service.[16] The findings of state PUCs in those proceedings (although in some cases still preliminary) can contribute useful analytical inputs to aid the Joint Board's understanding of universal service requirements and funding approaches, even though they may not be entirely consistent with the framework contemplated by the Act.

Concurrent with the state proceedings, the FCC has also been actively involved in reviewing methods of making universal service funding more efficient, more precisely targeted, and more consistent with competitive objectives. The Commission had completed the NOI phase of the *High Cost Proceeding*, CC Docket 80-286, and had made considerable headway in the NPRM phase of that docket (with both comments and reply comments filed) by the time the 1996 federal legislation was signed. Although the legislative history of the Act suggests that CC Docket No. 80-286 should not become the sole foundation for designing support mechanisms for universal service, the Commission has properly recognized that the record in that proceeding is highly relevant to the issue of support for rural, insular and high-cost areas, and need not be recreated from scratch. The Commission has singled out as worthy of further consideration the use of a cost proxy model (and, in particular, the BCM) for implementing support to rural, insular, and high cost areas. (Obviously, there are additional related issues that need to be considered within the framework of the Act, but they are compatible with those portions of CC Docket No. 80-286 that the Commission has incorporated by reference.)

The BCM is still an evolving tool, and the Joint Sponsors have indicated that they expect to issue a new release of the model in the July 1996 time frame.[17] As the Commission suggests in its NPRM, there are a number of areas in the model that could be improved, and these aspects range from minor fine tuning of assumptions to more fundamental conceptual adjustments. In this report, we examine certain modifications and corrections that are required both to correct certain deficiencies in the BCM as well as to focus it more directly at determining the specific cost of providing universal service. We note, in this regard, that the adaptability of the cost proxy approach should be viewed as a strength, not a weakness.

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16. See e.g., Florida PSC, Docket No. 950696-TP, *Determination of funding for universal service and carrier of last resort responsibilities*, Order No. PSC-95-1592-FOF-TP, December 27, 1995; Pennsylvania PUC, Universal Service Proceeding, *op cit.*, footnote 6.

17. See, e.g., California PUC, Universal Service Proceeding, AT&T's Response to Pacific Bell's Data Request, filed March 11, 1996, at 18.

1.3 Organization of this report

This report is organized as follows:

- Chapter 1 discusses the role of the Benchmark Cost Model in addressing universal service funding requirements.

- Chapter 2 discusses the essential attributes of a reliable cost proxy model, and the relationship of the *Telecommunications Act of 1996* to these attributes.

- Chapter 3 describes the Benchmark Cost Model in detail, and provides an overview of ETI's approach to evaluating the strengths and weaknesses of the model.

- Chapter 4 analyzes the BCM's assumptions about (1) the cost factor for translating investments into monthly costs that reflect a return on investment and relevant expenses, and (2) the price threshold against which costs are compared for the purpose of determining the need for universal service support.

- Chapter 5 develops corrected switch cost data for the BCM, and analyzes the implications of ETI's run of the model with the corrected data for this key variable.

- Chapter 6 analyzes the BCM's implicit and explicit assumptions about the outside plant that is necessary for providing universal service, and discusses the results of ETI's run that, where feasible, partially corrects outside plant variables and algorithms in the BCM to more accurately reflect the specific universal service goal.

- Chapter 7 discusses various approaches to determining the type of threshold that policy makers should use for establishing universal service support requirements, and also examines the multiple sources of revenues that should be considered as policy makers assess the need for and size of a universal service fund.

- Chapter 8 combines the results of our corrections and analyses in the preceding chapters in order to provide an upper bound estimate of the cost of basic residence local exchange service, and an upper bound estimate of the need for universal service support.

- Chapter 9 discusses state universal service proceedings and, in particular, provides details of the investigation of cost models that is now underway in California.

- Chapter 10 summarizes ETI's major recommendations regarding how the BCM should be appropriately used in universal service policy proceedings.

Clarifying some terminology may be helpful at the outset. As a general matter, the *Telecommunications Act* distinguishes among (and establishes varying levels of obligations and requirements for) (1) incumbent local exchange carriers, (2) local exchange carriers, and (3) telecommunications carriers, with the first group being a subset of the latter two categories, and the second group being a subset of the third.[18] Differing duties, obligations, and rights apply to these three categories of telecommunications service providers: For example, *incumbent* local exchange carriers must, among other things, provide unbundled access to network elements;[19] *all* local exchange carriers must, among other things, provide dialing parity;[20] and "*[a]ll providers of telecommunications services* should make an equitable and nondiscriminatory contribution to the preservation and advancement of universal service."[21] As defined by the Act, the term *telecommunications carrier* "means any provider of telecommunications services, except that such term does not include aggregators of telecommunications services."[22]

In this report, the use of the terms "local exchange carrier," "incumbent local exchange carrier" and "telecommunications carrier" is intended to conform with the definitions set forth in the Act. A competitive local exchange carrier (CLEC) is not defined in the Act, but in this report the term refers to those local exchange carriers that are not incumbent local exchange carriers.

18. *Telecommunications Act*, Sec. 3(a)(2)(44); Sec. 3(a)(2)(49); Sec. 251(h).

19. *Id.*, Sec. 251(c)(3).

20. *Id.*, Sec. 251(b)(3).

21. *Id.*,, Sec. 254(b)(4).

22. *Id.*, Sec. 3(a)(2)(49).

2 | ATTRIBUTES OF A USEFUL COST PROXY MODEL

2.1 Attributes of a reliable cost proxy model that would be useful for public policy purposes

Since the primary objective of this report is to evaluate the BCM as a tool for quantifying the need, if any, for high cost support, it is important to first identify the desirable attributes of a cost proxy model. Describing these attributes and assigning some priority to them will serve as a "yardstick" against which to measure the BCM. For the reasons discussed below, we conclude that a cost proxy model should possess the core attributes of relevancy, reliability (or accuracy), accountability (verifiability), and simplicity. It is both desirable and achievable for a cost proxy model to incorporate each and all of these attributes, although there will on occasion be tensions among them.

Of these four core attributes, clearly the most important is *relevancy*, i.e., the model must be addressing the correct policy question, "the cost of universal service" in this instance. The model must correctly address and provide cost estimates for only those services that are to be eligible for universal service support.[23] The model must, of course, provide reliable and accurate (*realistic*, but not necessarily *precise*) results. This means not only that all "hardwired" data must be based upon the requirements of "basic" service, but that user-specified inputs must also be carefully scrutinized to ensure that they are, in fact, modeling the correct definition.[24]

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23. Although the *Telecommunications Act* sets forth additional considerations for universal service (e.g., deployment of "special services" to public institutional telecommunications users) there is a specific need for a model that particularly examines the incremental cost of providing local public network connectivity to each US household. Other aspects of universal service are beyond the scope of this report, but, however, do not affect the conclusions and observations in this report.

24. In this regard, all assumptions/inputs that are directly affected by public policy determinations (e.g., the affordability threshold) should be specified as user inputs, rather than "hardwired" into the model.

The goal of universal service is to provide universal *connectivity* of all US households to the public telecommunications network. That goal is satisfied by the availability, in each household, of *one* primary residential exchange access line; additional residential access lines in the same dwelling unit are not necessary for the achievement of universal service and should not be included in a USF analysis. This condition must be accurately reflected in the model; i.e., *the model must be designed to examine the incremental cost of providing one and only one residential access line per legal dwelling unit.* This restriction affects a number of the engineering assumptions in the model because, in practice, local telephone switching and distribution infrastructures are designed to satisfy more than the stand-alone demand for primary residential access lines.[25] Similarly, where the requirements of basic local exchange service can be met by a simpler and lower cost technology or architecture, that approach, rather than any "conventional" method of providing service, must be modelled. For example, in some isolated and insular areas, wireless technology may be a far less costly means of providing basic network connectivity than the traditional wireline architecture. In such cases, the appropriate cost for inclusion in the model is that for the wireless method of service. Similarly, where a LEC chooses, for strategic reasons unrelated to the provision of the primary residential access line, to serve a particular rural exchange with a dedicated central office switch rather than employing a remote service unit (RSU) connected to a more distant host, the relevant cost for purposes of universal service funding is the least cost means of satisfying the primary line residential demand, even if that is not the least cost means of serving the *entire* demand in the community.[26]

It is also important that each investment and expense input assumption reflect the actual forward-looking costs that LECs are likely to incur. While it might seem that such information would be readily available from companies that have operated, for many years, under extensive and detailed corporate and regulatory accounting regimes, this has not been the case. In a recent submission to the California PUC, Hatfield Associates, Inc. reported that "[t]he inputs necessary for the model to determine plant investment in a forward-

25. Significantly, the BCM itself excludes *business* access lines even though the actual LEC network is engineered and constructed to jointly serve both residential and business demand. It is entirely reasonable, for the purpose of developing a cost proxy model, to introduce engineering assumptions that are relevant to the specific question being addressed but that may profoundly impact the ultimate architecture of the network. That the LEC can realize significant scale and scope economies by designing its network to satisfy multiple sources of demand is not disputed: The question before us is the cost of providing universal residential connectivity, which consists of the stand-alone cost of an infrastructure design specifically for this limited purpose *and offset by an appropriate share of the economies of scale and scope that are properly conferred upon the primarily residential exchange access line market.*

26. This is not to suggest that the LECs should not have the flexibility to construct their networks to include capabilities beyond those necessary for universal service, such as the enhanced capabilities provided by a digital switch rather than a more stripped-down RSU. The point is simply that the higher costs are not the appropriate ones to model for purposes of determining universal service support.

looking network design are notoriously unavailable from equipment manufacturers and their customers, the Local Exchange Carriers." The report goes on to say:

> It is difficult to obtain even the list prices of most types of telecommunications equipment. Even if they were readily available, the discounts large LEC purchaser obtain are necessary to determine the effective prices the LECs paid. Hatfield Associates Inc. ("HAI") understands that such discounts can be impressive: e.g., in the vicinity of 50% or more for switching equipment. The discount is therefore vital to the investment estimation.[27]

Thus, a key issue that regulators must address, if a cost proxy model is to be adopted, is how to obtain and then to verify the accuracy of investment and expense data.[28]

Another aspect of reliability is the ability to update critical inputs and assumptions. Both technological and economic forces work on the prices of many of the major inputs to the proxy model. As we enter a more competitive era, competition may result in deeper discounts for switching and other equipment, and in significant technological advances that lead to further decreases in costs overall. In some cases, the effective cost reduction is reflected in the form of capacity increments rather than in cost decreases *per se*; for example, by 1997, advances in electronic multiplexing equipment will make it possible for a single strand of fiber optic cable to carry 40 Gbps of digital bandwidth, as compared with a maximum capacity of only 2 Gbps in 1989.[29] Thus, while the installed cost of fiber cables might be relatively stable (or perhaps even increasing slightly), on a per-unit-of-capacity basis the cost of fiber optic transport is dropping like a rock.

In discussing the need for accurate and reliable data, a note of caution is necessary concerning the temptation to judge the reliability of a cost proxy model by whether its results can precisely match the cost results reported by the LECs through ARMIS or other embedded cost studies. It is neither necessary nor desirable that such data be completely comparable. First, it cannot be assumed that any failure to match is attributable to an error in the cost proxy model, rather than in reported costs. Second, since the cost proxy model

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27. AT&T Communications of California, Inc., MCI Telecommunications Corporation, and Hatfield Associates, Inc., *A Discussion of Input Assumptions Used in the Hatfield Proxy Model*, Response to Pacific Bell's Second Set of Data Request in California PUC Universal Service Fund Proceeding, March 11, 1996 ("California PUC, Universal Service Proceeding, *A Discussion of Input Assumptions Used in the Hatfield Proxy Model*"), at 2.

28. This role is hardly a new one, and the process of obtaining and verifying such input data for the limited inputs required in a proxy model should be considerably narrower than what is required to investigate and verify the costs of each LEC to provide service in a wide assortment of high-cost exchanges.

29. Brand, T.L. et al., "An Updated Study of AT&T's Competitors' Capacity to Absorb Rapid Demand Growth," AT&T Bell Laboratories, April 19, 1995 submitted as Attachment C to Pacific Bell's Second Set of Data Request in California Universal Service Proceeding, dated February 28, 1996, at 4-5.

is modeling long run incremental costs for an optimized network that is limited to providing basic universal residential connectivity, rather than the *actual* multipurpose networks that are constructed in practice, the costs are by definition not comparable, even if the embedded ARMIS-type costs were otherwise equivalent to the long run incremental costs of the proxy model.

Without a rigorous examination of the core assumptions and inputs, there is a substantial risk that the cost inputs of the model will be inflated and the engineering assumptions overstated to produce a higher than necessary support requirement. Thus, it is hard to separate the attribute of reliability from that of verifiability. The key to ensuring that the information being used to drive the model is accurate is to make it available for thorough public examination, with full disclosure of underlying data sources and an opportunity for in-depth analysis of that information by interested parties. Moreover, because the model is intended to be a tool for public policy deliberations, the model should be "open," that is, any user should be able to replicate the results, modify key inputs, and determine the source and accuracy of the underlying data.

The expectation in developing a cost proxy model, such as the BCM, is that it be widely deployed across multiple jurisdictions. This is far more likely to happen if the basic algorithms in the model are easy to follow. Along the same lines, it is important that any formulas incorporating inputs that will be user-designated or that will require regular updating be designed to facilitate such changes.[30]

Balancing of core attributes

Not surprisingly, optimization for any one of the goals described above may diminish the cost proxy model's ability to fully capture one or more of the other goals. For example, as the detail of specifications increases, accuracy may increase, but some simplicity and verifiability may be sacrificed. Similarly, the best publicly available data may not reflect

30. The BCM as originally published was implemented as a set of Microsoft Excel spreadsheets, in an extremely complex and physically imposing spreadsheet modelling effort. In fact, while probably permitting it to be completed more rapidly, the use of spreadsheet technology is entirely inappropriate for a model involving a data set of nearly a quarter of a million individual Census Block Group (CBG) records, each one of which contains some 14 elements of data. Even with the fastest Pentium processors available, a single replication of the entire model would require at least 110 hours and involve manual intervention of at least 20 to 30 hours. ETI estimates that a single full replication run would take a minimum of three weeks to complete. It is our understanding that a future revision (probably not the version that is expected to be issued in July) is being implemented in a more appropriate software technology, which should facilitate replication and analysis by others. We are concerned, however, that the implementation of the BCM in a high-level programming language (such as Visual Basic or C++), while vastly improving the program execution time, may make it even more difficult to examine and to understand the specific assumptions and algorithms that are hard-wired into the programming code. Accordingly, we would urge the Joint Sponsors to provide detailed documentation, as well as source code, for the revised model.

market reality. This is best illustrated with respect to switch and other component prices, for which the "list" price is commonly understood to be far greater than the net discounted prices that are actually being paid by LECs under sales agreements that have, traditionally, been treated as competitively sensitive and thus not subject to public disclosure. In our example, given the large impact that switching costs and other component prices have upon the accuracy of the BCM, it is clearly worthwhile to require LECs to disclose the net prices actually paid to vendors, even though the need to afford some confidential treatment to this information may pose some limitations on public discussion of the numbers. Finally, there must be a balance between getting the model near perfect and getting it completed and implemented. In balancing these competing considerations, policy makers should be guided by the Act's overriding purpose of promoting competitive opportunity and defining universal service support in a manner that is explicit, specific and competitively neutral. We have attempted to balance these competing considerations in our analysis and recommendations.

2.2 Defining the costs to be estimated by a cost proxy model for Universal Service

A prerequisite to formulating or evaluating a cost proxy model for universal service is to carefully define the nature of the costs that are to be modelled. As is generally true for any cost study, the appropriate definition of costs depends, in turn, upon how the results of the model are to be used. In this case, the public policy objectives for a cost proxy model have been established in part by the universal service provisions of the *Telecommunications Act of 1996*,[31] which calls for the FCC to assemble a Federal-State Joint Board to define the scope of universal service, after which the FCC and state PUCs must develop "specific, predictable, and sufficient Federal and State mechanisms to preserve and advance universal service."[32] Importantly, in the competitive local exchange marketplace also envisioned in the Act, universal service funding is not limited to incumbent LECs, but to any and all "eligible carriers," including new entrants, that accept universal service responsibilities and are so designated by the state PUC.[33]

These requirements have two direct consequences for defining how costs should be viewed in a proxy model. First, the basic telecommunications service to be costed in the proxy model ultimately will have to reflect the definition of universal service recommended by the Joint Board and implemented by the Commission. Second, the proxy model should

31. State PUCs may have additional objectives for a cost proxy model.

32. *Telecommunications Act*, Secs. 254(a)(1) and 254(b)(5).

33. *Id.*, Sec. 254(e), Sec. 102.

estimate the costs to supply the defined universal service as they would be confronted by *any local exchange services provider*, rather than to determine the costs incurred today by the incumbent LEC under its particular network configuration and architecture. The latter objective is central to the "proxy model" concept,[34] and has been overlooked by some incumbent LECs that have focused instead upon modeling costs specific to their own networks.[35]

Although the Joint Board investigation of universal service is just beginning, it is essential to consider how basic telephone service is likely to be defined. The Act provides specific guidelines to the Joint Board to assist with the task of defining the scope of universal service. When determining whether specific services should be recommended for universal service treatment, the Joint Board is required to consider whether the service:

- is essential to education, public health, or public safety;
- has been subscribed to by a substantial majority of residential customers as a result of the operation of market choices;
- is being deployed by carriers in public networks; and
- is consistent with the public interest, convenience, and necessity.[36]

As a starting point, we offer a definition drawing upon proposals advanced in industry discussions and pending state-level proceedings. The basic residential service for universal service purposes may encompass the following capabilities:

- single-line, single-party residential voice grade dial tone line providing access to local and toll calling;
- a defined, minimum level of local usage;
- access to emergency numbers, directory and operator assistance;
- touch tone dialing; and
- white pages listing and an annual directory.

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34. NPRM, *op. cit.*, footnote 1, at 19.

35. See the discussion of Pacific Bell's Cost Proxy Model, Chapter 9, *infra*.

36. *Telecommunications Act*, Sec. 254(c)(1).

The FCC, in the NPRM, identifies a similar, although somewhat less extensive, set of services that it suggests should be "among those core services receiving universal service support."[37] All of the elements enumerated above satisfy the Act's guidelines, particularly with respect to subscription by the majority of residential customers. In contrast, custom calling features (like Call Waiting, Selective Ringing, Call Return, and Caller ID) do not. In the same vein, additional residential access lines are ordered by only about 12.3% of residential subscribers,[38] with the greatest demand coming from customers in upscale communities.[39] Indeed, there are many more cellular telephones in use by consumers than there are additional residential access lines, yet no one would seriously propose that cellular be included within the scope of universal service at the present time.

Thus, the basic elements listed above are likely to be found necessary and sufficient to ensure that all citizens can participate in the public telecommunications network for social and business contact, regardless of their income or place of residence. Until a universal service definition has been formally adopted, however, a cost proxy model should permit the assumed elements of basic/universal service to be modified.

Once the basic residential service has been defined for universal service purposes, the goal of the proxy model is to estimate the economic costs of providing that service to all residential households in a given market area. Conceptually, a proxy model should develop the total service long run incremental cost (TSLRIC) for that defined basic service, taking the *total output of the basic service* as the increment of demand under study. One approach might be to consider only the costs of serving those residential customers that the LEC would otherwise not serve voluntarily at a defined "affordable" price level. Since the LEC would presumably serve all customers except those whose costs exceeded that price, the LEC would be capable of generating "contribution" from the remaining, lower cost customers (the significant majority of most LECs' customer base), at least some (if not all) of which could be used to offset the cost of serving that small minority of "highest cost" subscribers. Any claimed subsidy requirement would have to be developed relative to the *total* customer base for the defined basic service, net of the revenues generated by residential customers served at costs *lower* than the "affordable" threshold; hence, even if

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37. The FCC's initial definition does not include local usage or access to a white pages listing and annual directory. We have followed the FCC's practice of excluding access to telecommunications relay services (TRS) from the universal service definition since TRS is already funded by explicit support mechanisms adopted pursuant to the Americans with Disabilities Act. See, NPRM, *op cit.*, footnote 1, at para. 16 and note 42.

38. *Statistics of Common Carriers* ("SOCC"), FCC, 1994/1995 Edition, Table 2.5; *Monitoring Report*, CC Docket No. 80-286, Federal-State Joint Board ("FCC Monitoring Report"), May 1996, Table 3.6; Bureau of the Census, *1990 Census Population and Housing*, available from http://www.census.gov.

39. California PUC, Universal Service Proceeding, Deposition of Richard Scholl, Volume VII, March 26, 1996, at 964.

one were to limit subsidy funds to the highest cost customers, it would still be necessary to determine the costs and revenues associated with serving residential subscribers overall.

As with all TSLRIC applications, the definition of "long run" is crucial to the development of reasonable cost estimates for universal service. In a properly structured TSLRIC study, one seeks to identify and quantify all costs that would not be present in the long run if the LEC was no longer going to provide the service or functionality at issue. For this purpose, the "long run" should be defined to mean a planning horizon in which full replacement of all plant, equipment and other investment, as well as a major organizational restructuring, is physically possible if economically justified, but not so long that all existing plant will have become worn out and in need of replacement merely because of its age or physical condition. It is a time interval over which consideration of various architectural strategies, including but not limited to total plant replacement, incremental enhancement of existing resources, or some combination thereof, can be considered and acted upon in a prudent and economically efficient manner, or in which comprehensive organizational changes, such as the creation and/or elimination of entire functional units, can be considered and implemented. This TSLRIC approach will permit the identification of all costs that in the long run are caused by the defined basic service, that would not exist if it were not being provided.

One important parameter in creating a proxy model using TSLRIC cost methodology is the manner in which the geographic placement of network facilities is modelled. For modeling simplicity, it may be useful to begin with the existing wire center locations and outside plant routings to serve known customer locations (sometimes referred to as the "scorched node" approach). However, it should be recognized that the resulting "scorched node" approach will not necessarily produce the absolute, least cost network for providing universal service on a forward-looking basis. Advances in switching and distribution technology are affecting the optimal placement of network facilities.[40] Shifts in demographics and telecommunications usage patterns over time may also change the optimal locations of wire centers from those currently in use by incumbent LECs. Finally, the design of a network whose purpose is limited to serving primary residential access line demand may be far less complex — and less costly overall — than the multipurpose networks that are actually being constructed. All such adjustments that may have significant cost impacts, and that can be reasonably defined and modelled, should be incorporated into the proxy model in order to best approximate the forward-looking economic costs of providing universal service.

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40. For example, the penetration of fiber optic technology into the feeder network is reducing the distance sensitivity of feeder costs, just as it had previously done for interoffice and interexchange transport. Second, the increased modularity of newer-generation digital switches is allowing LECs to deploy switching resources more flexibly. As a result, many LECs have been consolidating wire centers, chiefly by deploying host/remote systems in which remote switching units operate as an extension to a centralized, remotely-located host switch.

3 | AN OVERVIEW OF THE BENCHMARK COST MODEL

3.1 Preliminary discussion of the BCM

The goals of the Benchmark Cost Model are to (1) estimate the forward-looking cost of providing basic local exchange service to households and (2) to quantify the universal service funding necessary to cover the differential between that cost and a desired price level. The BCM uses Census Block Groups (CBGs) as a unit of analysis for computing household line costs for each of 49 states and the District of Columbia.[41] The United States Census Bureau defines a "Census Tract" as a subdivision of a county containing between 2,500 and 8,000 housing units. Within this division, a block is a small area bounded by "visible features" such as roads or streams.[42] A CBG (the area for analysis in the BCM) is a cluster of blocks having the same first three-digit identifying numbers which, according to the Census Bureau, are "usually between 250 and 550 housing units, with the ideal size being 400 housing units."[43] Census block groups vary enormously in terms of the land area that they cover, the population they encompass, and the relative presence or lack of household clustering.[44]

The BCM's cost results are expressed (1) on an average CBG per-line basis; (2) on an aggregate basis for each CBG; (3) on an average statewide per-line basis; and (4) on an

41. Data are unavailable for Alaska. Throughout this report, the term "line" is used and the term "loop" is avoided so as to prevent confusion with the unbundled loop that LECs offer to other telecommunications providers. The BCM's method of allocating switch costs suggests that the scope of universal service being modelled includes a residential line and local usage. (The BCM assumes that 30% of switch costs relate to traffic-sensitive (TS) functions and that 30% of these TS costs are properly allocated to local traffic. See cells H9 and H12 of the "Tables & Inputs" sheet of the Output Module.)

42. Definitions from this section are summarized from the *1990 Census of Population and Housing, Summary Population and Housing Characteristics*, New York, at A-3 to A-5.

43. *Id.*, at A-4.

44. See Appendix 3A for the quantity of CBGs in each state.

aggregate statewide basis (i.e., the total cost for all household lines in the state).[45] The BCM arrives at these cost estimates by processing input in the form of individual CBG records for each state through three separate modules that each consist of an Excel® spreadsheet file.

The input to the BCM

The BCM is an incremental "scorched node" study, meaning that for the purpose of determining how to "deploy" theoretical telecommunications plant, the model is based upon the location of existing wire centers.[46] Although existing nodes (i.e., wire centers) are assumed for the purposes of the model, existing equipment is not assumed, and in fact the model reflects the deployment of state-of-the-art DMS 100 digital switches. The CBG records that serve as input to the BCM, are assigned to an existing central office switch and to an actual provider of local exchange services as well.[47] The BCM also assigns CBGs to one of four switch "quadrants." CBGs in the same quadrant are served by one of four main feeder segments which are assumed to leave from each switch in four directions (due east, north, west and south). The creation of these hypothetical wire center serving area boundaries is based upon V&H coordinates and NECA Tariff 4 CLLI codes. The CBG input records also include an estimate of the airline distance from the center of each CBG to the appropriate central office switch, a total household count, and the CBG's household density per square mile. Finally, the input records contain measures for bedrock depth and hardness, water table depth and a surface texture. These geological variables directly influence network design and cost algorithms throughout the BCM.

The Data Module

Although the BCM bases network development upon existing central office switches, the outside plant (feeder and distribution) is deployed without any reference to existing

45. The census data in the BCM (e.g., quantity of households and CBG boundaries) are based upon 1990 information. See Joint Submission, at 10.

46. By contrast, a so-called scorched earth model would not presume any information about the location of switches.

47. Each CBG is mapped to the closest existing wire center, regardless of whether the carrier that serves that wire center actually serves the geographic area encompassed by the particular CBG.

plant.[48] The Data Module characterizes the difficulty of constructing outside plant for individual CBGs on the basis of the geological and geographical variables mentioned above. For example, the "Data & Calcs" sheet of the Data Module includes formulas that derive the main feeder, subfeeder and total distribution distances for each CBG from the centroid distance and other geographic data provided in the input records. The BCM allocates sub-feeder segments to those CBGs not directly in the path of the main feeder route. Sub-feeder segments are assumed to branch off the main feeder route at a 90 degree angle and extend to the edge of the CBG. Distribution plant, which is always assumed to be copper, completes the connection to individual households in each CBG and is calculated on the assumption that households are evenly distributed throughout the CBG. Also, formulas in the Data & Calcs sheet transcribe geological variables such as rock hardness and surface texture into values that reflect for example the difficulty of deploying underground plant or of constructing new conduits or telephone poles.

The Data & Calcs sheet also includes formulas that generate terrain-based multipliers that are used later to calculate structure costs (or the costs of conduit systems, interduct, poles, etc.) for individual CBGs. The results of these formulas are pulled into columns labelled "Distribution Cable Multiplier," "Feeder Cable Multiplier," and "Fiber Multiplier."[49] The formulas in these columns "look up" multipliers in the "Weighted Cost Factor Table" located in the "Tables" sheet of the Data Module.[50] There are 54 weighted cost factors in this table ranging in magnitude from 0.233 (the multiplier for distribution plant in rural areas with the lowest household density and with "normal" surface texture) to 11.5456 (the multiplier for fiber plant in urban areas with the greatest household density and the hardest surface texture). The weighted cost factors themselves are generated by formulas that use as inputs 24 "unweighted" cost multipliers that are listed in four tables appearing in the same sheet.[51] The values in these tables are weighted by the percentage split between plant that is underground and plant that is aerial. Underground/aerial splits for distribution cable, copper feeder and fiber feeder plant for each of the six household density classes[52] are listed in three tables also found in the "Tables" sheet of the Data Module.

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48. This is necessary for modelling purposes since the locations of CBGs do not correspond to existing wire center serving areas. Indeed, if one assumes that the existing wire center serving areas are "efficient," then modelled areas based upon arbitrary (from the perspective of telephone network design) CBG boundaries are likely to be less efficient.

49. The "Distribution Cable Multiplier," "Feeder Cable Multiplier," and "Fiber Multiplier" columns are AB, AC and AD respectively in the Data & Calcs sheet of the Data Module.

50. See Appendix 3B.

51. These four tables are labelled "Urban Copper Cable Table," "Rural Copper Cable Table," "Urban Fiber Table" and "Rural Fiber Table".

52. See Appendix 3C for a listing of the six density classifications that are used in the BCM.

The 24 unweighted structure cost multipliers in the "Tables" sheet are calculated as a percent of cable costs based on ratios of a cost per foot to place the plant vs. the cost per foot of the plant itself. These estimates are provided for both underground and aerial copper and fiber plant in areas with different surface textures and different household densities. As such, they are among the most fundamental inputs to the BCM and yield the plant type structure multipliers described above. However, information on how these cost multipliers were determined is noticeably absent from the explanatory materials provided by the Joint Sponsors.

The Loop Module

The Loop Module is the second of three modules in the BCM and is perhaps the most important as it develops and costs out the outside plant portion of the network.[53] The Loop Module consists of five separate sheets, identified as "Input," "Main Logic," "Shared Allocation," "Costing," and "Output." The Input sheet consists of the output of the Data Module,[54] a column that divides the main feeder into individual segments so as to assign CBGs a new main feeder distance, many of the user-specified inputs, and costs for the outside plant.

The main feeder distance of the outermost CBG in a particular quadrant is set equal to its own total main feeder distance minus that of the CBG that is next closest to the central office switch.[55] Segmentation of the main feeder in this way is crucial as those segments closest to the central office switch will be engineered to carry the capacity of CBGs further out along the feeder. This becomes an important distinction later on as the cost of the main feeder is allocated among CBGs in the Shared Allocation sheet.

53. The BCM labels these "loop" costs, but for sake of clarity, we refer to this component of the cost that is being modelled as the outside plant cost.

54. Mechanically, to "run" the model, output data from the Data Module are copied and pasted into the Loop Module.

55. See Column M of the Input Sheet.

The default values for the user-specified variables in the "Input" sheet are shown in Table 3.1 below.

Table 3.1

User Inputs to the BCM in the Loop Module

User Input	**Default Values**
Maximum Copper Feeder Cable Size	4200
Maximum Copper Distribution Cable Size	3600
Fill Factor for AFC Electronics	.8
Fill Factor for SLC Electronics	.8
SLC Cost per Access Line	$500
AFC Cost per Access Line	$550
Fiber Cable Discount	20%
Copper Cable Discount	20%
AFC Electronics Discount %	10%
SLC Electronics Discount %	20%

The Input sheet also includes four new tables that are critical to the BCM's network design and costing functions. These tables include a Cable Fill Factor Table that assigns a feeder and distribution fill factor for each of the BCM's six household density classes; and three tables that provide per-foot costs for various sizes of copper distribution, fiber cable and copper feeder plant.[56] The costs in these tables are presented for both underground and aerial plant. Finally, the Input sheet includes discounted prices for both *Advanced Fibre Communication's* (AFC) and *AT&T's* "Subscriber Line Carrier" (SLC), the two fiber technologies employed by the BCM.[57] These discounted prices are derived from the baseline prices and percentage discounts described above.

56. See Appendix 3D

57. These are in cells Q89 and Q90, respectively.

The Main Logic sheet of the Loop Module assigns copper or fiber feeder plant of appropriate capacity to individual CBGs. As stated above, the distribution plant is always analog copper cable and is assumed to consist of four segments of equal size and capacity for each CBG. The main feeder route, however, may utilize (1) copper plant only, (2) fiber plant only or (3) a combination of copper plant and fiber plant. Copper plant is used for those CBGS where the total distribution distance (feeder and distribution) is less than 12,000 feet. Fiber plant is used when a CBG's total distribution distance exceeds 12,000 feet.[58] Where the model does deploy fiber, it then also deploys digital subscriber loop equipment — either an AFC or an SLC.[59]

After a copper or fiber technology has been assigned to each CBG, the BCM begins the process of ensuring that each main feeder segment has the capacity to meet the traffic demand of CBGs further out along the main feeder segment. It does this by assigning a "Segment Type 2" and "Segment Type 3" to CBGs whose main feeder segments contain multiple technologies. A CBG will have a Segment Type 2 if another CBG further out along the main feeder route employs a main feeder technology different from its own. For example, as illustrated below in Table 3.2, if the first CBG in a sequence of 3 CBGs, CBG 1, is served by a copper main feeder segment, and if CBGs 2 and 3 are served by SLC, then the Segment Type 2 for CBG 1 would be SLC. In this case, CBGs 2 and 3 would not have a Segment Type 2. If in the above example, CBG 3 was served by AFC, then CBG 1 would have a third Segment Type — AFC. Furthermore, CBG 2 would have a Segment type 2 of AFC and CBG 3 would have only a Segment type 1 — AFC.

58. The algorithm that determines the feeder plant type (Column F in Main Logic) does not consider capacity in the decision to use copper or fiber. In fact, fiber may be the correct economic choice for shorter distances in situations involving large blocks of capacity, and copper may be less costly even for longer distances if the capacity requirement is modest. Significantly, in Pacific Bell's Cost Proxy Model, the Company assumes a crossover point at 9,000 feet (see Chapter 9, below), but like the BCM does not allow that to vary based upon capacity. A major factor in the determining of the economic crossover point is the relationship between the cost of copper and the cost of the digital subscriber loop equipment that is used to "light" the fiber and to derive individual voice-grade (DS-0) channels therefrom. Unfortunately, the prices of the electronics are among the items that are considered highly proprietary, and are subject to heavy discounting from their respective manufacturers. Accordingly, not only is it impossible to verify the copper vs. fiber crossover assumptions incorporated into the BCM, it is also not possible to verify the pricing data that was used to drive that assumption.

59. An AFC (American Fibre Communications Next Generation Digital Loop Carrier System) is electronic gear that the BCM deploys only in the least dense of the six density zones (where there are fewer than five households per square mile) and the SLC (Subscriber Line Carrier Series 2000) is deployed in the other five density zones.

Table 3.2

Main Feeder Segment Types for CBGs in the Same Quadrant

Office	Quadrant	Block Group Seqnc. #	Segment Type 1	Segment Type 2	Segment Type 3
ABCDSTMA	1	1	Copper	SLC	--
ABCDSTMA	1	2	SLC	--	--
ABCDSTMA	1	3	SLC	--	--
ABCDSTMA	2	1	Copper	SLC	AFC
ABCDSTMA	2	2	SLC	AFC	--
ABCDSTMA	2	3	AFC	--	--

The BCM then assigns to each CBG an aggregate number of households for each main feeder technology, again for the purpose of calculating the capacity requirements of each main feeder segment. For example, as illustrated below in Table 3.3, the number of households "on copper" for the first CBG in a sequence of three CBGs that are all served by copper would be the total number of households in the three CBGs. The number of households on copper for the second CBG in this case would be equal to its own households plus those in the third CBG. Returning to our first example where CBG 1, CBG 2, and CBG 3 were served by copper, SLC and AFC respectively, the households on copper for the first CBG would equal the number of households in CBG 1, the households on SLC for CBG 1 would equal the number of households in CBG 2, and the households on AFC for CBG 1 would equal the number of households in CBG 3.

Table 3.3

Main Feeder Segment Types and Household Count for CBGs in the Same Quadrant

Segment Type 1	Households in the CBG	Segment Type 2	Segment Type 3	HH on Copper	HH on SLC	HH on AFC
Copper	250	--	--	400	--	--
Copper	100	--	--	150	--	--
Copper	50	--	--	50	--	--
Copper	300	SLC	AFC	300	150	100
SLC	150	AFC	--	--	150	100
AFC	100	--	--	--	--	100

The household totals for each main feeder technology are used to calculate the number and size of copper feeder pairs required by each CBG and the number and size of SLC and AFC fibers as well. In the case of CBGs served by copper main feeder, the BCM divides the number of households on copper by the feeder fill factor appropriate to the CBG's household density.[60] For example, a CBG with 6,000 households on copper and a household density of 1,000 households per square mile would, according to the BCM's default fill factors, have a feeder fill factor of .8 and thus require 7,500 copper feeder pairs.[61] In the case of copper plant, the BCM then translates the capacity requirements for each CBG into the number of maximum size cables that would be employed (4200 for copper feeder and 3600 for copper distribution by default) and the cable size necessary to carry any remaining fraction of total capacity. Sub-feeder and distribution plant carry only the traffic of their associated CBGs and so their capacity requirements are calculated on the basis of the number of households in that particular CBG as opposed to the total households served by that CBG's main feeder segment.

60. Column W in Main Logic.

61. 6,000/.8 = 7,500 copper feeder pairs. The corresponding calculations for SLC and AFC fiber requirements are found in columns L and O respectively. Column L calculates the number of SLC fibers for each CBG based on the assumption that each CBG with SLC main feeder utilizes a minimum of 4 dedicated fibers to provide up to 672 voice grade paths. Column O calculates the total number of AFC fibers for each CBG by dividing the number of households on AFC by the product of 672 and the fill factor for AFC electronics. This value in turn is multiplied by 4 to yield a final result.

Formulas in the Main Logic sheet labelled "Cable Structure %," "SLC Structure %," and "AFC Structure %" return percentages that add up to 100% for each CBG and serve to weight the copper feeder and fiber multipliers previously calculated in the Data & Calcs sheet of the Data Module.[62] For example, the cable structure percentage for a CBG that was served by cable feeder but which had a Segment Type 2 of SLC and a Segment Type 3 of AFC — meaning that other CBGs further out along the main feeder route are served by SLC and AFC feeder — would be 80% while the SLC Structure percentage and AFC Structure percentage would be 10% each. The copper multiplier for that CBG then, would be weighted by 80% and the fiber multiplier would be weighted by 20%.

The Shared Allocation and Costing sheets of the Loop Module cost out the network that has been developed in the Main Logic sheet by matching the copper and fiber cable sizes calculated in Main Logic with per foot plant costs for copper feeder, copper distribution and fiber. These costs are located in three tables in the Costing sheet that include per foot costs for each plant type and cable size for each of the six household density classes. For example, column H in the Costing sheet looks up the appropriate per foot cost for the maximum size copper feeder calculated in Main Logic and multiplies this cost by the number of maximum size cables employed and the length of the Main Feeder segment. The cost for other plant types is calculated in much the same way. Formulas in the Shared Allocation sheet then assign a proportion of plant costs to each CBG and then to each household using the "Segment Type" and "Household Count" columns described above. Structure cost percentages from Main Logic are applied to each plant type and incorporated into final cost calculations for total copper, total SLC, and total AFC feeder. These three columns are combined in a Total Feeder Cost column and added to the Total Distribution Cost to yield a Grand Total Loop Cost. The Output sheet of the Loop Module then, includes this Total Loop Cost as well as a Loop Cost per Household column, a household density range, and a measure of the average Total Loop Length for each CBG.

The Output Module

The Output Module adds the cost of switching plant to the outside plant calculations completed in the Loop Module. There are four sheets in the Output Module titled, "Data & Calcs," "Tables & Inputs," "Results," and "Summary."[63] The BCM also includes a formula that multiplies the number of households in each CBG by a "Business Gross Up

62. These are in columns Q, R, and S, respectively.

63. As before with the output of the Data Module, the output from the Loop Module is copied and pasted into the Data & Calcs sheet of the Output Module.

Factor" of 1.75 which is a user input in the Tables & Inputs sheet.[64] This factor is described in the Joint Submission as the ratio of total lines to residential lines and is used to account for economies attributable to the presence of non-residential lines.[65] The "new" grossed up number of households is converted into a total switched line count for each CBG by dividing the grossed up number of households by the switch fill factor.[66]

The switched fixed cost per line is calculated as follows: The formula first multiplies the BCM's default fixed cost per switch of $647,526 by the "Basic Local Service Factor" or the percent of the switch cost that is allocated to the line.[67] This product is divided by the total number of lines in the wire center to yield a total fixed switch cost per line. The BCM then uses a fixed common cost per switch of $238.87 that was generated through a regression analysis of per line costs for a Northern Telecom DMS 100 switch for 20 different line sizes.[68] This fixed common cost per switch is added to the switched fixed cost per line described above and multiplied by the BCM's default Switch Land and Building Factor of 1.043 to yield a total Switched Investment per Line.

The Tables & Inputs sheet also includes the two cost factors used by the BCM. The first cost factor of 31.6765% was calculated on the basis of historical accounting data and total expense levels of Tier 1 LECs utilizing 1994 ARMIS Form 43-01, while an alternate cost factor of 22.97% is based on the Hatfield/MCI study approach and reflects limited expense categories and amounts.[69] Both of these cost factors are applied to the Total Investment per line to yield two separate annual costs. Annual cost figures are converted to monthly costs which are then compared to the BCM's three benchmarks for high cost support of $20, $30 and $40 to yield the total monthly support requirement if any for each CBG. Finally, the Summary sheet presents the aggregate support at the three benchmark support levels for all of the CBGs in the state under the two different cost factor scenarios. Statewide totals for the sum of households, average total loop length, average loop cost per household, and average total investment per line for each of the six density classes are also presented in the Summary sheet.

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64. See Column M of Data & Calcs, which is labelled "Households Including Business."

65. Joint Submission, September 12, 1995, at 35.

66. The BCM's default fill factor of 80% is located in cell H17 of Tables & Inputs.

67. See column C of the Tables and Input sheet. The percentage of the switch cost that is allocated to the line is a combination of the percent of switch costs that are non-traffic sensitive and the percent of traffic sensitive costs that is local. The BCM's default values for these percentages are 70% and 30% respectively and yield a total switch cost allocation figure of 79%.

68. *Op. cit.*, footnote 65, at Attachment 1.

69. *Id.*, at 4.

Summary of the uncorrected BCM results

The Joint Sponsors' Submission of December 1, 1995 contained average monthly costs for local exchange service for the entire nation (except Alaska) of $23.04 and $16.71 respectively for the Annual Cost Factor 1 (the embedded cost factor) and the Annual Cost Factor 2 (the Hatfield/MCI cost factor). These results and the national universal service support requirements for the three benchmark support levels are presented below in Table 3.4.

Table 3.4

Summary Results of the BCM
National Total (excluding Alaska)

	Annual Cost Factor #1	**Annual Cost Factor #2**
Annual Benchmark Cost	$25,377,893,663	$18,402,608,162
Support at $20	$8,082,313,345	$3,977,572,193
Support at $30	$4,916,517,444	$2,203,441,910
Support at $40	$3,208,565,853	$1,372,205,121
Average Monthly Cost	$23.04	$16.71

Source: Joint Submission of December 1, 1995 at II-2.

As Table 3.4 highlights, the BCM's aggregate national support requirement ranges between $1.4-billion and $8.1-billion, depending upon the cost factor selected and the price level being supported. If one considered the entire country to be the relevant "study area" — this is not an approach we recommend — and used the Annual Cost Factor 2, universal service support would be required only if the price threshold were set below $16.71.[70] In fact, one of the key questions facing policy makers is to define the appropriate boundaries of the "study area." This issue is discussed in more detail in Chapter 6, below.

70. Therefore, on *average*, any price above $16.71 would exceed the average cost. Furthermore, a household that subscribes to basic local exchange service also typically subscribes to discretionary services (such as call waiting) and makes toll calls. Thus on average, the telecommunications revenues associated with providing any given household with basic local exchange service are significantly above the cost for basic local exchange service.

The data shown in Table 3.4 are based upon the printed document submitted by the Joint Sponsors to the FCC on December 1, 1995. However, the results that are generated by actually running the most recent *public* version of the BCM (i.e., September 12, 1995) with the most recent *public* copies of the state files (i.e., December 1, 1995) do not coincide with the results submitted to the FCC in the Joint Submission.[71] The Joint Sponsors updated the BCM since the September filing with, at a minimum, an expanded list of soil types.[72] We incorporated these new soil types into ETI's analyses, which may explain the discrepancy of $0.08 between the Average Monthly Cost for cost factor #2 for Washington State, under the ETI run of the BCM and the Joint Sponsors' run of the BCM.[73] In Chapters 4 through 8, below, where we discuss the results of our analyses, we use as our "status quo" benchmark the results that we obtain by running the model, even though these differ slightly from those published by the Joint Sponsors.

3.2 The Joint Sponsors have, in some ways, facilitated public scrutiny of the model, and, in other significant ways, frustrated a close examination of some key parameters and algorithms

The Joint Sponsors have, at one level, made a commendable effort to develop and make available a "public" cost proxy model. The demonstration version of the model and data for six states has been available for public examination since September 1995, and data for the entire country has been available since December 1995. The Joint Sponsors have also held four workshops to facilitate use of the model by interested parties.[74] Furthermore, the Joint Sponsors have been responsive to various criticisms of the model, and where they

71. In fact, running the most current public version of the BCM with the state data files generates error messages because the September version of the BCM does not account for all soil types. For example, in the Washington State WADTIN_1.XLS File, these are the unspecified soil types: BY-FSL, BY-LS, CBV-MUCK, CBX-SIL, ST-VFSL, STV-LS, STX-FSL, and STX-LS, which do not appear in the soil "look-up" tables sheet (beginning at row 38 column A) of the data60~1.XLS file. These abbreviations correspond to soil types bouldery and fine sandy loam, bouldery and loam, very cobbly and muck, extremely cobbly and silt, stony and very fine sandy loam, extremely stony and fine sandy loam, and very stony and loamy sand. These omissions were overcome by obtaining a more up-to-date Surface Texture Table from the Joint Sponsors and inputting this new information.

72. Conversation with James Dunbar (Sprint) on March 25, 1996. See Appendix 3E for the up-to-date, complete list of soil types.

73. The printed results presented by the Joint Sponsors in the December 1, 1995 filing showed Washington State's average monthly cost to be $17.02 for cost factor #2. After we incorporated the new soil types into the September 12, 1995 version of the BCM, our analysis yielded an average monthly cost of $16.94.

74. Joint Submission, at I-3.

concur and believe feasible, have indicated their intent to correct the BCM accordingly.[75] Finally, because all of the algorithms, inputs, and formulas that are in the full model are also in the demonstration model, many of the attributes of the model can be readily evaluated through use of the demonstration model alone.[76]

There is, however, one significant aspect of the BCM that belies its characterization as an "open" model and that frustrates efforts at pursuing a comprehensive and objective analysis. The Main Logic, Shared Allocation, Costing, and Output sheets of the Loop Module are password protected and cannot be adjusted by the user.[77] The Loop Module, as described above, is perhaps the most important of the BCM's three separate modules as it assigns plant types and costs to the outside plant portion of the network. Among the types of analyses that cannot be readily performed because of the password protection are the following:

- Adjustment of the 12,000 foot crossover point for the deployment of copper or fiber feeder plant.
- Alteration of the allocation of plant and structure costs among CBGs in the same quadrant.
- Adjustment of the plant costs associated with different size cables of all plant types.

The overall credibility of the BCM is diminished by the Joint Sponsors' decision to "lock" these aspects of the model and to prevent their modification by other users. As we discuss below in Chapter 6, preliminary efforts to modify one of these three "locked" parameters — the copper/fiber crossover point — suggests that the BCM has adopted a fundamentally uneconomic decision rule that appears to result in a significant overstatement of the costs that are required by LECs to furnish primary residential access lines.

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75. *Ex parte* submission in CC Docket No. 80-286 by Glenn Brown, Executive Director—Public Policy, US West (" *Ex parte* submission"), January 26, 1996. *Ex parte* submission, February 21, 1996.

76. The difference between the demonstration model and the full model is simply the size of the database, which, in turn, affects the hardware required to run the model. The "Demo" can be run on an ordinary personal computer, where as the full model requires substantial computer requirements. The full model is designed for use with up to 600,000 CBG input records while the demonstration model includes space for only 50 CBGs.

77. The Joint Sponsors consider the password proprietary to the developers of the model and thus will not divulge it to others. Conversations with Mark Bryant, MCI, March 27, 1996; Peter Copeland, US West, April 1, 1996.

3.3 Purposes of the BCM analyses undertaken for this report

There are several distinct purposes of the analyses of the BCM that we have undertaken here. They are to:

- Gain hands-on familiarity with the algorithms used in the model, e.g., the relationship of engineering assumptions to cost results;
- Identify the sensitivity of the results to some of the individual parameters, variables and assumptions; and
- Analyze the implications of changing certain parameters to derive what we believe are more accurate results.

For the purposes of this report, we ran the model for illustrative samples of CBGs that we selected from the full-state data input files, and we also ran the model for the entire state of Washington for most of our analyses. The analyses of very small samples are clearly not intended to be either statistically significant in any fashion nor comprehensive, but rather to illustrate some probable results and to frame future analyses that should be undertaken by or on behalf of the Joint Board. We believe that the analyses undertaken in this report of an entire state are, however, indicative of the effect of changing the BCM parameters upon the national results.

Washington State has 1,871,765 households and 4,542 CBGs (which places it 17th in the number of census block groups). Washington State includes a diversity of natural terrain and population densities, ranging from Seattle (a metropolis with a population of over 500,000 and a density of over 6,000 people per square mile) to rural areas, including 21-million acres of forested land.[78] Other than the cities of Seattle, Spokane and Tacoma (the latter two each having populations in the 175,000 range), no other city in Washington has a population approaching 100,000. The densest CBG has an average of 33,713 households per square mile,[79] and the most sparsely populated CBG has an average of 0.03 households per square mile.[80] According to the BCM, within the State of Washington, the monthly average line cost, as measured within a CBG, ranges from a low of $5.70 per

78. See Appendix 3F for the classification of households in Washington among the BCM's six density zones.

79. There are a total of 885 households in a 0.03 square mile area in this CBG which is in Seattle (CBG #530330074006).

80. There are a total of 22 households in a 711 square mile area in this CBG which is in Twisp, a rural area in the northern part of the State located in Okanogan County (CBG #530079601001).