchange Carriers (CLECs), especially when demand is low. Handing off loop elements from the switch interface uses up a DS1 port in that switch interface, reducing its capacity. This "loopback" increases costs by reducing capacity. The alternative of handing off loop elements at the Central Office Terminal/Fiber Optic Terminal (COT/FOT) either as a DS0 or, if demand is high enough, as a DS1 is much more economic. Of course, a switch vendor would prefer a LEC to use up switch ports thus, purchasing more switch equipment which is considerably more expensive.

M. Drop parameters are still problematic.

The drop parameters have improved with HM 3.0, however there are still some problems. HM 2.2.2 drop cost per line was a single cost for all density zones and all types of plant. The default cost was $40.00 per drop. In HM 3.0, drop cost is based on an aerial buried mix by density zone, a material cost per foot for both aerial and buried drop, an average length of drop by density zone, and a labor cost per placement (not by foot) for aerial cable in each of the density zones. Two problems occur with this calculation. The default material cost per foot for both types of drop is understated. Examples are, aerial drop cost for density 0-5 is $72.58, density 10,000+ is $16.42, buried drop cost for density 0-5 is $133.50, and density 10,000+ for buried drop is $257.00, where buried drop includes trench.[4] The other problem is drop mix should match distribution cable structure mix. In 0-5 density zone 50% of drops are aerial yet only 25% of structure is aerial.

N. Terminal and Network Interface Device (NID) Investments are understated by a greater amount in HM 3.0 than in HM2.2.2.

Both Hatfield models' terminal costs per line are unreasonable since only a single cost is applied to all zones. In reality, less dense zones would have a much higher cost per line since sharing of terminal cost would be shared by fewer households.

In HM 2.2.2 the terminal default cost per line was $32.00 for all types of terminals in all density zones. NID cost was also the same cost ($30.00) in all density zones. The NID was not explained but was universally assumed to be a standard 2 pair NID.

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[4] The material drop in the HM 3.0 is $0.095 for aerial drop and $0.14 for buried drop. The average cost of this material that ILECs have provided in data requests is $0.12 for aerial (a 26% difference) and $0.21 for buried drop (a 50% difference). The length of drop assumed in the HM 3.0 ranges from 150 feet in the lowest density to 50 feet for the highest density. The average distance provided by ILECs ranges from an average of 219 feet in the low density (a 46% difference) to an average of 83 feet in the highest density (a 66% difference). Therefore, the material cost for buried drop is understated for the low density by 119% ($21.00 versus $46.00). The highest density is understated by 143% ($7.00 versus $17.00).

In HM 3.0, terminal cost per line is now based on either a buried terminal cost per line ($42.50) or an aerial terminal cost per line ($32.00) and the mix is based on the Drop Structure Fraction Tables. While page 29 of the documentation indicates that a 2-line NID is placed for residential and a 4-line NID is placed for business, the Model actually places 6-line NID for residential and it is unclear what is placed for business. NIDs for single line businesses would typically be the same as NIDs for residential unless the business is located in a multi-business complex. Then another type of arrangement would be typical. Usually it would be an indoor cross-connect where protection would be placed at or near the building entrance (this was discussed earlier when commenting on HM 3.0's assumptions on SAIs). NID cost assumes a 6 line NID which is not standard in a typical 2 line per household network. From the table it is assumed that the installed cost of the 6 pair NID is $25.00. Then $4.00 is added for protection for every line assumed working in the NID. This results in a cost of $29.00 for a single line which decreases in total cost per line for each additional line. Installing a six line NID is not the standard practice for most telecommunications companies. This assumption underestimates NID costs.

O. HM 3.0 still grossly understates switching costs.

Although HM 3.0 changed the way in which switch costs are developed from HM 2.2.2, it still substantially underestimates the true cost of switching. HM 2.2.2 relied on three switch cost points and the total number of lines in a wire center to determine the switch cost, size and number of switches. It appears HM 3.0 still relies on three switch cost points[5], but has been modified. HM 3.0 employs two switch cost curves, one for large and one for small companies. The large company curve is determined by a logarithmic curve using least-squares regression. Based on the default line sizes in HM 2.2.2 the per line switch costs from HM 2.2.2 and HM 3.0 (large companies) are:

Line Size	Costs HM 2.2.2	Costs HM 3.0
2,782	$220.00	$124.39
11,200	$86.00	$103.60
80,000	$59.00	$74.26

The small company curve was determined by multiplying the constant for the large company curve by a factor of 1.7, shifting it upward to reflect the relative differences in purchasing power. Whether a company experiences an increase or decrease in total switching costs from HM 2.2.2 to HM 3.0 depends on where most of the Company's switches are on the curve, as well as the amount of port costs subtracted to arrive at the

[5] The switch cost functions developed by HM3.0 are totally misleading and are based on erroneous statistical analysis. With only three data points, it fitted a log curve using least square technique and found the R square to be more than 96%. But that 96% does not mean anything. They could have done better by using a curve consisting of 2 straight line segments going through the three points which would have produced an R square of 100%.

Model's value for "installed EO switching per line." [6]

HM 3.0 performs what are termed, "additional capacity checks." They are based on Busy Hour Call Attempts ("BHCA") and Busy Hour Hundred Call Seconds ("BHCCS"). The BHCA default maximum in both HM 2.2.2 and HM 3.0 is 600,000.[7] BHCA is ostensibly used to determine whether the switch is line limited or processor limited. HM 3.0's treatment of BHCA differs from HM 2.2.2 by employing a processor feature loading multiplier to account for the additional processing load associated with vertical features. This variable was included in HM 2.2.2 but had no effect on the model. HM 3.0 includes default values that range from 1.2 to 2.0. Both HM 2.2.2 and HM 3.0 contain two different BHCA input fields for "Switch realtime limit, BHCA", "Busy hour call attempts, residential" and "Busy hour call attempts, business." A decrease in the BHCA capacity should cause an increase in the number of switches and the cost of switching. However, when BHCA was decreased by 20% the total amount of the end office switching costs and the per minute usage cost did not increase as expected. The results were unchanged from the default results. End office switching investment was also unchanged. In fact, when the realtime busy hour capacity of the switch was cut 50% there was no change in switch related costs. The Model does not exhibit any sensitivity to these real time capacity limits as claimed in the documentation. These alarming findings suggest that a fundamental flaw exists in the Model's design.

P. HM 3.0 includes significant, unexplained changes in the tandem switching parameters.

These changes are as follows:

Parameter	HM 2.2.2	HM 3.0
real time limit, BHCA	1,500,000	750,000
port limit, trunks	120,000	100,000
max. trunk fill[8]	.8	.9
comm. equip. intercept factor	25	.50

The common equipment intercept factor in HM 2.2.2 was used for the "scaling of tandem loop investment

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6. There is what appears to be an error in the calculation of one of the cells that has an impact on these calculations. The labeling of cell U2 in the Wire Center Investment spreadsheet indicates that it is the total of only the direst routed access trunks. However, the calculation adds the value from cell W2 on the same sheet to the end of its calculations. This effectively makes the cell U2 the total of all access trunks (both direct and tandem). In the first subtraction of trunk terminations in the end office switching calculation, cell W2, is added to cell U2 in an apparent attempt to count all trunk terminations. However, this means that the trunk terminations for tandem routed access have been accounted for twice in this formula. The second instance of trunk terminations in this formula (where the amounts are added back) does not contain the reference to cell W2. The reason for this omission is unknown, although it is missing in most references to total trunk terminations.

7. This is based on HAI (Hatfield Associates, Inc.) assumptions. See HM 2.2.2 - Input Summary, page 6 of 31.

8. The nomenclature changed. In HM 3.0 this is termed "maximum initial trunk port occupancy."

account for joint usage based on HAI experience."[9] The net impact of these changes is unclear.

It also appears that certain assumptions and calculations are being used to determine the so called "excess tandem switches" on a real time and trunk constrained basis. These algorithms are still under investigation and no documentation references have been found to explain them as yet.

Q. In HM 3.0 there is a decreased sensitivity of outputs to user defined inputs.

Consequently, this diminishes the analyst's understanding of the Model and reduces the analysts flexibility in modifying the Model.

HM 3.0 seems to be less sensitive than HM 2.2.2 to changes in user defined inputs. This would lead one to believe that the model is designed with more hard-coded inputs than HM 2.2.2. (Please see the sensitivity analysis in Appendix A for more details.)

II. Converting Investments into Annual Costs

A. Despite criticisms of depreciation lives being too long in HM 2.2.2, depreciation lives for assets having a significant impact on costs have been lengthened in HM 3.0.

HM 3.0 bases its depreciation lives upon prescribed results from Commission rulings. However, these results do not necessarily reflect economic lives since they may be based on political compromise. One potentially reasonable surrogate for depreciation lives is an estimate of actual lives recently espoused by the Interexchange Carriers (IXCs). In 1994, the last time that AT&T had to appear before the FCC to obtain approval for asset lives, it advocated the following lives. The table below compares AT&T's proposed depreciation lives with those used in HM 2.2.2 and HM 3.0.

		1994 AT&T Proposal	HM 2.2.2 Proposal	HM 3.0 Proposal
	Switch	9.7	14.3	16.54
Copper Cable:	Aerial	3.4	20	16.8
	Buried	15	20	19.86
	Under Ground	9	20	21.17
Fiber Cable:	Aerial	14.3	20	22.11

[9] HM 2.2.2 - Input Summary, page 8 of 31.

	Buried	**16.8**	**20**	**24.13**
	Under Ground	**12.8**	**20**	**22.87**

In addition to these plant specific lives, if one uses 1995 financial data from AT&T and MCI, their depreciation rates range from 10-11%. These would yield a 9-10 year average plant life. These values are well below what Hatfield has proposed and even the values used in the BCPM, BCM2, and the CPM.

B. Capital cost calculations remain extremely problematic in HM3.0.

There has been no improvement nor change to capital cost calculations in HM 3.0 (from HM 2.2.2). HM 3.0 still takes a simplistic approach to developing its capital costs. Its algorithms are based on a simple straight line depreciation method. The only "improvement" made to the capital costs methodology was the recognition of mid-year placement convention.

HM 3.0 still assigns an inordinate amount of embedded costs. In an effort to validate the new release of the Hatfield Model, INDETEC International has undertaken a validation analysis similar to that conducted using HM 2.2.2. In particular, INDETEC International compared the dollar amounts of investment and expenses as predicted by HM 3.0 to the corresponding actual ARMIS reported accounts. The results for CONTEL/ GTE of California, Inc. and GTE Texas, presented in Appendix E, indicate that on average HM 3.0 underestimates total expenses by 31% in California and 41% in Texas.

C. HM 3.0 is still deficient in its methodology for calculating expenses.

HM 3.0 does not address the shortcomings of HM 2.2.2 in the calculation of expenses. HM 3.0 inputs still include underestimated values from a New Hampshire Marginal Cost Study, e.g. Billing /bill inquiry per line per month, alternative CO switching factor, and the alternative circuit equipment factor. In addition, like HM 2.2.2, HM 3.0 assumes that the level of investment is the major driver of expenses.

In addition, Hatfield's use of the ARMIS ratios is flawed. HM 3.0 still uses HM 2.2.2's method of using embedded plant to determine ARMIS expense ratios. However, these ratios are applied to Hatfield's forward looking investments.[10] Furthermore, HM 3.0 multiplies these discounted expenses by an additional discount to account for "future efficiency improvements". Specifically, HM 3.0 adjusts the Network Support expense factor by a forward looking adjustment of 50%. HM 2.2.2 was severely criticized for reducing costs by 30% to

[10] These forward looking expenses only represent 769/1609 of the embedded investment (based upon the 2.2.2 results as reported in paragraph 31 of the FCC staff analysis from, "*The Use of Computer Models for Estimating Forward-Looking Economic Costs: A Staff Analysis*," CCBPOL97-2, DA97-56 (rel. Jan. 9, 1997). Therefore, the expenses in the Hatfield model reflect only 769/1609 of the current operating expenses.

account for future efficiency adjustments. Yet, without any justification, HM 3.0 utilizes an expense factor that reduces costs by an unfathomable 50%.

III. Inaccessibility of the Model

Accessibility of the algorithms drastically diminished with HM 3.0.

HM 3.0 structure is vastly different from HM 2.2.2. Most importantly, HM 3.0 uses a visual basic front end and execution routine which makes it much more difficult to analyze than the single Excel spreadsheet that HM2.2.2 was written in. In addition, the algorithms are now buried in multiple Excel spreadsheets with data being pulled from an Access database running behind the Visual Basic front end, which makes tracing the algorithm through the model nearly impossible in the time provided. This is a major deficiency given policymakers objective to utilize models that are widely accessible.

IV. Limited Value of Reported Outputs

HM 3.0 continues to be severely limited in its ability to provide meaningful output, given the potential policy applications of the Model. There have been no improvements in reporting, including the reporting layer itself which is hard to understand. Reports can only be generated at the density zone or wire center level. The report is further restricted to output for a particular company in a particular state, e.g. GTE in CA. HM 3.0's inability to generate total state and total company (in multiple states) reports, severely limits the utility of the Reports for the FCC and State Commissions looking for a tool to provide bench marking for universal service. The wire center report is of little value since it is not on a per line basis. In addition, the Hatfield Model still cannot generate CBG reports. This is extremely problematic since the CBG is being considered as the geographic unit of funding for universal service. In general, the reports do not yield much useful information for policymakers.

V. Inaccuracy of Raw Data Inputs

A. The input data developed by PNR may be flawed.

The data in HM 3.0 appears to be different than in HM 2.2.2. The documentation does not address how the Donnelly database was geocoded, nor does it mention that the geocoding process typically has a lot of misses (non-assignments resulting from insufficient address information) in the rural area. The manner in which these misses were handled will impact how effectively the geocoding was performed. In addition, the Documentation does not mention the fact that unlisted phone numbers were not used and what impact this has on the final results.

B. Household counts deviate significantly from Census based numbers and are different from HM 2.2.2's.

The Census based CBG data has been the cornerstone of all proxy models used to date. This data is used to approximate the number of residential customers. For some reason, HM 3.0 has switched vendors of its customer data. In so doing, household counts and resulting line counts do not match either census data or ARMIS data. This is of major concern to the reviewers. These values are the basis of the model. They are used to size cable, determine densities, size the switch, etc. In addition, these values are used to determine costs and subsidies for universal service purposes. The table in Appendix C shows the summation of Hatfield households by state. (This summation is developed from the CBG data in the Access database). This is subsequently compared to the 1995 derived household counts. (This derivation is based upon the ratio of 1995 to 1990 population counts at the county level, applied to the 1990 CBG housing data by county). As one can see from the table, there are significant differences in the two columns. The PNR data is said to be adjusted to incorporate first and second line penetration. Using the 1995 estimated household counts, INDETEC International estimated what PNR has indicated as second line penetration (assuming that we have 100% first line penetration). These penetration rates do not correlate with actual data from ARMIS. The Actual Second line penetration column is based upon 1995 ARMIS data compared to the 1995 estimated houses (assuming that 100% of houses have first lines). For example, Appendix C indicates that for CA, there is a 40.4% difference between the number of households according to HM 3.0 and the 1995 Census Household count. Only 17.1% of that can be explained by second line penetration. Thus, an inexplicable 23.3% discrepancy exists.

C. HM 3.0 substantially understates CBG square miles.

The HM 3.0 data, while an improvement over HM 2.2.2 data, seems to continue to substantially understate CBG square mile areas. Despite more than doubling the square mile area covered by GTE California, HM 3.0 merely doubles the numbers of households and fails to result in intuitively commensurate associated expenses and investment.

California CBG square mile areas from Claritas 1990 cartographic boundary areas were compared to areas appearing in the HM 3.0 GTE California default workfile, and those in the HM 2.2.2 GTE California input file. The total square mile area of all CBGs appearing in the default GTE California HM 3.0 workfile is 55,462. The Claritas data calculates a sum of 53,693 for those CBGs. The total square mile area of all CBGs appearing in the default GTE California HM 2.2.2 input file is 27,036; the corresponding figure for those CBGs is 18,397. The actual total square mile area of GTE California wire centers is 29,912. Thus, HM 3.0 overstates the GTE California service area by 85%, while HM 2.2.2 only understated it by 10%.

Using the areas appearing in the models, HM 3.0 assigns over twice as much area (105% more) to GTE California CBGs than does HM 2.2.2. Using Claritas areas, HM 3.0 assigns almost 3 times as much area (192% more) to GTE California CBGs than does HM 2.2.2. However, despite significantly greater area, total distribution costs are smaller in HM 3.0's GTE California default than in HM 2.2.2's. Once again, there appears to be a systematic "correction" taking place which avoids cost increases. Additional information is

provided in the table in Appendix G.

D. HM 3.0 Misrepresents GTE Service Areas to a greater degree than HM 2.2.

Maps provided in Appendix H contain a visual representation of differences between CBGs assigned to GTE Washington by HM 3.0 and by HM 2.2.2 to the actual GTE California wire centers. HM 3.0 assigns 428 more CBGs to GTE California than did HM 2.2.2. In Washington, HM 3.0 assigns 13 fewer and in Texas, 36 fewer. In California, 3,976 CBGs appeared in both HM 3.0 and HM 2.2.2. Overall, in California, HM 3.0 contains 643 that do not appear in HM 2.2.2, and HM 2.2.2 contains 215 that do not appear in HM 3.0.

E. The HM 3.0 data also seems to consistently underestimate the distance from the serving central office to the centroid of the CBG, though it is greater than HM 2.2.2.

This finding is based on a comparison of the average distance of Hatfield to BCPM data. INDETEC International is not stating that BCPM is always more accurate. And, in fact BCPM may assign various CBGs to different serving offices. <u>However, one would not expect that for every state analyzed that Hatfield distances would be systematically shorter.</u> This under calculation may arise from the miscalculation of households. The HM 3.0 assigns CBGs to a wire center based on the prevalent NPA/NXX's, potentially exacerbating the problem of assigning CBGs to the wrong wire center and thereby inaccurately estimating the costs associated with a particular CGB. For greater detail, see the analysis of CBG Hatfield in Appendix C.

Concluding Remarks

The analysis provided in this report conclusively demonstrates that HM 3.0 systematically, substantially underestimates the cost of the network. These underestimates of costs stem from poor economics, flawed engineering practices, grossly inaccurate assumptions, unrealistic data inputs, omission of relevant material, and additional hard coding of assumptions that somehow systematically ensures an understatement of costs. Furthermore, HM 3.0's algorithms are much more difficult to assess. The lack of documentation, combined with the additional hard coding and added complexity in the basic structure of the Model renders this model highly inaccessible to analysts. In addition, the Model failed a number of validity checks with respect to raw data inputs.

The Report emphasizes problems with the Model that are of paramount importance and indicate that the Model is fundamentally flawed. In particular, the Report describes counterintuitive outcomes that are significant. Most notably, while HM 3.0 distribution distances are 17 times larger than in HM 2.2.2 and the cable sums are 36 times larger, there is only an insignificant increase in costs. Also of grave concern is the fact that HM 3.0's network design results in situations where customers can't talk to each other.

Given the aforementioned findings, INDETEC International does not recommend that the FCC and State Commissions base regulatory policy on the outputs of HM 3.0. Reliance on a model that is biased in systematically underestimating costs will have deleterious consequences for attaining universal service objectives and maintaining the integrity of the ubiquitous network.

Appendix A

Sensitivity Analysis: HM 2.2.2 versus HM 3.0

Summary Description of Analysis and Results

Sensitivity analysis was performed on Hatfield Model 2.2.2 (HM2.2.2) and Hatfield Model 3.0 (HM3.0) to compare the total loop unit cost per month for both of the models resulting from twenty different scenarios for the state of Washington.[11] Several of the models' inputs are modified including: fill factors, depreciation rates, cost of capital, distribution and feeder structure fraction assigned to telephone, and the variable/corporate overhead rate. The results are provided in the tables below. Two sets of analyses were performed distinguished by the value of the forward-looking network operations factor. HM2.2.2 employs a default value for this input of 70% which corresponds to a 30% reduction in costs, while HM3.0 uses 50% as the default value, corresponding to a 50% reduction in costs. The first set of results leaves the forward-looking network operations factor at the respective default values for each of the models. On the other hand, the second set of results provides a more accurate comparison, where the forward-looking network operations factor is set equal to 70% in both models.

The result tables below provide several interesting features. First, the monthly dollar amount of the total loop unit cost is provided for both of the models. In the far right column, the percent difference between these two amounts is provided. Below each monthly dollar figure is a percentage value in parentheses. This value is the percent difference between the monthly dollar figure for that particular scenario and the monthly dollar figure in the default scenario for that model. For example, in the first results table, scenario 11 shows a monthly dollar value of 15.76 for HM2.2.2 and a monthly dollar value of 17.09 for HM3.0. The percent difference between these two numbers is 8.44%. However, the monthly value of 15.76 is 25.58% greater than the default value for HM2.2.2 of 12.55. Likewise, the monthly value of 17.09 is 26.69% greater than the default value for HM3.0 of 13.49.

[11] The data used for this analysis is that supplied with the Hatfield Models for Pacific Northwest Bell in the state of Washington.

The results show that, HM2.2.2 is generally more sensitive to input changes than is HM3.0.

Following the tables of results is a section describing each of the scenarios. The exact input modifications made to each model for each of the scenarios is described in detail in the subsequent section.

Total Loop Unit Cost per Month – Results 1

Scenario	HM 2.2.2	HM 3.0	Percent Difference
Default	12.55 (0.00%)	13.49 (0.00%)	7.49%
1	13.51 (7.65%)	14.43 (6.97%)	6.81%
2	15.13 (20.56%)	15.92 (18.01%)	5.22%
3	12.83 (2.23%)	13.82 (2.45%)	7.72%
4	13.69 (9.08%)	14.85 (10.08%)	8.47%
5	15.33 (22.15%)	16.86 (24.98%)	9.98%
6	13.63 (8.61%)	14.73 (9.19%)	8.07%
7	14.76 (17.61%)	16.03 (18.83%)	8.60%
8	14.59 (16.25%)	14.87 (10.23%)	1.92%
9	13.70 (9.16%)	14.66 (8.67%)	7.01%
10	14.72 (17.29%)	15.87 (17.64%)	7.81%
11	15.76 (25.58%)	17.09 (26.69%)	8.44%
12	18.21 (45.10%)	18.78 (39.21%)	3.13%
13	19.86 (58.25%)	20.42 (51.37%)	2.82%
14	21.89 (74.42%)	22.30 (65.31%)	1.87%
15	21.93 (74.74%)	22.83 (69.24%)	4.10%
16	21.32 (69.88%)	22.01 (63.16%)	3.24%
17	24.14 (92.35%)	24.13 (78.87%)	-0.04%
18	23.49 (87.17%)	24.04 (78.21%)	2.34%
19	23.22 (85.02%)	24.30 (80.13%)	4.65%
20	25.56 (103.67%)	25.67 (90.29%)	0.43%

HM 2.2.2: Forward-Looking Network Operations Factor set equal to default value of 70%.
HM 3.0: Forward-Looking Network Operations Factor set equal to default value of 50%.

Total Loop Unit Cost per Month – Results 2

Scenario	HM 2.2.2	HM 3.0	Percent Difference
!!w10 Default	12.55 (0.00%)	14.10 (0.00%)	12.35%
1	13.51 (7.65%)	15.06 (6.81%)	11.47%
2	15.13 (20.56%)	16.56 (17.45%)	9.45%
3	12.83 (2.23%)	14.44 (2.41%)	12.55%
4	13.69 (9.08%)	15.47 (9.72%)	13.00%
5	15.33 (22.15%)	17.48 (23.97%)	14.02%
6	13.63 (8.61%)	15.35 (8.87%)	12.62%
7	14.76 (17.61%)	16.65 (18.09%)	12.80%
8	14.59 (16.25%)	15.50 (9.93%)	6.24%
9	13.70 (9.16%)	15.33 (8.72%)	11.90%
10	14.72 (17.29%)	16.50 (17.02%)	12.09%
11	15.76 (25.58%)	17.73 (25.74%)	12.50%
12	18.21 (45.10%)	19.43 (37.80%)	6.70%
13	19.86 (58.25%)	21.12 (49.79%)	6.34%
14	21.89 (74.42%)	23.02 (63.26%)	5.16%
15	21.93 (74.74%)	23.54 (66.95%)	7.34%
16	21.32 (69.88%)	22.71 (61.06%)	6.52%
17	24.14 (92.35%)	24.85 (76.24%)	2.94%
18	23.49 (87.17%)	24.76 (75.60%)	5.41%
19	23.22 (85.02%)	25.01 (77.38%)	7.71%
20	25.56 (103.67%)	26.38 (87.09%)	3.21%

Forward-Looking Network Operations Factor set equal to 70% in both models.

Sensitivity Analysis Scenarios

1. Fill Factors decreased 20%

2. Fill Factors [illegible] 40%

3. Economic Lives shortened 10%

4. Economic Lives shortened 30%

5. Economic Lives shortened 50%

6. Cost of Money increased from 10% to 12%

7. Cost of Money increased from 10% to 14%

8. Distribution and Feeder Structure Fraction Assigned to Telephone = 66%

9. Variable/Corporate Overhead Factor increased to 20%

10. Fill Factors decreased 20%
    Economic Lives shortened 30%

11. Fill Factors decreased 20%
    Economic Lives shortened 30%
    Cost of Money increased from 10% to 12%

12. Fill Factors decreased 20%
    Economic Lives shortened 30%
    Cost of Money increased from 10% to 12%
    Distribution and Feeder Structure Fraction Assigned to Telephone = 66%

13. Fill Factors decreased 20%
    Economic Lives shortened 30%
    Cost of Money increased from 10% to 12%
    Distribution and Feeder Structure Fraction Assigned to Telephone = 66%
    Variable/Corporate Overhead Factor increased to 20%

14. Fill Factors decreased 40%
    Economic Lives shortened 30%
    Cost of Money increased from 10% to 12%
    Distribution and Feeder Structure Fraction Assigned to Telephone = 66%
    Variable/Corporate Overhead Factor increased to 20%

15. Fill Factors decreased 20%
    Economic Lives shortened 50%
    Cost of Money increased from 10% to 12%
    Distribution and Feeder Structure Fraction Assigned to Telephone = 66%
    Variable/Corporate Overhead Factor increased to 20%