AN ECONOMIC EVALUATION

OF NETWORK COST MODELS

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I. Introduction and Summary

The purpose of this paper is twofold. First, we will explain the economic principles that underlie two cost models licensed by Telcordia—the Switching Cost Information System ("SCIS") and the Common Channel Signaling Cost Information System ("CCSCIS"). Second, we will demonstrate that these models are consistent with the rules and principles used by regulators to determine the costs associated with network elements and interconnection.

These cost models have both a business planning and a regulatory function. On the business planning side, the models have been consistently used by telephone companies, in particular by most of the Regional Bell Operating Companies ("RBOCs"), for over twenty years to determine their costs of providing specific services. These companies operate highly complex and investment-intensive computer systems and network infrastructure. The same network equipment is used to provide many different services to many different customers. Accurately assigning network costs to specific services is, therefore, a highly complex, but critically important, part of business planning. These companies have depended upon Telcordia's models to determine accurately the individual costs of providing each of their telecommunications services over a common network.

Telcordia's models have also been endorsed and adopted by regulators throughout the United States and the rest of the world. State regulators have for decades used Telcordia's models to determine rates for the telecommunications services offered by incumbent local exchange carriers. Those models have also been endorsed in ratemaking proceedings by the Federal Communications Commission ("FCC"). For example, in December 1993, the FCC conducted a rigorous examination of Telcordia's SCIS model and found it to be "fundamentally sound" and "internally valid." *Open Network Architecture Tariffs of Bell Operating Companies*, Order, CC Docket 92-91, ¶¶ 82, 83

(Dec. 15, 1993) ("ONA Order"). As many as 12 foreign carriers have used Telcordia's models in developing cost support for regulatory rates and strategic business purposes.

More recently, state regulators and the RBOCs have come to rely upon Telcordia's models in determining fair prices for the leasing of RBOC network components, switching capacity, and services on an unbundled basis to Competitive Local Exchange Carriers ("CLECs"), as required by the Telecommunications Act of 1996. Across the country, at least thirty state public utility commissions have used Telcordia's models to help determine the appropriate price for unbundled network elements ("UNEs").[1]

Despite this widespread use and long-standing dependence upon Telcordia's cost models—including its own prior endorsement of those models—the FCC recently has expressed certain concerns about cost models in general as a means of determining appropriate charges, and about Telcordia's models in particular.[2] Specifically, in the context of calculating the costs of introducing telephone number portability, the FCC inquired whether an analysis of actual and planned expenditures might produce a more accurate estimate of incremental costs than a cost model. The FCC also expressed concern that, in this particular context, Telcordia's models might result in some double-counting of embedded costs and that, in any event, the models could not be easily verified because they were not publicly available.

These concerns are unfounded. As we will demonstrate in the body of this paper, Telcordia's cost models produce more accurate estimates of the incremental costs of services than would be

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[1] *See* Addendum 1: Listing of State Regulatory Proceedings on TELRIC in which Telcordia's costing models have been used.

[2] Order Designating Issues for Investigation, Telephone Number Portability, CC Docket No. 99-35, DA 99-374 ¶ 17 (rel. Feb. 26, 1999).

produced by a simple accounting for actual and planned expenditures. Or, to put the point another way, Telcordia's cost models do analyze actual and planned expenditures, but they do so from a forward-looking, long-run perspective that corrects for and smoothes out distortions that would arise from a simple compilation of actual historical and planned expenditures. The FCC's departure from such a forward-looking, long-run approach in the number portability context was unexplained and, frankly, inexplicable in terms of the cost accounting principles upon which the FCC itself has insisted in all other contexts.

Furthermore, the models do not double-count embedded costs. Nor are Telcordia's models in any sense a "black box." The models are publicly available to any party willing to sign a non-disclosure agreement. That is all the FCC has requested, and that is all that could be reasonably required.

Despite the FCC's recent expression of concern, the fundamental concepts underlying these models have not changed; nor have the regulatory conditions that led regulators to adopt Long Run Incremental Cost ("LRIC") approaches to calculating costs. SCIS and CCSCIS today are the same flexible models that have been endorsed and used extensively by regulators and RBOCs; they are still relevant, effective, and readily verified.

II. The Purpose of a Cost Model

In Appendix A to this paper, we review in detail the economic literature on cost models. Briefly, cost models translate the investments and expenditures required over some period of time into a meaningful cost estimate for specific functions and services. It is impossible to make a reasonable estimate of virtually any sort of costs without a "model." Cost estimates that do not employ a model will be highly and inappropriately sensitive to the timing of expenditures and random events.

An analogy is that of estimating the cost of driving a car one mile. While it is relatively easy to drive a car for that distance and not incur any immediate, specific costs, there are still costs associated with driving the car. Even aside from the embedded cost of purchasing the car in the first place and filling the tank with gas, there are forward-looking incremental costs, such as maintenance, the need to refill the tank, and the eventual need to replace the car. If you just look at any particular mile or group of miles driven and inquire as to the "actual expenditures" during that period, you are likely to get a highly random and inaccurate sense of "cost." It is critical to use a model to determine accurately the cost per mile of driving the car.

It is, moreover, relatively simple to construct a model for determining the cost of driving a car. There is only one principal use for the car and the list of relevant investments and expenditures is circumscribed and easily calculated. A telecommunications network, by contrast, is highly capital intensive, incorporates a myriad of different technologies and types of equipment, and is used to provide many different services to many different customers. Constructing a cost model for such a network is much more complicated. But, for just that reason, a cost model is all the more critical in getting a proper sense of network costs. Regulators must employ sophisticated cost models—like Telcordia's SCIS and CCSCIS—because (in the FCC's words) "there is no other practicable method by which to reasonably and consistently recognize the use and associated investment of [the network] in a variety of service offerings." ONA Order ¶ 8.

The FCC itself has required the use of cost models to determine pricing for UNEs. The FCC concluded that such pricing must be based on Total Element Long-Run Incremental Cost

("TELRIC").[3] TELRIC looks not to actual, historical expenditures, but to the projected costs of providing a particular UNE to a CLEC. Any such forward-looking approach requires a cost model. TELRIC cannot be determined without such a model.

Telcordia's cost models are consistent with the Total Service Long-Run Incremental Cost ("TSLRIC") concept, which is conceptually similar to TELRIC. The only appreciable differences between these two concepts are (1) that TELRIC estimates the incremental cost of network *elements*, while TSLRIC estimates the incremental costs of network *services* and (2) in practice TELRIC tends to apportion certain volume-insensitive costs shared by multiple elements to particular elements. The incremental cost of an *element* differs from that of an otherwise similar *service* primarily because the latter includes the costs of serving retail rather than wholesale customers. But models consistent with TSLRIC, such as those developed by Telcordia, are readily adaptable to reach TELRIC results for particular network elements. Indeed, in its Local Competition Order, the FCC described its method for setting prices for the unbundled network elements as merely a special case of TSLRIC. Moreover, as already noted, some thirty state regulatory commissions have already adapted Telcordia's TSLRIC studies to reach TELRIC results for individual elements.

TSLRIC and TELRIC methodologies share certain important characteristics for determining pricing for telecommunications network elements and services.

First, costs identified in studies based on TSLRIC/TELRIC concepts are *incremental*. TSLRIC/TELRIC studies include costs that are incurred only on behalf of that service or element, are justified by that service alone, and would not be incurred had the service not been introduced.

[3] Implementation of Local Competition Provisions in the Telecommunications Act of 1996, First Report and Order, ¶¶ 672-707 (Aug. 8, 1996).

Conversely, TSLRIC/TELRIC studies do not include any costs that would be incurred if the service were not produced.

Second, costs identified in a TSLRIC/TELRIC analysis are *forward-looking*. Embedded and historical costs are ignored in favor of the lowest costs incurred using currently available technology whose cost can be reasonably estimated based on available data. Although some versions of TSLRIC analysis assume the existing configuration in terms of switch and facility locations, they do not estimate the historical cost of the actual equipment in place.

Third, the forward-looking costs identified in TSLRIC/TELRIC studies are *long-run* costs.[4] In the long run, plant and equipment would eventually need to be replaced by the best and most cost effective equipment available, and it is that forward-looking replacement cost for new equipment (rather than the embedded historical cost for existing equipment) that is relevant to the cost study. Thus, cost studies based on the TSLRIC/TELRIC methodology generally do not consider capital costs to be sunk, and the costs derived from these studies reflect the optimal mix of plant and equipment necessary to produce the required output.

These studies are effective, moreover, because they take into account that each new increment of traffic uses capacity that would otherwise be usable for the growth of other services or for the introduction of new services. Each unit of traffic thus contributes to the eventual need to augment and enhance the network. A strictly short-run cost methodology not accounting for these costs would generate erroneous results.

Fourth, TSLRIC/TELRIC studies identify both *volume-sensitive* and *volume-insensitive* costs. *Volume-sensitive* costs are costs that vary with changes in demand for a service or

[4] In Appendix A, we describe how the definition of long-run depends on the business decision being analyzed.

functionality. Switching costs are a classic example of volume-sensitive costs. The more switching minutes required, the greater the capacity (and hence cost) of the necessary switch. *Volume-insensitive* costs do not vary with the changes in the level of demand. Right-to-use fees for switch software are a good example of volume-insensitive costs. Once the switch is in place, these costs are fixed regardless of usage. Both types of costs must be included, but accounted for separately, in constructing an accurate cost model.

III. Telcordia's Cost Models Are Economically Sound and Comply with Existing Regulatory Mandates

SCIS, which is described in detail in Appendix B, is a computer-based model that is used to determine the actual costs (investments) associated with using a switch to perform a particular central office service or function. SCIS encompasses a family of 25 modules that analyze costs for 8 switching system technologies from switch manufacturers. SCIS develops a 'model office' which is an average of all the existing switches of a certain type in a carrier's network. As the FCC has explained, "SCIS employs the model office to generate unit investments [or costs] associated with providing each [service] over a particular switch type." <u>ONA Order</u> ¶ 7. CCSCIS, which is a variant on SCIS, is a computer-based model that is used to determine the unit cost associated with using various types of signaling links for a particular service or function. Both CCSCIS and SCIS are upgraded several times each year to reflect changes in the software and hardware used in switches and signaling networks.[5]

[5] In this paper, we will focus our discussion on SCIS. The same economic principles, however, also apply to CCSCIS.

A. Telcordia's Cost Models Are Fully Consistent with Economic Cost Principles

In conjunction with its Open Network Architecture proceeding, the FCC conducted an exhaustive review of Telcordia's SCIS model. Telcordia (then Bellcore), in cooperation with switch vendors, made a version of SCIS available, so that carriers who opposed the use of SCIS could observe the model in operation.

At their own expense, the Regional Bell Operating Companies ("RBOCs") hired an independent auditor (Arthur Andersen and Co.) to review SCIS and to file a report with the FCC. Arthur Andersen conducted "[a] detailed review of the SCIS model, its architecture and information flow, [and] underlying cost principles and specific methods. This evaluation involved extensive analysis of actual . . . investment calculations, underlying investment equations, model options and their implications, and model sensitivities to changes in key parameters. Arthur Andersen also reviewed in detail the model development process, software implementation and testing, ongoing support, documentation and training - all of which influence the reasonableness of the model for service costing."[6]

At the end of this exhaustive review, Arthur Andersen concluded that the SCIS model is "fundamentally sound and provides reasonable estimates of switching system investment attributable to service and feature usage of the switch."[7] More specifically, Arthur Andersen made four "findings," which it explained and documented in the body of the report:

- The costing principles inherent in SCIS are appropriate for estimating long run incremental investments attributable to switching system usage, and the specific methods for implementing these principles are reasonable.

[6] Independent Review of SCIS/SCM Report at 2 (July 1992).

[7] *Id.* at 7.

- SCIS accurately estimates the cost of actual switching systems engineered according to manufacturer engineering rules as evidenced by Bellcore's validation procedures and results.

- Extensive software development controls and testing are used to assure SCIS models are properly implemented and installed by model users.

- Finally, although SCIS is a complex model requiring considerable understanding of switching systems and service costing, the model documentation, training and technical support are adequate to provide reasonable support for the model in use. [*Id.*]

After considering the Arthur Andersen report and comments filed by interested parties, the FCC's independent staff review of the SCIS models also concluded that the model was "internally valid." ONA Order ¶ 83. We have reached the same conclusion in our analysis.

One reason why SCIS identifies and classifies economic costs properly is that it is based on the well-established and widely accepted capacity cost concept. In Appendix C, we provide a detailed economic analysis of capacity costs. As we there explain, the capacity cost concept is firmly linked to the crucial principle of cost-causation—how investments a firm is required to make change to accommodate an increase in demand. Starting with this bedrock principle, the capacity cost approach then identifies and classifies costs using widely-accepted practical calculations that produce reasonable estimates of economic costs. The exact calculations, however, will vary depending upon the purpose of the inquiry.

In other words, the SCIS models can readily accommodate both the indefinite long-run addressed by TSLIRC/TELRIC studies and intermediate-run business decisions, such as whether or not it is economic to add capacity to an existing switch. In the former case, the models depict the capacity costs of particular switches (or a group of switches representative of an area) from the beginning of their lives into an indefinite time horizon. The models also examine how these costs would change if demands on the switches changed. For intermediate run studies, the SCIS models can be used to calculate the forward-looking economic costs of using particular switches that are already in place and have additional years to serve.

When SCIS is used to calculate costs for a new switch, the relevant calculation identifies the minimum unit price that can be charged for usage, in the sense that such a price would recover the additional costs associated with increased usage, but would not recover costs associated with maintaining the spare capacity that arises from the lumpy nature of switching capacity.

When a switch is in the middle of its life, SCIS can be used to determine how much investment will need to increase to accommodate an increase in demand. Existing capacity is considered to be a sunk cost and is therefore not counted: if existing capacity is sufficient to accommodate such an increase, volume-sensitive costs are set at zero. But SCIS can also be used to address the impact an increase in demand will have on the expected addition of capacity to the switch at an intermediate point in its life-span.

After identifying volume-sensitive costs, SCIS also provides a number of options for identifying and assigning non-volume-sensitive costs. Consistent with the usual practice in unbundled element studies of uniform assignment of non-volume-sensitive costs, SCIS can be run in the average cost mode, thus adding spare capacity costs to the marginal costs. The actual utilization (processor utilization factor) is calculated as a weighted average of utilization over the switch's time in service, where the weights are the annual discount factors. Defining average utilization in this way produces the following result: if the average cost per unit were charged to actual usage over the life cycle of the switch, the present value of the resulting revenue stream would equal the present value of cumulative investment.

The SCIS models also properly provide for other assignments of non-volume-sensitive costs. First, by choosing the marginal cost mode, non-volume-sensitive costs are not explicitly identified.

Implicit in this fact is the fundamental economic principal that efficient recovery of these costs depends on the demand characteristics of the various services that make use of switching resources. For example, economic efficiency is promoted by recovering proportionately more non-volume-sensitive costs from less elastic services. Thus, the costs produced by the marginal cost equations can be viewed as price floors, with the actual recovery of non-volume-sensitive costs treated as a pricing, rather than costing, decision.

The SCIS models are also flexible in their ability to answer different types of costing questions. For example, if the switching facilities being studied are capable of offering a variety of services (as is generally the case), SCIS can be used to attribute and assign to each such product the costs incurred from producing the volumes in question. These costs would include all the volume-sensitive costs associated with producing the appropriate volume of the service (unit cost times volume) plus the requirement that non-volume-sensitive cost be recovered in the prices for the products in question. Alternatively, if the firm is viewed as a producer of wholesale inputs used by retail firms, all of the volume-sensitive costs plus a uniform assignment of the non-volume-sensitive costs are assigned to network elements, consistent with the economic concept of average incremental cost and the FCC's prescription to use average utilization factors. In this way, SCIS can provide information for both regulatory applications (UNEs) and business decisions (retail services).

B. Various Criticisms Directed at the Cost Models are Unfounded

In its recent proceeding on Local Number Portability ("LNP"), the FCC departed from TELRIC (and indeed from any long-run incremental cost approach) in determining the costs for implementing LNP, preferring instead to conduct a study based on a review of vendor invoices for various pieces of equipment. This appears to be an aberration based on the particular concerns in that proceeding. The FCC did not, for example, indicate any general departure from its TELRIC approach to calculating the price of UNEs. And, as explained above, TELRIC necessitates the use of a cost model, rather than simply a tally of vendor invoices.

Moreover, the FCC did "not question the fundamental soundness" of the SCIS and CCSCIS models in its July 1999 Order, even though it disallowed the use of these models in assessing tariffs for LNP. LNP Order ¶ 69. The FCC did, however, suggest that "[t]he models do not accurately track only new, incremental costs" because they (in the FCC's view) improperly "included costs attributed to usage of network components that were already in place before the implementation of number portability." LNP Order ¶¶ 70, 72. The FCC also expressed concern that Telcordia's models might result in some double-counting of embedded costs. And the FCC expressed concern that the models could not be easily verified because they were not publicly available.

As explained below, these, and other criticisms of Telcordia's cost models that were raised by parties to that proceeding, are unfounded.

1. The FCC's approach to costing in the Local Number Portability docket is fundamentally at odds with the very costing principles that the FCC has firmly endorsed in its other proceedings. As we explained in detail in Part IIIA, *supra*, Telcordia's SCIS models are fully consistent with the latter, and the FCC's *sui generis* departure from those principles in the particular context of assessing the costs of implementing local number portability should not be viewed as any reflection on the validity or soundness of Telcordia's models.

This departure from its own established principles is unfortunate. The FCC is the most influential telecommunications regulator in the world. As such, it has a responsibility to proceed with some consistency in formulating and applying the costing principles that are best designed to promote competition and regulatory accuracy. The FCC should not make *ad hoc* exceptions to those principles to reach a particular result in a particular matter. Yet, by its own admission, that is precisely what the FCC did in the Local Number Portability proceeding.

2. Neither SCIS nor CCSCIS includes any embedded costs or any costs attributable to other elements and services. As explained above, SCIS and CCSCIS both track only incremental costs attributable to a particular service or element and they do so on a purely forward-looking basis. The Commission itself acknowledged this fact only a few years previously in its Open Network Architecture proceeding. ONA Order ¶ 21 ("SCIS is a forward-looking model that calculates investment based on switch replacement costs rather than historical or embedded costs, and the more recent SCIS software provides the most up-to-date design and pricing basis from which to estimate future [service-specific] investment.").

Nor does accounting for the cost of capacity result in double counting. Telcordia's models are specifically designed to prevent double counting. The modeler must specifically identify if any part of the feature is already covered by existing tariff structures; the same is true for the "model office" approach.

3. Valid cost calculations depends not only on the theoretical validity of the cost model, but also on whether proper values for critical inputs are used. Among the most critical of such inputs are the prices (and price structures) a carrier pays for switching equipment, *e.g.,* processor capacity. Some parties have claimed that SCIS underestimates the relative proportion of switch investment driven by growth in lines (rather than growth in usage per line). They note that some switch capacity becomes exhausted due to line growth rather than usage and that telephone exchange carriers purchase switching resources at a fixed price per line under the contracts now in place with switch vendors.

The problem with these claims is that flat rate pricing does not provide incumbent local exchange carriers ("ILECs") with the proper indicia of how usage affects costs. Just as charging nothing (or too little) for usage could cause customers to use the resource more, ultimately exhausting capacity on the basis of usage, flat-rate vendor pricing for switching capacity is not economically viable over the long term (beyond, say, the duration of a promotional contract) from a production perspective.

In any event, where switching capacity exhausts on lines, rather than usage, SCIS does provide an option that is consistent with economically efficient pricing principles. By assigning spare capacity costs to lines, rather than usage (and assuming that prices reflect this assignment), economic efficiency is enhanced, because the demand for subscriber lines is generally less elastic than the demand for usage services.

4. Another issue in conjunction with switching costs is that switch vendors typically employ discounts off the list price and provide steeper discounts for new installations than for additional lines added to existing switches. These vendors tend to use new switch installations as a loss leader to help "lock in" high-margin add-on software and hardware revenue over the life of the switch.

Proper representation of this "razor/razor blade" pricing strategy in cost studies is both complicated and controversial. The controversy has arisen primarily in studies purporting to implement the TELRIC prescription that forward-looking technology be used. An extreme interpretation of this requirement is that brand-new equipment with sufficient capacity to handle current volumes be deployed. And since brand-new equipment has a deeper discount, switch cost models should price such equipment using the new equipment discount only. In contrast, real firms buy both new and add-on equipment. Therefore, if the objective of the cost study is to represent the costs an efficient firm actually incurs, both discounts should be reflected in the cost study. In contrast, other parties have insisted that investment prices should reflect some appropriately weighted average of the new and add-on discounts.

Competing interpretations of TELRIC are between a realistic view of a network (including switching) growing over time versus a brand new complete network emerging from thin air. However, there is a distinction between a long-run model and a "snapshot" model that is not necessarily real.

To establish an equivalence between a long-run view and a "snapshot," observe that cost models typically produce a fixed annual cost over the life of the investment in question. This cost can be viewed as a "steady-state" average cost. A snapshot of a typical year would show that the investments in switching facilities in that year were a mix of new lines and growth lines and that the business making that investment would expect to earn a return on and of that investment based on the prices it actually paid for that equipment. This price would entail a weighted average of the new and add-on vendor discounts. At no time could one take a "snapshot" that showed the company purchasing all of its lines at the new line discount. Another way to represent the firm's pricing problem is to consider a scenario in which the carrier "sells" switching services at a single up-front price and that price is the same for customers served by new and add-on lines. In this case, it is clear that the single price would be the weighted average of the price of the new and add-on lines acquired in a particular year.

The magnitude of the difference between assuming all lines are new on the one hand and that they are a mix of new and add-on lines on the other depends on (1) what the mix actually is and (2) how much the prices for new and add-on equipment differ. These two factors would differ for different carriers, depending on the types of contracts they negotiate with vendors and the characteristics of their service territories. Data from Northern Business Information ("NBI") suggest that both factors are significant. Over the period from 1993-1999, the NBI data indicate that (1) only about one-quarter of sales revenue and one-third of lines were new (the rest were add-ons) and (2) the price for add-on lines was about 50 percent higher than the new line price. Assuming that these figures are accurate and applicable to steady state conditions, the average prices for a mix of new and add-on lines would be about one-third higher than the price for new lines only.

5. Finally, we wish to address the suggestion that the Telcordia cost models cannot be easily verified because they contain proprietary elements and are not, therefore, publicly available. Telcordia's models do indeed contain proprietary elements. That is to be expected of a complicated and important piece of intellectual property that has taken years to develop and refine and that is constantly updated at great expense. In a competitive environment it is critical that firms be permitted to maintain the confidentiality of their proprietary information.

The fact that SCIS and other models contain proprietary information does not mean, however, that those models are not "publicly available." Confidentiality concerns can be, and have been, addressed by the signing of a standard non-disclosure agreement ("NDAs"). The FCC has standard procedures for dealing with confidential materials.[8] NDAs are common in the industry and impose no undue burden either on regulators or other parties to proceedings. Indeed, in the course of various regulatory proceedings, Telcordia has provided hundreds of diskettes containing SCIS's executable software code for the parties' use in those proceedings. Thus, the model information is in fact widely and conveniently available.

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[8] Telcordia accepts the FCC's own model NDA adopted in General Counsel Docket 96-55 for use in tariff and other proceedings.

It is worth noting the contrast between the ready availability of Telcordia's cost models and the proxy model adopted by the FCC in its Universal Service Proceeding, CC Docket No. 96-45. In that proceeding, the FCC purportedly adopted a requirement that any model used in the proceeding had to be "open to the public." *See* Fifth Report and Order ¶ 78 (rejecting the Benchmark Cost Proxy Model because of its reliance on "proprietary" information). And yet the proxy model adopted by the FCC uses PNR's proprietary National Access Line Model to generate surrogate geocode data. PNR allows parties to review the details of this model only on PNR's premises.[9]

Proprietary information is simply unavoidable in a complicated context such as this. The key point is to deal with confidentiality concerns with a standard NDA while maintaining the open and public nature of the proceeding.

IV. CONCLUSION

The incremental cost methods in these models are economically rigorous, yet flexible enough for not only regulatory applications such as establishing prices for interconnection and unbundled network elements, but also to support business decisions such as whether to add a new pricing option to the currently available options. Although these seemingly unrelated applications differ in detail, the fundamental question in both cases is the same: do the prices for the services to be sold cover the costs that they cause the firm to incur?

An important component in analyzing the capacity required to accommodate incremental volumes is the capacity cost method. This method, which is a central component of the Telcordia

[9] Federal Communications Commission, *Federal-State Joint Board on Universal Service* and *Forward-Looking Mechanism for High-Cost Support for Non-Rural LECs*, Tenth Report and Order, adopted October 21, 1999 (released November 2, 1999), ¶ 60.

models, flexibly addresses a wide range of long-run incremental cost (LRIC) applications, not just the total service (TSLRIC and TELRIC) currently being widely used by regulators. We have examined these models by examining their description, and in the case of SCIS/MO, comparing key algorithms and equations to the requirements of the capacity cost approach. Based on this review, we conclude that with accurate physical descriptions of the facilities being analyzed and reasonable estimates of input prices and demand, these models produce economically valid network cost estimates that are appropriate to support both regulatory and business decisions. In addition, these models generally meet the widely-accepted requirements for calculating forward-looking incremental (economic) costs that have been recently adopted in the US, the UK and Europe.

Addendum 1: List of state regulatory proceedings on TELRIC in which Telcordia's costing models have been used

Before the Alabama Public Service Commission:

Petition by AT&T Communications of the South Central States, Inc. for Arbitration of Certain Terms and Conditions of a Proposed Agreement with GTE Alabama, Inc., and Contel of the South, Inc. Concerning Interconnection and Resale under the Telecommunications Act of 1996, Docket No. 25704

Before the California Public Utilities Commission:

Alternative Regulatory Frameworks for Local Exchange Carriers, I.87-11-033
Rulemaking on the Commission's Own Motion to Govern Open Access to Bottleneck Services and Establish a Framework for Network Architecture Development of Dominant Carrier Networks, R.93-04-003
Investigation on the Commission's Own Motion into Open Access and Network Architecture Development of Dominant Carrier Networks, I.93-04-002
Rulemaking on the Commission's Own Motion into Universal Service and to Comply with the Mandates of Assembly Bill 3643, R.95-01-020
Investigation on the Commission's Own Motion into Universal Service and to Comply with the Mandates of Assembly Bill 3643, I.95-01-021

Before the Connecticut Department of Public Utility Control:

Application of the Southern New England Telephone Company for Approval of Cost Studies for Unbundled Network Elements, Docket No. 00-01-02

Before the Public Service Commission of the District of Columbia:

Implementation of the Requirements of the District of Columbia Telecommunications Act of 1996, Formal Case No. 962

Before the Florida Public Service Commission:

Petition by MCI Telecommunications Corporation for Arbitration with United Telephone Company of Florida and Central Telephone Company of Florida Concerning Interconnection Rates, Terms, and Conditions, Pursuant to the Federal Telecommunications Act of 1996, Docket No. 961230-TP

Determination of the Cost of Basic Local Telecommunications Service, Pursuant to Section 364.025, Florida Statutes, Docket No. 980696-TP

Discovery for Study on Fair and Reasonable Rates and on Relationships Among Costs and Charges Associated with Certain Telecommunications Services Provided by LECs, as Required by Chapter 98-277, Docket No. 980733-TL

Fair and Reasonable Residential Basic Long Telecommunications Rates, Special Project No. 980000A-SP

Petition of DIECA Communications Inc. d/b/a Covad Communications Company for Arbitration of Interconnection Rates, Terms, and Conditions and Related Arrangements with GTE, Docket No. 990182-TP

Before the Georgia Public Service Commission:

Review of Cost Studies, Methodologies, and Cost-Based Rates for Interconnection and Unbundling of BellSouth Telecommunications Services, Docket No. 7061-U

Before the Hawaii Public Utilities Commission:

Application of GTE Hawaiian Telephone Company Incorporated for Approval of Rate Increases and Revised Rate Schedules, Docket No. 94-0298

Before the Indiana Utility Regulatory Commission:

Commission Investigation and Generic Proceeding on Ameritech Indiana's Rates for Interconnection, Service, Unbundled Elements And Transport and Termination Under the Telecommunications Act of 1996 and Related Indiana Statutes, Cause No. 40611

Investigation on the Commission's Own Motion Into Any and All Matters Relating to Access Charge Reform and Universal Service Reform Including, but not Limited to, High Cost or Universal Service Funding Mechanisms Relative to Telephone and Telecommunications Services within the State of Indiana Pursuant to: IC-8-1-2-51, 58, 59, 69, 8-1-2.6 et seq., and Other Related State Statutes, as well as the Federal Telecommunications Act of 1996, Cause No. 40785-S2

Before the Idaho Public Utilities Commission:

Investigation to Determine an Appropriate Cost Model Using Forward-Looking Economic Costs for Calculating the Costs of Basic Telecommunication Service in Idaho, Case No. GNR-T-97-22

Investigation to Establish the Idaho Non-Rural Universal Service Fund as Required by Idaho Code § 62-610A-F, Case No. GNR-T-00-2

Before the Kansas Corporation Commission:

Application of Sprint Communications Company L.P., United Telephone Company of Kansas, United Telephone Company of Eastern Kansas, United Telephone Company of South Central Kansas, and United Telephone Company of Southeastern Kansas for the Commission to Open a Generic Proceeding on Southwestern Bell Telephone Company's Rates for Interconnection, Unbundled Elements, Transport and Termination and Resale, Docket No. 97-SCCC-149-GIT

Before the Kentucky Public Service Commission:

Deregulation of Local Exchange Companies' Payphone Service, Admin. Case No. 361

Before the Louisiana Public Service Commission:

Review and Consideration of BellSouth Telecommunications, Inc.'s TSLRIC and LRIC Cost Studies Submitted Pursuant to Sections 901(C) and 1001(E) of the *Regulations for Competition in the Local Telecommunications Market* as Adopted by General Order dated March 15, 1996, in Order to Determine the Cost of Interconnection Services and Unbundled Network Components to Establish Reasonable, Non-Discriminatory, Cost-Based Tariffed Rates, Docket No. U-22022

Before the Maine Public Utilities Commission:

Investigation into Regulatory Alternatives for New England Telephone and Telegraph Company, Docket No. 94-123

Before the Michigan Public Service Commission:

Application of Ameritech Michigan to Restructure its Basic Local Exchange Rates and Service, Case No. U-11148

The Commission's Own Motion to Establish Permanent Interconnection Arrangements Between Basic Local Exchange Service Providers, Case No. U-10860

Application of Ameritech Michigan for Approval of New TSLRIC Studies for Interim Number Portability, Case No. U-11155

Application of Ameritech Michigan for Approval of New TSLRIC Studies for Unbundled Loops and Local Traffic Termination, Case No. U-11156

The Commission's Own Motion to Consider the Total Service Long Run Incremental Costs for All Access, Toll and Local Exchange Services Provided by GTE North Incorporated, Case No. U-11832

Before the Minnesota Public Utilities Commission:

The Commission's Generic Investigation of USWC's Cost of Providing Interconnection and Unbundled Network Elements, Docket No. P-442, 5321, 3167, 466, 421/C-06-1540

Complaint of MCImetro Access Transmission Services, Inc., Against U S West Communications, Inc. for Anticompetitive Conduct, Docket No. P421/C-97-1348

Before the Mississippi Public Service Commission:

Notice of Tariff Filing for Flat Rate Option(s) for Customer Provided Public Telephones and Smartline_Service for Public Telephones, Docket No. 97-UN-302

Before the Missouri Public Service Commission:

AT&T's Petition for Arbitration to Establish an Interconnection Agreement with Southwestern Bell Telephone Co., Case No. TO-97-40

MCI's Petition for Arbitration to Establish an Interconnection Agreement with Southwestern Bell Telephone Co., Case No. TO-97-67

Before the New Jersey Board of Public Utilities:

Notice of Pre-Proposal, Notice of Investigation: Local Exchange Competition for Telecommunications Services, Docket No. TX95120631

Before the New Mexico State Corporation Commission:

Petition by AT&T Communications of the Mountain States, Inc., for Arbitration of Certain Terms and Conditions of a Proposed Agreement with GTE Southwest Incorporated Concerning Interconnection and Resale Under the Telecommunications Act of 1996, Docket NO. 97-35-TC

Before the New York Public Service Commission:

Joint Complaint of AT&T Communications of New York, Inc., MCI Telecommunications Corporation, WorldCom, Inc. d/b/a LDDS WorldCom and the Empire Association of Long Distance Telephone Companies, Inc. Against New York Telephone Company Concerning Wholesale Provisioning of Local Exchange Service by New York Telephone Company and Sections of the New York Telephone Company's Tariff No. 900, Case No. 95-C-0657

Proceeding on Motion of the Commission to Examine Issues Related to the Continuing Provision of Universal Service and to Develop a Regulatory Framework for the Transition to Competition in the Local Exchange Market, Case No. 94-C-0095
Proceeding on Motion of the Commission Regarding Comparably Efficient Interconnection Arrangements for Residential and Business Links, Case No. 91-C-1174
Proceeding on Motion of the Commission to Consider Loop Resale and Link and Port Pricing, Case No. 94-C-9657

Before the North Carolina Utilities Commission:

Establishment of Universal Support Mechanisms Pursuant to Section 254 of the Telecommunications Act of 1996, Docket No. P-100, SUB 133b
Proceeding to Determine Permanent Pricing for Unbundled Network Elements, Docket No. P-100, SUB 133d

Before the Public Utilities Commission of Ohio:

Application of Cincinnati Bell Telephone Company for Approval of a Retail Pricing Plan Which May Result in Future Rate Increases and for a New Alternative Regulation Plan, Case No. 96-899-TP-ALT
Application of United Telephone Company of Ohio, d/b/a Sprint for Authority to File and Gain Approval of TELRIC Cost Studies for Reciprocal Compensation Unbundled Network Elements, Case No. 99-238-TP-UNC
Complaint of AT&T Communications of Ohio, Inc. v. GTE North Incorporated, Case No. 99-1181-TP-CSS
Complaint of Office of the Consumers' Counsel v. Cincinnati Bell Telephone Company, Case No. 93-551-TP-CSS
Review of Ameritech Ohio's Economic Costs for Interconnection, Unbundled Network Elements, and Reciprocal Compensation for Transport and Termination of Local Telecommunications Traffic, Case No. 96-922-TP-UNC

Before the Oklahoma Corporation Commission:

Application of Ernest G. Johnson, Director of the Public Utility Division Oklahoma Corporation Commission, to Review the Rates and Charges of GTE Southwest Incorporated, Cause No. PUD 940000476
Application for a General Change in the Rates, Charges, and Tariffs of GTE Southwest Incorporated, Cause No. PUD 940000479
Application of AT&T Communications of the Southwest, Inc. for Compulsory Arbitration of Unresolved Issues with Southwestern Bell Telephone Company Pursuant to § 252(b) of the Telecommunications Act of 1996, Cause No. PUD 960000218
Application of Cox Oklahoma Telcom, Inc., for a Determination of the Costs of , and Permanent Rates for the Unbundled Network Elements of Southwestern Bell Telephone Company, Cause No. PUD 970000213

Before the Oregon Public Utility Commission:

Investigation into Universal Service in the State of Oregon, Docket No. UM-731
Investigation of Cost Studies Filed by GTE Northwest Incorporated, Docket No. UM-874

Before the Pennsylvania Public Utility Commission:

Formal Investigation to Examine and Establish Updated Universal Service Principles and Policies for Telecommunications Services in the Commonwealth, Docket No. I-00940035
Notice of Proposed Rulemaking to Establish a Universal Service Funding Mechanism, Docket No. L-00950105
Application of MFS Intelenet of Pennsylvania, Inc., Docket No. A-310203F0002
Application of TCG Pittsburgh, Docket No. A-310213F0002
Application of MCImetro Access Transmission Services, Inc., Docket No. A-310236F0002
Application of Eastern Telelogic Corp., Docket No. A-310258F0002

Before the Texas Public Utility Commission:

Application of Southwestern Bell Telephone Company and GTE Southwest, Inc. for Approval of LRIC Workplan Pursuant to Subst. R. § 23.91, Docket Nos. 12475, 12481
Petition of MFS Communications Company, Inc. for Arbitration of Pricing of Unbundled Loops, Docket No. 16189
Petition of Teleport Communications Group, Inc. for Arbitration to Establish an Interconnection Agreement, Docket No. 16196
Petition of AT&T Communications of the Southwest, Inc. for Compulsory Arbitration to Establish an Interconnection Agreement between AT&T and Southwestern Bell Telephone Company, Docket No. 16226
Petition of Teleport Communications Group, Inc. for Arbitration to Establish an Interconnect Agreement, Docket No. 16244
Petition of MCI Telecommunications Corporation and its Affiliate MCImetro Access Transmission Services, Inc. for Arbitration and Request for Mediation under the Federal Telecommunications Act of 1996, Docket No. 16285
Petition of American Communications Services, Inc. and its Local Exchange Operating Subsidiaries for Arbitration with Southwestern Bell Telephone Company Pursuant to the Telecommunications Act of 1996, Docket No. 16290
Petition of Sprint Communications Company, L.P., for Arbitration of Interconnection Rates, Terms, Conditions, and Prices with Southwestern Bell Telephone Company, Pursuant to the Federal Telecommunications Act of 1996, Docket No. 16455
Petition of Sprint Communications Company, L.P., for Arbitration to Establish Interconnection Agreement with GTE Southwest, Inc., and Contel of Texas, Inc., Pursuant to the Federal Telecommunications Act of 1996, Docket No. 16476

<u>Petition of American Communications Services, Inc., for Arbitration of Unresolved Interconnection Issues with GTE Southwest, Inc., and Contel of Texas, Pursuant to the Federal Telecommunications Act of 1996</u>, Docket No. 16473

<u>Petition of Western Wireless Corporation d/b/a Cellular One for Arbitration of Unresolved Interconnection Issues with GTE Southwest, Inc., Pursuant to the Federal Telecommunications Act of 1996</u>, Docket No. 16402

Before the Virginia State Corporation Commission:

<u>Petition of MCI Telecommunications Corporation and MCImetro Access Transmission Services of Virginia, Inc. for Arbitration of Unresolved Issues with GTE South, Inc. Pursuant to § 252 of the Telecommunications Act of 1996</u>, Case No. PUC960124

Before the Washington Utilities and Transportation Commission:

<u>Pricing Proceeding for Interconnection, Unbundled Network Elements, Transport and Termination, and Resale</u>, Docket No. UT-960369

<u>Pricing Proceeding for Interconnection, Unbundled Network Elements, Transport and Termination, and Resale for U S West Communications, Inc.</u>, Docket No. UT-960370

<u>Pricing Proceeding for Interconnection, Unbundled Network Elements, Transport and Termination, and Resale for GTE Northwest Incorporated</u>, Docket No. UT-960371

Appendix A: A Review of The Economic Literature

Incremental costs measure how much a firm's total costs of doing business change as a result of some business decision such as a change in the price of an existing product, offering or discontinuing an entire product line, and so forth.[1] In competitive, unregulated markets, firms want to make decisions for which the *incremental revenue* of the decision is at least as large as its incremental cost. Indeed, markets enforce this discipline on firms as a matter of survival. And the result of all these decisions is the efficient production and consumption of goods and services.

In regulated markets, incremental cost, when properly used, can serve to facilitate sound business decisions as well as to promote efficient production and allocation of resources. When market forces are not strong enough to control market power,[2] incremental cost forms the basis for prices that protect both consumers and competitors from improper exercise of that market power. Thus, the regulatory purpose of measuring incremental costs is to establish prices and associated safeguards, e.g., price floors, so that the competition that emerges between unregulated entrants and the incumbent firm approximates the working of unregulated markets until price regulation is unnecessary. The intended outcome is simple: in the long run, a competitive firm does not lose money when offering its products and services. Therefore, the firm expects to recover its total forward-looking costs in its prices, including costs (such as corporate overheads) that are shared among two or more products, and the procompetitive *price floor* is the relevant incremental cost.

[1] The linkage of cost determination to a business decision that changes a firm's output is flexible, with particular decisions varying by the length of the planning horizon and the size of the increment of volume.

[2] The ability to charge prices higher than those that would prevail in competitive markets.

The role of incremental cost in regulated industries draws upon two areas: regulatory economics and antitrust economics. Both traditions deal with rules to prevent and/or detect anticompetitive pricing. Indeed, regulatory rules such as cost-based price floors and imputation can be viewed as preventative antitrust. Regulatory economics also deals with the use of cost information in setting prices, because regulators have traditionally overseen ratemaking. Because prices for unregulated firms are established by the market, determining prices is not a concern of antitrust economics.

Although we mention these economic traditions at the outset, proper incremental cost methods should not be viewed as something only for regulators and academics. As we described above, these techniques address the same concerns that businesses face when making pricing and product decisions; indeed, in a fundamental sense, incremental cost is not completely defined until that business decision has been specified. The implication of this observation is that practical and flexible tools for measuring incremental cost are useful not only for regulators in setting prices, but also for businesses, both regulated and unregulated, in evaluating the profitability of their business decisions.

A. Implications for Telephone Exchange Carrier Incremental Cost Studies

As we discuss below, the economics literature provides considerable support for cost-based pricing. The basic notion of incremental cost is long run incremental cost ("LRIC"): the change in cost necessary to serve an increment of demand over a period of time sufficient to capture all of the effects of the change in demand on the costs and revenues of the firm. Total service long run incremental cost ("TSLRIC") is a special case of the more comprehensive and generally applicable

LRIC principles applied to a pricing or product decision that deals with the entire volume of service: i.e., to offer a service or not.

Thus, in applying LRIC in general, it is necessary to: (1) define the services affected by the decision; (2) measure the volumes affected by the decision; (3) determine the prices that will be charged; and (4) measure the costs of the firm with and without the decision.

Service definition is a critical step. Services must be defined commensurate with the business or public policy decision, not necessarily in terms of the total service. For example, when carriers offer discount plans for high volume residential toll users, the service and volume in question should be those of these particular customers, not the total volume of toll service offered to all toll customers.[3] The definition of service must recognize the product and service differentiation that exists in the marketplace.

The definition of services cannot be done in a vacuum, or as part of a formalistic cost-study methodology. Indeed, cost information, by itself, is not sufficient to define services (or establish incremental costs). Definitions of markets and services always require information about relevant demand. Firms always take demand into account in setting price. Regulators seeking to simulate competitive conditions in a regulated market must do the same. In particular, if the cost is measured in terms of a service that is not subject to the business decision at hand, economic inefficiency is a likely outcome.

B. Regulatory Requirements for Forward-Looking Cost Studies

[3] In fact, casual observation of the plethora of calling plans for long-distance services show that real carriers recognize these considerations.

1. The FCC's Total Element Long-Run Incremental Cost ("TELRIC") Method[4]

In its *Local Competition Order*,[5] the FCC described its method for setting prices for the unbundled network elements incumbent local exchange carriers are required to offer to competitors. It viewed its approach as a special case of the TSLRIC concept described above, where costs are calculated for network elements, rather than retail services;[6] hence the acronym "TELRIC."

In terms of the more general concept of incremental costs, TELRIC maintains the following specific assumptions.

First, the business decision being modeled is that of a hypothetical local exchange carrier[7] that offers unbundled elements to retail providers (possibly itself) at undifferentiated prices. Hence the increments in question are the total volume for the elements demanded by the retail providers.

Second, the time horizon over which the ILEC offers the wholesale elements is assumed to be the longest of the long-run.[8] Implicit in this definition are the assumptions that (1) the ILEC will effectively be a monopolist in the provision of network elements for the indefinite future and (2) competitors will need to obtain such elements to compete over this time frame.

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[4] The FCC also promulgated essentially the same cost standard for determining the forward-looking costs of basic service for universal service purposes. Dubbed "Forward-looking Economic Costs" ("FLEC") when used for universal service, the FCC's description closely aligns with its earlier discussion of TELRIC and, in fact, the FCC urged state commissions to use the same costing approach for both unbundled element pricing and in determining the cost of universal service. Federal Communications Commission, *Federal-State Joint Board on Universal Service*, Report and Order, adopted May 7, 1997 (released May 8, 1997), ¶s 250-251.

[5] Federal Communications Commissions, *Implementation of the Local Competition Provisions in the Telecommunications Act of 1996* ("Local Competition Order"), adopted August 1, 1996 (released August 7,1996).

[6] Local Competition Order, ¶s 672 and 678.

[7] The carrier is hypothetical in the sense that its wholesale services are considered as separate services, in contrast to services produced in combination with retail services. Therefore, by design, costs that are shared costs across retail services that use common network elements become direct costs for the elements themselves.

[8] In presenting its definition of long-run in ¶ 677, the FCC quotes William Baumol, who gives a definition of a *very* long-run period.

Third, because it focuses on undifferentiated costs and prices for network elements, the FCC's methodology calls for the assignment of certain non-volume-sensitive costs to the unit costs (prices) for the elements. For example, in ¶ 682 of the *Local Competition Order*, the FCC prescribes the assignment of shared costs (e.g., support structures such as telephone poles) to the elements that share these costs and the assignment of spare capacity to element costs, through the use of actual fill factors.[9] Similarly, in ¶ 696, the FCC calls for the allocation of a firm's common costs to elements.[10]

Fourth, the ILEC's costs are determined with reference to a hypothetical carrier that is able to install new network equipment in the current locations of the ILEC's central offices.[11] This assumption will produce valid economic costs to the extent to which the assumed new network equipment approximates the market value of the ILEC's existing facilities.[12] Although the FCC believes that its assumption of new forward-looking technology placed in existing wire center locations produces the best approximation of an ILEC's economic costs, it appears that its choice was a compromise between a complete "scorched earth" approach, in which the hypothetical carrier has a completely blank slate upon which to build its network[13] and basing costs on the ILEC's

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[9] In a later section, we will describe how the costs of providing service at demand levels less than the effective capacity of the facilities in question (spare capacity) is a fixed cost (which can be either product-specific or shared) that in general does not necessarily have to be recovered uniformly over uses of the facility.

[10] The distinction between shared costs and common costs is the following. Shared costs are costs that are incurred in the production of two or more services (but not all the firm's services) and only go away if the firm ceases production of all the services in question. Common costs are costs shared among all the firm's services.

[11] Local Competition Order ¶ 685. How far the definition of new forward-looking network equipment extends is an area of considerable controversy. For example, entrant local exchange carriers ("CLECs") routinely argue that the rebuilt network called for by TELRIC should include brand-new ideally configured central office buildings. This literal interpretation of what a rebuilt network means appears to be inconsistent with both the objective of a cost study—to approximate the ILEC's economic costs—because real firms do not always deploy brand-new buildings to house their network facilities and what the FCC had in mind, as indicated by its subsequent discussion of pricing for central office use by CLECs, which only makes sense in the context of using existing buildings.

[12] Emmerson, *op. cit.,* p. 188.

[13] Local Competition Order ¶ 683.

current network design and deployment of technology.[14] In fact, the FCC's choice of new network technology deployed in existing locations is quite similar to costing approaches that had emerged before the passage of the Telecommunications Act from state proceedings (e.g., Oregon and California), where the chosen approach was an explicit compromise among competing interests developed in negotiating workshops.

Finally, some interpretations of the FCC's forward-looking cost prescriptions specify a hypothetical, narrowband-only local carrier, even though real carriers may provide narrowband and broadband offerings on an integrated basis. Basing prices on costs the actual carrier does not incur can produce economically inefficient outcomes. Conceptually, the insistence on the narrowband-only network simply repeats the tired old arguments that were used to support the erroneous claim that local service subsidizes toll—arguments based on comparing a putative local service-only network to real networks optimally designed to produce both local and toll services. Professor Kahn has cogently described the error in such arguments as follows.

> The foregoing enunciation of first-best principles applies equally to the assertions that . . . the telephone companies are attempting illegitimately to load on to POTS [plain old telephone service] customers a portion of the costs of upgrading their non-traffic-sensitive access networks in order to offer various sophisticated services. The first question is *whether those investments are economically efficient*, minimizing the combined costs of access, calling, and the newer services; and in this assessment it is necessary to take into account the sufficiency of the incremental net revenues flowing from the services the investments make it possible to offer. If the expenditures are efficient—that is, if they conduce to the efficient design of the entire system—then the marginal costs of the several services at which their prices should be set are their marginal costs under that system. Specifically, if the efficient system entails a higher proportion of NTS subscriber plant costs than some other design, the economically first-best flat rates to POTS customers will reflect those higher costs:

[14] Local Competition Order ¶ 684.

> The marginal costs of access are what they are in the system that is optimally designed to satisfy all demands it serves.[15]

Thus, if a joint-use, integrated broadband network is the most efficient way to provide both broadband and narrowband services, the broadband network should be built and the incremental cost of the narrowband services is the cost of those services in the integrated network, not in some hypothetical network designed to supply only narrowband services.

2. Economic Cost Studies in the UK and Europe

Both the UK and the European Union ("EU") have called for a cost basis for interconnection prices. While the discussions in their respective documents call for approaches that are broadly similar to the theoretical concept of LRIC and to the FCC's TELRIC approach, neither party has provided details at the level found in the FCC's *Local Competition Order*. As a result, no particular cost model is specified or required and, as a result, models that are consistent with economic costing principles would appear to comport with what these regulators are seeking.

In the UK,[16] incremental cost techniques are one component of several techniques used to establish interconnection pricing. In addition to determining the incremental cost of interconnection services, the OFTEL approaches include (1) provisions for assigning shared and common costs; (2) provisions for price ceilings and floors; and (3) reconciliation with cost estimates based on a "top down" approach.

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[15] Alfred E. Kahn and William B. Shew, "Current Issues in Telecommunications Regulation: Pricing," *Yale Journal on Regulation*, 1987, p. 228, emphasis in the original.

[16] This discussion is based on OFTEL, Pricing of Telecommunications Services From 1997: Controls and Consultative Document on BT Price Interconnection Charging, Annex D.

In general, forward-looking cost studies implicitly pose and answer a number of questions, and the first is the nature of the company being modeled: do we measure costs of the regulated firm in its existing network or the minimum costs of a hypothetical firm in a forward-looking hypothetical network, or something in between? OFTEL appears to call for the forward-looking costs of British Telecom ("BT") itself, in that the proper cost is viewed as one that provides incentives for more efficient firms to enter the market, but discourages less efficient firms from entry. However, the approach departs from BT's own costs to some extent, because OFTEL calls for modeling only domestic standard services (loops and usage), thus excluding international services and advanced services. To the extent that there are economies of scale or scope in the joint provision of basic and advanced services, OFTEL's prescription could cause deviations from BT's actual costs.

The second general assumption in a cost study is the time horizon, and the OFTEL directive does not appear to give an explicit definition of the time horizon of the study (the length of the "run" in long run). However, its comment that the purest form of a forward-looking cost study calls for the use of modern equivalent assets ("MEA")[17] suggests that it intends a definition of the long run that is similar to that employed by the FCC.

The third component of the definition of an incremental cost study is the size of the increment of demand over which the change in cost is to be measured. For OFTEL, the definition of the size of the increment is the total demand (both incumbent and interconnector volumes) for two broad classes of service: access and usage. The directive presents a precise (and standard) definition that can be represented by the following equation.[18]

[17] The lowest cost asset which serves the same function as the asset being valued.

[18] This equation will be useful in the discussion of ceilings and floors below. Note that the second term on the right side of the equation is the *standalone* cost of producing the current volume of service Y.

$$LRIC_X = C(V_X, V_Y) - C(0, V_Y) \qquad \textbf{(1)}$$

That is, the incremental cost of service X (e.g., loops), is the difference between the total cost of producing both services at current volumes and the cost of producing only the second service (e.g., usage) at the current volume. To the extent that there are economies in the joint production of the two services (scope economies), the sum of the separate LRICs will be less than total cost. This difference is the shared (or common) costs associated with the two services, i.e.,

$$Shared\ Costs_{X,Y} = C(V_X, V_Y) - LRIC_X - LRIC_Y \qquad \textbf{(2)}$$

Having calculated incremental costs for services, the economist then moves to prices. From an economic perspective, (1) the *prices* of individual services must (collectively) recover the firms' shared and common costs and (2) the *price floor* for individual services can be as low as the incremental cost defined in Equation 1 (provided that prices for other services are sufficiently high to satisfy the first condition). OFTEL's prescription departs from these principles in the following way. First, OFTEL divides usage services into switching and transmission. Then, to the extent that there are shared costs in the provision of switching and transmission (but not access), the incremental costs for these individual services are marked up so as to recover the shared costs *as part of the price floor*. As a result, the price ceilings for switching and transmission are lower than their respective stand-alone costs, because the stand-alone cost includes the full amount of the costs shared between switching and transport, while OFTEL's ceiling contains only the portion of the shared costs that are included in the floor.

Having calculated price floors and prices, the OFTEL directive then calls for a reconciliation between the bottoms-up incremental costs just described and a top-down cost calculation based on the accounting books of the firm. While it is unclear what weight OFTEL will give to this reconciliation, it should be clear that it is the bottoms-up incremental cost calculation—not the top-down study—that measures (i) what economists mean by economic costs and (ii) what firms need to run their business. Performing a top-down study can give regulators more confidence in the incremental cost study because it enables them to understand how incremental costs relate to historical costs (which can approximate forward-looking costs for some components) in the books of account—which are, themselves, subject to accounting rules and audits. However, beyond that, top-down costing methods are not an adequate alternative to proper economic cost studies, fundamentally because they measure the wrong thing.

To understand this problem, examine the OFTEL top-down method. It resembles the traditional use of historical (book) costs as a basis for pricing in the US in that the books of account are the starting point. The UK approach then attempts to go beyond this starting point in two ways. First, current replacement costs of assets are used in place of book costs.[19] Second, the study develops relationships between certain cost drivers (e.g., minutes of use) and the accounting categories.[20] In this way, the costs organized by the books of accounts are assigned to the services that require prices.

Because the top-down costs start with an embedded view of the firm, they are subject to the usual criticism of any historical measurement of costs—what you paid for equipment in the past and what it takes to operate it are not necessarily what the firm will experience going forward. The use of current costs in place of book costs mitigates some of the problems with embedded cost studies,

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[19] In some cases, the current costs are based on a forward-looking technology, e.g., switching. Otherwise, the current cost is the cost of installing the asset in question at today's input prices, e.g., the value of a telephone pole would be based on what the company pays for poles today, not what it paid in the year it was installed.

[20] For example, 70 percent of the cost in a particular category might vary linearly with the number of lines. The remaining 30 percent is treated as a service-specific fixed cost or a shared cost.

because investment valued at current costs reflects current asset prices rather than the prices of the assets originally purchased. If the asset in question is the same type that would be placed in a forward-looking view (e.g., a digital switch) then the current cost might approximate the forward-looking cost. To the extent there are differences (e.g., the embedded facility is copper, while the forward-looking placement would be fiber), there will remain differences between the costs calculated by the top-down study and a proper LRIC study.

Even when such discrepancies between forward-looking and embedded technologies are present, a top-down study can serve as a useful sanity check on the result of a LRIC study.[21] Because the latter is necessarily a simplified approximation of the complex operations of the real firm, its validity is only as good as the accuracy of its simplifying assumptions. The top-down study, on the other hand, captures what the real firm has paid for real, albeit backward-looking, inputs. Especially in the case of common technology (e.g., digital switching), large discrepancies between the top-down and bottom-up costs could indicate problems with the latter.

The European Union[22] has adopted LRIC principles for the pricing of interconnection between competing networks. The approach calls for a long-run perspective in which the firm is free to vary all its inputs, including the telecommunication plant. In addition, the increment of demand for which costs are measured is the combined volumes of the incumbent and interconnecting carriers, and the total cost of producing these volumes is averaged over the total volume, thus producing a

[21] In addition, current cost accounts have, in fact, been used in studying the cost structures of telephone companies. For example, such costs have been used in total factor productivity studies that have been used to establish the productivity targets of price cap plans in the US.

[22] This summary is based on Commission of the European Communities, *Commission Recommendation on Interconnection in a liberalised telecommunications market: Part 1 – Interconnection Pricing*, Brussels, October 15, 1997. As we understand it, implementation of the broad principles will be carried out within each country. In general, other European countries are not as far along as the UK.

long-run *average* incremental cost ("LRAIC"). Thus, in a manner similar to the FCC's TELRIC, this approach assigns product-specific fixed costs and shared costs that do not vary with volume on a uniform basis. In addition, the directive suggests that common costs be added to the LRAIC of each service, perhaps through the use of uniform mark-ups.

C. Review of the Economic Literature

In this section, we review the work of two major contributors to regulatory economics over the last several decades. Not only were their contributions precedent-setting, they continue to contribute to and be widely cited in regulatory and legal deliberations over incremental cost concepts that continue around the world today. Starting 30 years ago with his *Economics of Regulation*, Professor Alfred Kahn described how long-run incremental cost should be used to establish efficient prices for regulated industries. Somewhat later, Professor William Baumol popularized a special case: total-service long-run incremental cost ("TSLRIC"). Professor Baumol's contributions were widely cited in several costing proceedings at the state level that were precursors to the FCC's introduction of its own method of incremental cost, based closely on the TSLRIC concept.

1. Kahn

Professor Alfred Kahn's seminal text on regulatory economics, originally written almost 30 years ago, anticipated many of the cost issues that have been debated in the 1990s throughout the world.[23] Starting from the basic premise that prices at short-run marginal cost are optimal under static conditions, Kahn extended his inquiry into dynamic conditions, e.g., demand patterns varying

[23] Alfred E. Kahn, The Economics of Regulation, Cambridge: The MIT Press, 1988, originally published in 1970-71 ("Kahn").

over time, competition growing and changing, etc. Kahn concluded that, for practical purposes and in competitive situations, long-run marginal cost was the appropriate standard for pricing:

> ... society's interest is in having ... communications provided at the lowest possible cost, with due allowance for possible differences in the quality of services supplied or the costs imposed on the users. And economic efficiency requires, additionally, that no business be turned away that covers the cost to society of providing that service. These basic goals are served by permitting rates to be set at long-run marginal costs. The consequence will be that, after consumers have made allowance in their choices for possible differences in the quality of the service, the competing company with the lowest long-run marginal cost will get the business; and the services will thus be provided by those companies which, in so doing, will impose the minimum opportunity costs on the economy at large.[24]

The concept of long-run is often understood to be a very long period of time, i.e., a time period sufficiently long so that all costs are either variable or avoidable.[25] However, in order to determine the costs associated with a particular business decision, the time perspective of the cost analysis must align with the time horizon of the business decision, not with some abstract textbook definition. Therefore, a more economically useful definition of long-run is: Long run captures the period of time over which a decision to offer a new service or change the price of an existing service has an impact on the costs and revenues of the business.[26]

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[24] Kahn, pp. 160-161.

[25] For example, the FCC's staff has defined forward-looking economic costs as follows: "…the costs that would be incurred if a new element or service were provided, or that could be avoided if an existing element or service were not provided, assuming that all input choices of the firm can be freely varied." Jay Atkinson, Chris Barnekov, David Konuch, William Sharkey, and Brad Wimmer, "The Use of Computer Models for Estimating Forward-Looking Economic Costs: Staff Analysis," January 9, 1997, ¶ 9.

[26] In fact, in his graduate textbook, Professor Varian notes that: "Long run and short run are of course relative concepts. Which factors are considered variable and which are considered fixed depends on the particular problem being analyzed. You must consider over what time period you wish to analyze the firm's behavior and then ask what factors can the firm adjust during that time period." Hal R. Varian, Microeconomic Analysis, Third Edition, New York: Norton, 1992, p. 66. Thus, the time period encompassed by "long-run" may be short (e.g., for a new entrant in the planning stages) or long (e.g., for a going concern complete with its inescapable history).

In a more recent filing before the FCC, Professor Kahn expanded upon the proper formulation of the LRIC standard, as follows:

> In strict economic terms, the concept of long-run marginal costs relates to a hypothetical situation in which all inputs are variable, and a supplier confronts the possibility of installing entirely new facilities, in effect from the ground up. And the "marginal" relates to the incremental cost of a single unit of output. The concept of long-run incremental cost, in contrast, is more pragmatic: it takes a firm's past history as given, does not assume that it is writing on a blank slate, but recognizes that it will ordinarily be planning the installation of new capacity, at whatever that additional investment will cost given its current situation, and it spreads the costs over either the total output of that additional capacity - in that sense it is a kind of average incremental cost - or over the additional output that is likely to be induced by a price reduction under consideration (or curtailed in response to a price increase).[27]

In addition to the length of time that is captured by the long-run, it is also necessary to specify the size of the increment of output over which the additional costs to the firm are being measured. Incremental cost is the additional cost a firm incurs (or avoids) in providing (or discontinuing) a service (or some increment of that service).[28] The correct measure of incremental cost depends on the specific business decision at issue. For example, if the issue is whether revenues from an entire service exceed cost, the relevant volume is the entire service. Alternatively, a

[27] Affidavit of Alfred E. Kahn, "The Necessary Conditions of Effective Competition for Local Transport," CC Docket No. 91-141, August 6, 1991, p. 22.

[28] A formal definition of incremental cost is given by the following equation:

$$LRIC_i = C(V_1{}^0, V_2{}^0, \ldots. V_i^1 \ , \ldots V_k{}^0) - C(V_1{}^0, V_2{}^0, \ldots. V_i^0, \ldots V_k{}^0)$$

In words, the cost for a service is the difference in the company's total cost at two different levels of output. If V^0_i = 0 and V^1_i = current output, the equation defines total-service long-run incremental cost (TSLRIC). Because this difference in cost is brought about by increases (or decreases) in the resources required for particular services, it is necessary to understand how increases in outputs cause increased requirements for particular resources used by the firm, a "bottom up" assessment of costs. In contrast, "top down" approaches that arbitrarily allocate the total accounting costs of a firm to services typically fail to properly measure the costs that are brought into being by particular business decisions.

particular pricing decision may affect only a subset of the entire service's volume and it is that volume that defines the correct incremental cost (including service-specific fixed costs).

Kahn identified several issues and principles that needed to be considered in establishing costs. Among the most fundamental of these was cost-causation. Users of a service are responsible for the costs imposed by using the service, but only for those costs.[29] Only if either the future size or timing of resource purchases is affected by having the service in question (as compared to the resource purchases which would be made if the company did not have the service in question, *ceteris paribus*) should the resource cost be considered to be caused by the service. Costs excluded by this principle include any assigned through arbitrary allocations, such as through uniform assignment of fixed costs to usage services.

Next, Kahn recognized that practical cost analysis must consider the size of the increment and the time horizon of the decision. Kahn described these issues as follows:

> ... long-run incremental cost (which we shall loosely refer to as long-run marginal cost as well) would be based upon (1) the average incremental variable costs of those added sales and (2) estimated additional capital costs per unit, for the additional capacity that will have to be constructed if sales at that price are expected to continue over time or to grow. Both of these components would be estimated as averages over some period of years extending into the future.[30]

Kahn's definition of the appropriate increment is clearly related to a particular business decision: "Of course, the proper size of the incremental unit of output depends on the perspective of the decision under consideration."[31] As explained by Kahn, "total service" is the appropriate

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[29] Kahn, p. 71.

[30] Kahn, p. 85.

[31] Kahn, p. 76. The relationship between incremental cost measurement and the business decision at hand is thoroughly discussed in Richard D. Emmerson, "Theoretical Foundations of Network Costs," in William Pollard, ed., Marginal Cost Techniques for Telephone Services: Symposium Proceedings, The National Regulatory Research Institute, January 1991, pp. 145-189.

increment only for business decisions involving the total service. Indeed, basing costs on the wrong increment (e.g., all toll volumes instead of the toll services purchased by the users affected by a pricing action) would violate cost-causation in that costs not caused by those users would be assigned to them anyway. For example, if the cost of billing were lower for a particular group of toll users, assigning an average billing cost would overstate the cost of providing toll to that group.

Kahn's incremental cost definition is also based upon the firm's own cost structure and how that structure is changed by real business decisions, and not upon the cost structure of some hypothetical firm. In fact, in the context of competitive pricing, Kahn observed that: "[t]he marginal costs against which competitive rates should be judged are the costs of the company quoting or proposing to quote those rates, *not the costs of their competitors*."[32]

Finally, because telephone exchange carriers are multiproduct firms, the familiar proposition from competitive markets that price equals marginal cost for every service generally does not hold. Rather, the cost of any specific service depends on the outputs of all products and services, and because there are economies of scope (fixed costs that are shared by two or more services), the prices of services that share fixed costs must exceed their incremental costs in order that the firm recovers all its costs. Thus, even if telecommunications markets are vigorously competitive, prices for all services will not be driven *to* incremental cost. Rather, the price for each service must generally exceed its incremental cost by a margin primarily determined by the demand conditions faced by the firm in each of its markets.

To summarize, where shared fixed and common costs are an important characteristic of the industry, the incremental cost of a service defines its *minimum* price level. Prices themselves will

[32] Kahn, p. 164, emphasis in the original.

typically be above the minimum, with more price elastic services being priced closer to the minimum than services that are less elastic. A regulatory regime designed to emulate this competitive outcome would use incremental costs to establish *price floors*, not to set prices and would permit local exchange carriers to price at or above these floors depending on the market conditions they faced.

2. Baumol

A number of years after Kahn's textbook was published, Professor Baumol proposed an incremental cost standard for multiproduct firms that face competition for some services, but not others. Baumol's discussion primarily responded to two proposed cost standards at the time—fully distributed costs and the short-run marginal cost test for predatory pricing proposed by Areeda-Turner.[33] As an alternative, Baumol proposed the price floor that today is known as "total-service long-run incremental cost" ("TSLRIC").[34]

While sharing the procompetitive motivation of Kahn's approach, Baumol's analysis is more narrowly focused in several respects. First, in proposing the total service standard, Baumol did not consider how discrete business decisions influence the definition of a service and the related costs. For example, the decision to offer a discount toll service to high-volume customers is a different decision than offering an undifferentiated toll service. Only if services are defined commensurate with such decisions will economic efficiency be served. Second, Baumol's analysis assumed specialized conditions that may not apply to the current state of competition in telecommunications.

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[33] Phillip Areeda and Donald Turner, "Predatory Pricing and Related Practices Under Section 2 of the Sherman Act," Harvard Law Review, 1978.

[34] TSLRIC is the difference in the firm's total cost with and without the service in question. In a recent book, Baumol expanded his price floor to require that a firm price at or above both the TSLRIC and the marginal cost for the last units sold. William J. Baumol and J. Gregory Sidak, *Toward Competition in Local Telephony*, Cambridge: The MIT Press, 1994.

He assumed that regulated firms have a total profit constraint, which used to be the case with rate-of-return regulation, but which does not apply under the incentive regulation plans now pervasive in the state and federal jurisdictions in the United States as well as in European markets.[35] He also assumed, contrary to the developing state of telecommunications, that all providers compete with the same technology. Finally, Baumol's foremost concern was fairness to the users of the regulated firm's services. Economic efficiency was explicitly treated as a secondary consideration.

To illustrate the potential problems with a total service definition, Professor Baumol's original exposition of incremental cost is informative.[36] Baumol considered a simple situation where a firm offered two services, one subject to competition and the other facing less competition. In Baumol's model, the business decision was whether to offer the total volume of service, or to not offer the service at all. Based on this assumption of a single service, Baumol concluded that the procompetitive *price range* for that service was between its stand-alone cost and incremental cost.

Suppose Baumol's two services were physically identical subscriber access loops offered to two groups of customers.[37] Because the services are physically identical (e.g., loop lengths and subscriber densities are the same) they would have the same incremental cost (say $10) and share product-specific fixed costs. Suppose further that one group of services faces competitive alternatives while the other does not: e.g., based upon geography. Baumol's solution would result in a single price that did not depend on the physical nature of the services. However, if the firm were permitted to price down to incremental cost for its customers having competitive alternatives, it

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[35] Indeed the UK was the pioneer in this form of regulation.

[36] William J. Baumol, op. cit.

[37] Indeed, the intellectual precedent for Baumol's article was Faulhaber's article, which used as its example identical water service offered to different groups of customers. Gerald R. Faulhaber, "Cross-Subsidization: Pricing Public Enterprises," *American Economic Review*, 1975.

could win business that it otherwise would not, provided that it can serve these customers at a lower cost than the competitor.

This assumption of a single service thus frustrates economic efficiency. When UNEs are defined as services with a uniform price, for example, the firm would be allowed to offer only one service at a single price, e.g., a price that recovers the $10 incremental cost plus a uniform allocation of $2 to recover the shared cost. This price would be necessarily higher than the incremental cost of serving those customers with competitive options. Consequently, less efficient competitors (e.g., one whose cost to serve the customers with alternatives is $11) could win business, and consumers would be harmed in the process.

3. Cost Standards In Antitrust

While antitrust analysis and regulatory economics have the same purpose for price floors—enforcing pro-competitive pricing—the context is quite different. Under regulation, regulators involve themselves in rate setting and price floors to prevent anticompetitive prices before they occur. In contrast, in unregulated markets, prices are set by the market, and cost information is used to test prices after alleged anticompetitive pricing has occurred. Nevertheless, the fundamental economic analysis is the same.

In recent years, there have been a number of tests for predatory pricing proposed in the industrial organization literature.[38] Ordover and Saloner discuss five cost-based tests. The Areeda-Turner test is based upon short-run marginal cost, approximated in practice by average

[38] These tests are summarized by Janusz A. Ordover and Garth Saloner, "Predation, Monopolization, and Antitrust," in R. Schmalensee and R. D. Willig, eds., *Handbook of Industrial Organization*, Volume I, Elsevier, 1989, Chapter 9.

variable cost. Joskow and Klevoric call for an "average total cost" test, after an initial inquiry indicates market structure makes predatory pricing plausible. Posner substitutes long-run marginal cost for short-run marginal cost in the Areeda-Turner test. Ordover and Saloner also mention Baumol's TSLRIC test. Finally, Ordover and Willig propose an appealing rule that predatory pricing is that which causes a firm to lose profits relative to its profit maximizing price, given the presence of its competitors, such that lost profits cannot be recouped except through exit of those competitors from the market and subsequent price hikes. The attractiveness of this approach is that the assessment of the alleged predatory action is in the context of specific business decisions—services actually offered, prices actually charged, and costs actually incurred.

Appendix B: Telcordia's SCIS Overview Document

SWITCHING COST INFORMATION SYSTEM (SCIS)

Introduction

Telcordia Technologies has developed a suite of cost models to assist in determining the average and marginal cost for provision of basic and value-added services. Both vendor information and actual network data are used in the cost models. Telcordia Technologies' suite of cost models consist of:

- Network Cost Analysis Tool (NCAT)
- Switching Cost Information System (SCIS)
- Common Channel Signaling Cost Information System (CCSCIS)
- Network Vision

Figure 1 shows the application of these models to the costing of the various network functionalities.

This document provides an overview of the Switching Cost Information System (SCIS). It will focus on the following topics:

- History of SCIS
- Problem SCIS solves
- Basic hardware/software attributes of the system
- System overview
- Description of the Model Office Module Development Process
- Description of the Vertical Services Module Development Process
- Description of required inputs
- Description of output reports
- Summary

1.0 History and Problem Statement

This section introduces the Switching Cost Information System (SCIS) by providing the history of the system (i.e., why it was first designed), the problem it solves, and some software/hardware attributes of the model (e.g., program size).

The provisioning of the telecommunications services became increasingly complex in the early 1970's. The complexity arose from the proliferation of the new technological developments, which, in turn, permitted the introduction of sophisticated new services. Developments in switching technology greatly contributed to this phenomenon. Concurrently, it became increasingly important to obtain a high degree of accuracy in the costing of these sophisticated services for both business decision and tariff purposes.

Prior to the 1970's, switching was mostly mechanical in nature and was used, primarily, to set up POTS (Plain Old Telephone Service) telephone calls. However, the introduction of computerized electronic switching systems raised questions regarding the costing and pricing for the new vertical services these switches could provide. Indeed, since the new services shared the same switching resources within the switch that provided POTS, it became increasingly important for the telephone companies to have a process whereby they could address the shared equipment phenomenon while accurately identifying the individual cost of these new services. This was critical to insure that informed business decisions could be made and that just and reasonable rates could be developed based on the principle of cost causation.

In analyzing the intricacies of how such a problem could be solved, it became evident that the solution would be both time consuming and costly. Indeed, the new switches were among the most sophisticated computers ever built with a multiplicity of components that were shared by thousands of users and hundreds of services. Nonetheless, the cost solution evolved as a mathematical model called the Switching Cost Information System (SCIS). The underlying mandate for the model was the need to determine the actual switching costs (investments) required to provide specific central office services using proven economic theory and methods. For that reason, the model had to be capable of assigning shared switching resources to individual services. Moreover, the model not only had to conform to the emerging requirements of that period, but also had to maintain pace, as a function of time, commensurate with the anticipated diverse needs of both the user and the provider. SCIS has lived up to these expectations. Accordingly, it has been in use by the telephone companies for over 20 years.

1.1 SCIS Today

Today's telecommunications environment continues to become more complex. Technology continues to evolve, the regulatory environment continues to undergo substantial change and competition continues to proliferate. Consequently, it is a fundamental objective for companies, the regulatory bodies and intervenors to have a mechanism that can identify the costs of providing service in such an environment. In fact, it is an essential prerequisite to establish the necessary certainty for making rational planning and pricing decisions and for the development of the competitive and dynamic telecommunications market envisioned by regulatory agencies.

In accordance with these objectives, SCIS has become a robust, dynamic and complex PC software model. It encompasses a family of 25 modules which analyze investments for 8 switching system technologies from switch manufacturers: Lucent Technologies Inc., Ericsson Network Systems Inc., Nortel, Siemens Stromberg-Carlson, NEC Corporation, and Alcatel. For each technology (where appropriate), cost analysis is done for the complete product line including all remote switching entities and tandem entities, including ISDN and SS7 functionality. Figure 2 depicts a complete list of switch technologies addressed by SCIS. The program also provides feature-costing algorithms for hundreds of features (varies by technology). SCIS contains 37 Megabytes of programmable code (over 500,000 lines of code). The hardware and software requirements and recommendations for SCIS include:

	Required	Recommended
IBM-compatible personal computer based on:	Pentium microprocessor	Pentium II microprocessor
RAM	16 megabytes	32 megabytes
Hard Disk Space	30 megabytes + 2 megabytes/100 offices	80 megabytes
Printer	Printer	Printer
Operating System	Windows 95	Windows 95 or later

As alluded to above, SCIS is not a static system. In fact, it is extremely dynamic. It requires interaction among Telcordia Technologies, the switch vendors, and the users. Since 1995, there have been over 40 SCIS software releases reflecting new technologies, engineering rules, switching architectures, features and/or price revisions. The above described releases also reflect conceptual/analytical and human factor-related enhancements.

2.0 System Overview

This section provides an overview of the SCIS framework used to calculate switching related investments. In addition, it is shown how the framework manifests itself in the model. Finally, brief descriptions are provided relative to: output information that is generated, technical information which is required to perform the modeling, and the user inputs required for the model to perform its calculations.

2.1 Solution Framework

When faced with a very complex problem, problem solvers usually begin by defining a framework or philosophy that will provide a solid foundation to the ultimate solution. This is referred to as "bounding the problem". In accordance with this concept, the original SCIS architects composed the following principles.

The first principle was that the solution had to incorporate a "bottom-up" approach. Indeed, it was determined that a top-down approach could not accurately or effectively address the shared equipment phenomenon. The bottom-up approach, on the other hand, would provide the requisite level of detail to distinguish the use of the switch resources by feature application. Such detail was considered a prerequisite if shared equipment was to be properly assigned to individual services. Thus, one of the underlying principles of SCIS is the development of a list of basic common denominators of cost that define switch usage in such a way that feature investments can be generated via a mapping sequence.

The second principle was that the solution needed to be a forward-looking one. SCIS was going to be used to support tariff-filing activities. Accordingly, it was determined that the solution had to be based on the latest technology, and up-to-date vendor pricing and engineering information. This is not only appropriate, but also logical since the rates derived from the costs generated are pertinent to the current environment and not to some historical period.

Most economics literature recommends developing costs that are long term and stable in nature, the third principle was that the solution should have a long term perspective. This would have the desired effect of reducing cost fluctuations resulting from lumpy investments, or the sequencing of services or customers that are introduced during the life of the switch. This also would mean that services or customers would not benefit, or be disadvantaged as a result of the above.

The fourth principle was that cost results would be based on usage. That is, the solution would express the cost of the shared equipment as a function of the "capacity" consumed to perform service specific activities. From an objective standpoint, implementation of this principle achieves, among other things, a cost causative solution.

2.2 Solution Implementation

The preceding philosophy resulted in the development of two interrelated, but separate modules of SCIS: a Model Office Module (SCIS/MO) and a Vertical Service Module (SCIS/IN) for each switch technology. Herein it should be noted that Engineered, Furnished and Installed (EF&I) investment results could be generated in the above two modules. In addition, if the user supplies an Annual Charge Factor, SCIS/IN will produce Annual or Monthly Costs. Accordingly, investment and cost can be used interchangeably in SCIS/IN. Figure 3 displays the relationship between SCIS produced investment and total annual cost.

2.2.1 SCIS/MO – The Model Office Module

SCIS/MO is needed to analyze all switching components for purposes of identifying equipment costs associated with the least common denominators of cost (i.e., basic investment drivers of the switch). This process, in turn, permits the identification of service specific costs. Examples of investment drivers sometimes referred to as SCIS/MO "cost primitives" or "resource costs", are: the cost of a central processor millisecond; the cost of a distributive processor millisecond; the non-usage sensitive cost per line termination; the cost per originating + terminating

(O+T) CCS; the cost per outgoing + incoming (O+I) CCS; and the cost per call set-up function (e.g. originating call function that includes recognizing dial tone, digital collection, etc.). See figure 4 for a complete list of potential SCIS/MO cost primitives that may be produced for each switch technology, depending on its architecture and engineering rules.

The SCIS/MO analysis may involve a single office, or multiple offices. If multiple offices are involved in the user's study, the model analyzes each office individually and provides a weighted average output for each cost primitive the technology requires. If any office studied serves as hosts for remote switching entities, costs of the remotes are also analyzed and weighted in with that of the host office.

This weighting process is the basis for the model office determined by SCIS/MO. In other words, the results of the SCIS/MO analysis reflect a "model" office for the complete study. This approach produces a cost for a particular investment driver (or ultimately a portion of a service) which is the same, regardless of the specific switch entity serving the customer, or the particular technology used to implement the service (e.g., analog or digital line termination).

Figure 5 depicts how vendor engineering and pricing information and actual switch data are used by SCIS/MO to produce the cost primitives. These cost primitives are subsequently used in NCAT and SCIS/IN.

2.2.2 SCIS/IN – The Vertical Service Module

The second module developed for each switch technology is SCIS/IN, the Vertical Service Module. As shown in Figure 5, SCIS/IN utilizes cost primitives from SCIS/MO, resource consumption data stored in tables, and feature specific input data to obtain feature costs. SCIS/IN performs the aggregation of the cost primitives, or the resource costs quantified by SCIS/MO with the required resources (such as real time, memory, CCS, signaling packets, etc.) to implement a specific service in the switch. The output of each feature costing algorithm may be expressed on a per call basis, per line, per customer, per group, etc. Also, each feature cost output includes results categorized by each resource cost.

Once SCIS/IN provides costs for individual services by switch technology, SCIS/IN can compute a weighted average of respective service costs by switch, if the service is provided to the market via more than one switch technology. The user must enter factors upon which SCIS/IN can base the weighting.

2.2.3 Required Vendor Information

In order for Telcordia Technologies to perform the above analyses, certain technical information must be obtained from all switching vendors. Following is a list of informational requirements that are transmitted to the vendors on a recurring basis.

- Long range product development plans and delivery schedules.
- Detailed technical descriptions of the switch architecture.
- Current hardware engineering rules and engineered capacities.
- Current unit level prices of individual switching components.
- Universal discounting schemes.
- Automated engineering and pricing tools, for purposes of model verification.
- Detailed service descriptions, including how the switch implements the service.
- Resource consumptions on a per feature or function basis, if required.
- Documentation that describes where feature traffic measurements may be obtained (e.g., usage, activations, or deactivations).

Some of these data items are stored in the SCIS Resource Consumption or Assumption tables (e.g., real times, memory, signaling packets for ISDN services, equipment capacities, etc.), see Figure 6.

2.2.4 Required User Inputs

Each model in SCIS requires similar, but unique specific inputs which allow for accurate representation of the switch's resource and ultimately, its service costs. Following are brief descriptions of the four categories of data required:

The first category defines study parameters. Such inputs establish the standards that will apply to all the offices in the study. Examples include: study type (marginal or average), vendor discounts, cost of money, and switch generic program version.

The second category pertains to office parameters. Examples include: line and trunk quantities, usage by line and trunk type, processor utilization data and line concentration ratios (if known).

The third category provides detailed information for each remote switch that may be served by a host office. Examples include: host office interface parameters (umbilical CCS), and usage and quantities of lines served at the remote office.

These three data types are required by SCIS/MO to develop the basic resource investments.

The fourth category of input is associated with vertical service costing. Each vertical service requires incorporation of a unique data set that is relevant to the specific analysis requirements of the feature. Typical inputs include: Busy Hour attempts, and holding times for specific vertical service functions. Separate algorithms for each feature combine these inputs with SCIS/MO calculated resource investments to develop feature specific costs.

3.0 SCIS/MO - Development Process

The output reports generated by SCIS contain a complex body of analytical work. The primary effort in that work is the establishment of SCIS/MO. The Telcordia Technologies modeler develops the model based on the philosophy described preceding and a standard methodology that is not dependent on switch technology. Following is a sequential step-by-step description of the SCIS/MO development process. In addition, Appendix A contains a flowchart depicting the process detailed below.

Step 1: To develop a switch cost model, engineering data and technical information must be obtained from the vendor. Once obtained, the switching system architecture is studied to determine the functional characteristics of each of the equipment items. Inasmuch as, the SCIS modeling approach views the switch as a set of functions that are necessary to provide services, this step is referred to as the "conceptualization phase".

Step 2: Central offices representing a wide range of traffic volumes and office sizes are selected for purposes of subsequent verification of the resulting model. This verification occurs in Steps 7 and 8 of the process. The types of characteristics included are: quantities of lines and trunks, usage data and call data.

Step 3: Each office selected in Step 2 is engineered and priced according to the vendor's recommended engineering rules and utilizes vendor supplied software. The total cost is computed and is used to validate the SCIS/MO model in Step 8.

Step 4: Once the functionality within a switch has been determined (Step 1), it is possible to identify the cost categories represented by the functions, as well as the cost drivers of the various functions by category. For example, a function may be the capability to terminate a line. This functionality can be represented by the Line Termination Cost Category into which all equipment used to terminate a line is grouped. The cost drivers of the category are the quantity of lines in the office and the BH CCS /line. Another example is the Getting Started Cost Category, which contains equipment, that while not associated with any particular switching function, has an investment driver (Central Processor real time),since it is the resource that potentially forces the purchase of a new switch.

Steps 5 and 6: Once the Cost Categories and Cost Drivers have been identified, each piece of equipment is analyzed and mapped into one or more of the cost categories via a thorough examination of the engineering rules and respective switching functions. This is referred to as the "partitioning process". Such mappings are performed by mathematically modeling each equipment item's contribution to each of the respective cost categories. In simple terms, the modeler is performing a "bottom-up" analysis that takes the switch apart and puts it back together in terms of physically significant mathematical cost expressions Most mathematical relationships are linear, resulting in linear coefficients in the mathematical cost expressions. However, a few non-linear relationships are occasionally encountered resulting in both coefficients and exponents in the mathematical cost expressions. The developed expressions are physically significant because each is developed from the bottom up independent of each other. The expressions truly represent the cost of the switching attribute being modeled.

Steps 7 and 8: The accuracy of the partitioning process, described above, is validated by comparing the results obtained from the above process for each of the offices selected in step 2 using SCIS/MO, with the bottom line total generated in step 3 using vendor provided engineering and pricing information. If the difference from the complete sample is less than or equal to 5%, then the model is released. Otherwise, the differences are investigated and corrective action is taken in the partitioning process and/or SCIS/MO algorithms until the 5% difference is achieved.

Step 9: The results of the partitioning process are referred to as cost expressions (i.e., coefficients and exponents) and are stored into the SCIS Investment Tables. These cost expressions represent starting points for the SCIS/MO algorithms. They are determined outside SCIS without needing data for any specific office or remote.

Steps 10 – 13: These steps take the cost expressions, described above, and transform them into the SCIS/MO cost primitives that are representative of their investment drivers, using switch specific input data entered by the user. Some of the cost expressions developed in the partitioning process either do not yield results which are directly applicable to feature costing, or are but one of multiple versions of the same switching function. An example of the first type of non-applicable cost expression is the getting started cost. It must be transformed into another mathematical expression that is representative of its investment driver (central processor real time) such that it is usable for feature costing. The user must apply some processor related data (e.g., utilization) in order to perform this transformation.

An example of the second type is the line termination cost category where one expression exists for each potential line concentration ratio (LCR). The user must either supply the LCR or the model determines it from user supplied usage data. Similar to the above, this step is necessary for the model to produce a cost expression applicable for feature costing.

During this phase of the process, the model also incorporates other user input data for the purpose of calculating the ultimate resource costs or cost primitives. Examples of such user controllable parameters are:

- Study type (marginal or average)
- Vendor discounts
- Cost of money
- Office characteristics required for weighted averaging in multiple office
- Use of capacity cost calculations or a more rigorous approach in connection with marginal cost studies only.
- The elimination of all excess capacity costs when calculating marginal costs
- Modification of the getting started cost
- User decision to treat growable processor switches and SS7 signaling costs in a marginal study
- The inclusion of right-to-use fees
- User controlled maximum available processor and signaling link capacity due to local engineering practices
- Administrative fill factors
- The mix of analog and digital interface technology
- Use of current switch generic programs vs. older vintages
- Annual change factors, if properly input

Many of the parameters listed preceding are controlled by the user via SCIS/MO setup data. This input data is unique to each user community. Accordingly, SCIS/MO results reflect local conditions and attendant costs, which will vary from one jurisdiction to another. In order to ensure accuracy, user range edits are also provided to reflect the minimum and maximum capacity of the switch (e.g., busy hour holding time cannot exceed 3600 seconds or 1 CCS).

Step 14: A study report is generated that provides the resource costs calculated in steps 10-13. Single office studies also produce total cost reports.

Step 15: Unit resource costs are stored in a database along with the user inputs for all respective offices in the study. This database is used for future feature costing use.

4.0 SCIS/IN Development Process

This section describes the steps required to develop feature-costing algorithms. It should be noted that the modeler need not perform the following steps in the exact sequence depicted. However, each step must be performed.

Step 1: The modeler is informed of new features/services from either meetings with the vendor where future plans are presented, or via advance documentation of the services.

Step 2: The operation of the feature is researched from both the subscriber's viewpoint, as well as from the switch resource perspective.

Step 3: The types of switch resources being utilized by the feature are identified, including any special hardware required only for vertical services. An equation is developed that replicates the use of the special hardware in terms of the investment driver (e.g., CCS for a 3-port conference circuit).

Step 4: The feature activities that consume switch resources is determined (e.g., activations, holding time, etc.).

Step 5: Feature specific switch resource measurements for processor(s) real time (milliseconds), memory utilization, packet utilization, etc. are obtained from the vendor.

Step 6: A determination is made whether or not the specific switch measures feature usage (e.g. number of activations, etc.).

Step 7: Possible tariff structures are identified.

Step 8: In order to determine the cost of the feature, it is necessary to identify if any part of the feature is already recovered by existing tariff structures (e.g., the forwarded leg of a call is addressed by the normal POTS tariffs on the forwarding station). These tariffs could be local, toll, or long-distance. In the above example of call forwarding, if a station forwards its calls from Washington to California, the access and long-distance tariffs would charge for that forwarded leg of the call.

Step 9: Create the actual feature costing algorithms using the SCIS/MO cost primitives, user-entered inputs and vendor supplied switch resource measurements. Similar to SCIS/MO, user input range edits are used for purposes of ensuring accuracy. Sometimes, additional algorithms must be composed to generate the feature investment output in the same format as the possible tariff structures (e.g., Multiline Hunt Groups may be tariffed per line or per group).

Step 10: Weight the cost of a service across the switch technologies that offer the service. Depending on the switch technology mix, average results could vary among user communities. In fact, these cost differentials could be magnified if a particular feature costs considerably more, or less in a particular switch technology.

Step 11: For intelligent network services, it is necessary to identify the SS7 signaling resources utilized. Once identified, separate algorithms are constructed to define these investments using methodology similar to the above.

Step 12: In addition, to be complete, the cost analyst running SCIS/IN must identify the right-to-use packages required to make the feature operational. *RTU fees are not included in the total feature cost produced by SCIS/IN.*

5.0 SCIS Output Reports

SCIS produces two types of output reports: Model Office Reports from SCIS/MO which display the cost of basic switching functionalities (resource costs); and Vertical Service and Feature Reports from SCIS/IN which display the switching cost for vertical features and services.

5.1 SCIS/MO - Model Office Reports

Basic and ISDN reports are generated for each switch model. They display all functional cost category results (resource costs). Additional reports are available that display line and trunk type specific results. There are also reports for the user inputs used in SCIS/MO calculations.

The outputs from the basic and ISDN reports are used to tabulate vertical service and feature cost information in SCIS/IN. SCIS/MO generates all reports at a number of levels as described below:

[1] Grand Weighted Unit Investment – Displays the average of all standalone/host and associated remote switches weighed by the relative size, or traffic of the individual switches in the study.

[2] Weighted Unit Investment – Set of reports which display the weighted cost associated with various subsets of offices and/or remotes included in the study. Such subsets include all host/standalone offices in the study, all remotes in the study, etc.

[3] Unit Investment – Displays the costs associated with each switch included in a study, and includes total investment costs for the switch.

5.2 SCIS/IN - Vertical Service and Feature Report

This report is produced for each of the hundreds of vertical services and features available in the SCIS family of switch models. Each switching model will produce a specific vertical service, or feature output report based upon the switch hardware required by the feature, switch model output data from a user-selected Model Office report from SCIS/MO, and user-specified feature inputs. Seven (7) cost categories are displayed on the report: getting started cost, usage costs, call costs, minimum line cost, feature-related hardware cost, memory cost, and total resource cost.

6.0 Summary

SCIS utilizes a bottom-up engineering approach and proven economic theory to produce the individual costs of technology specific features. It is also a proven solution to solving the problem of assigning the costs of shared equipment to individual switched-based services.

SCIS is dynamic and reflects the latest technologies and features.

Economic theory is appropriately applied to produce practical approaches without sacrificing validity or credibility.

SCIS, with its cost primitives, can identify the cost of any switch capability that is sufficiently defined by the vendor.

SCIS methodology guarantees that a cost primitive's value is the same regardless of the service, or customer.

The consistent development and application of SCIS processes and procedures across technologies, switch types, and services attests to the universality of the approach.

The SCIS process is predicated on the principle of defining cost causation over the long run.

The SCIS process and results are verifiable.

SCIS has been effectively used for over 20 years for business decision and tariff filing purposes.

Figure 1 - Network Cost Analysis Overview

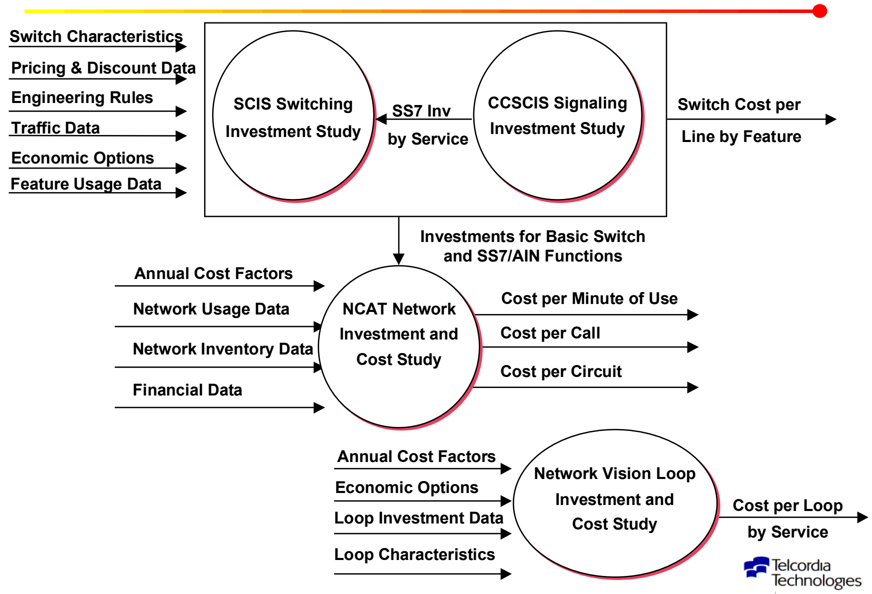

Figure 2 - Switching System Technologies In SCIS

5ESS	Local/Tandem Host/Remotes SSP ISDN	EWSD	Local/Tandem Host/Remotes SSP ISDN
DMS-100F	Local/Tandem Host/Remotes SSP ISDN	AXE-10	Local/Tandem Host/Remotes SSP ISDN
DMS-10	Local Host/Remotes SSP ISDN	NEAX-61E	Local/Tandem Host/Remotes SSP ISDN
Fetex	Local/Tandem Host/Remotes SSP ISDN	S12	Local/Tandem Host/Remotes SSP ISDN

Figure 3 - SCIS Produced Investment & Total Annual Cost

SCIS Produced Investment

+ Telco Engineering

+ Telco Installation

+ Telco Other

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Total "In Plant" Investment →

Annualized Depreciation, Taxes, Cost Of Money

+ Direct Maintenance

+ Direct Admin. Expense

+ Direct Misc. Expense

Total Annual Cost For Switch Equipment

Telcordia Technologies
Formerly Bellcore... Performance from Experience

Figure 4 - SCIS/MO Investment Primitives

- Getting Started Investment (Per Millisecond)
- Distr. Processing Investment (Per Millisecond) (Non-ISDN, ISDN)
- Line Termination Investment (Non-ISDN, ISDN)
  - Per Line
  - Per CCS (Orig., Term.)
- Trunk Termination Investment
  - Per Local CCS (Out., Inc.)
  - Per Tandem CCS (Out., Inc.)
- Call Type Investment
  - Per Originating Call
  - Per Terminating Call
  - Per Outgoing Call
  - Per Incoming Call
  - Per DTMF Call Increment
- Special Hardware Investment (Per CCS)
- Memory Investment (Per Byte)
- SS7 Octet Investment (Per Octet)
- ISDN Packet Investment (Per PPS) By Type

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Figure 5 - SCIS Model Office Process

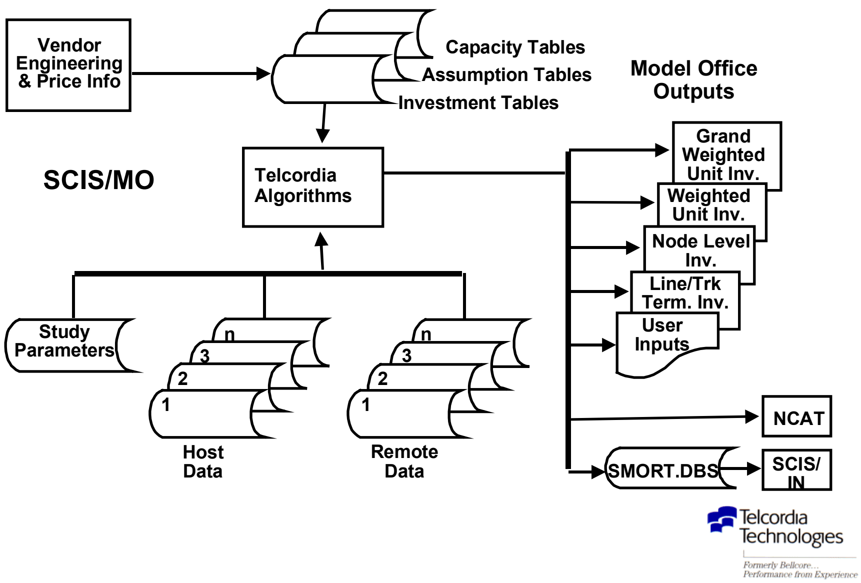
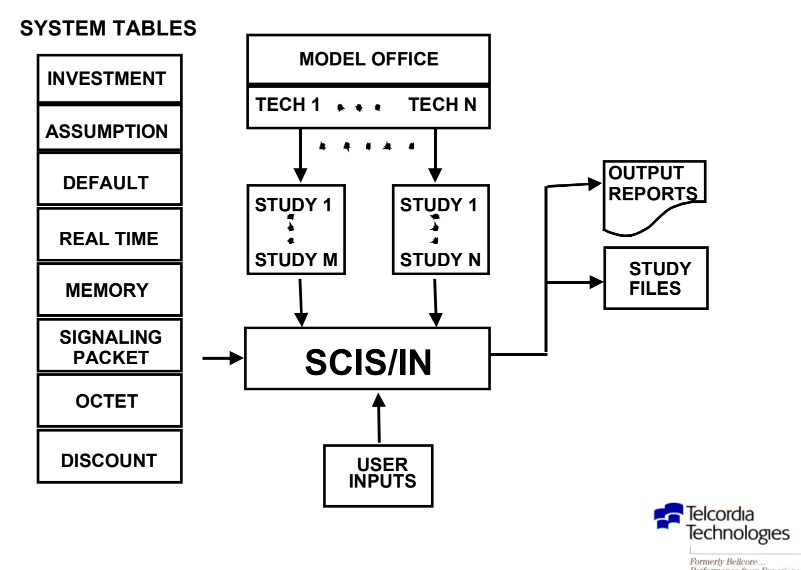


Figure 6 - SCIS/IN Overview



Appendix C: An Economic Analysis of Capacity Costs

A fundamental characteristic of telecommunications facilities is that capacity to accommodate demand efficiently often comes in sizes greater than one unit. Therefore, when demand increases, capacity is not added a unit at a time to meet this increase.[1] Rather, capacity is added at discrete intervals to accommodate the demand. Figure 1 represents this phenomenon. Note, for example, that capacity to accommodate 100 units, say, is installed at the beginning of the period. No additional capacity needs to be installed until demand reaches 100 units, at which point, a second module capable of serving 100 units is installed.

In one sense, the "lumpiness" of telecommunications capacity does not change the fundamentals of long-run costing. We are still interested in how much cost has increased to accommodate a demand increase of a particular size. The difference comes in performing the calculations necessary to determine by how much an increment of demand has increased cost. In the simple case of non-lumpy capacity, one unit of demand can be accommodated by the cost of an extra unit of capacity, purchased as a single unit. In the lumpy case, however, the effect of a demand increase is different; from an economic perspective, a permanent increase in demand advances the time when the additional increments of capacity need to be placed.

[1] The magnitude of the demand increase depends on the business decision being analyzed, with the need for increases in capacity varying accordingly. The capacity cost technique discussed in this section accommodates different definitions of this demand increment. Therefore, the approach can be used in the context of a LRIC study for a particular business decision as well as in the special regulatory applications of TSLRIC and TELRIC methods.

Figure 1

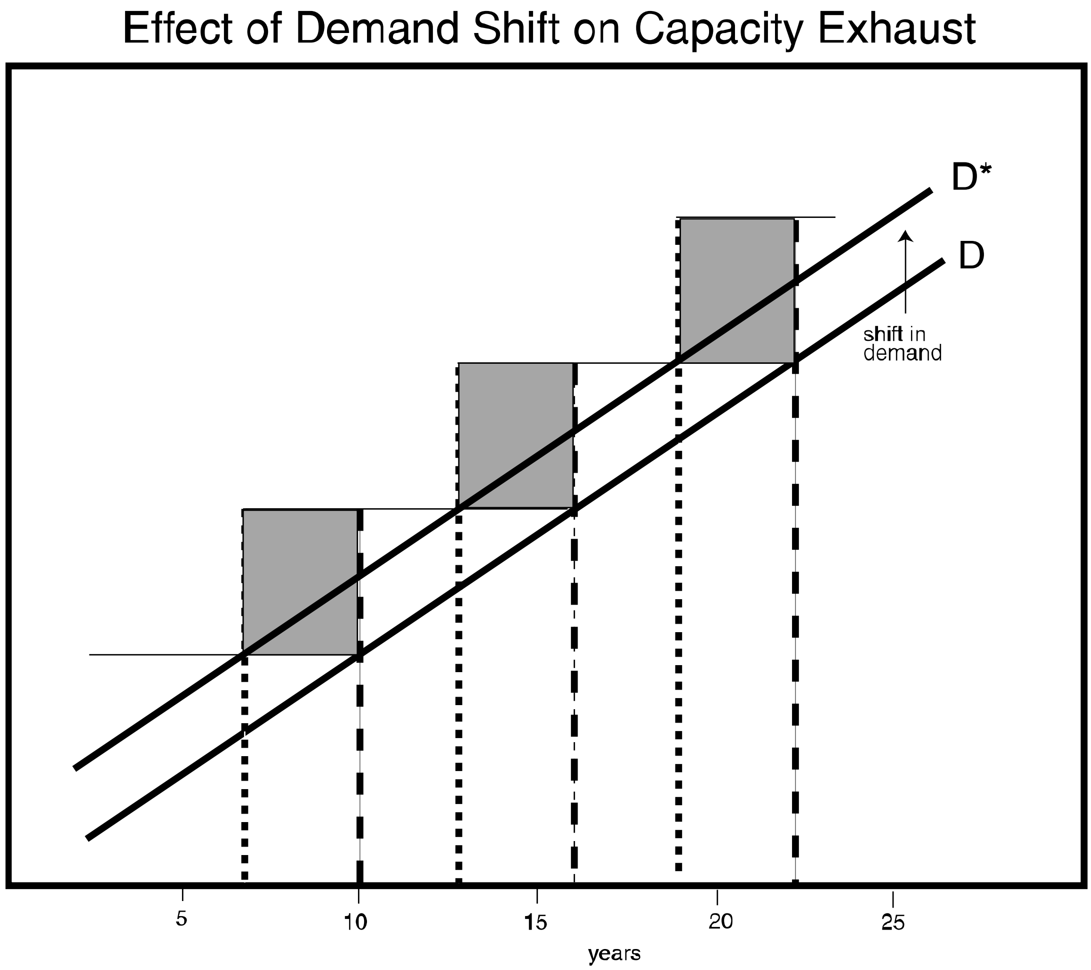


Figure 1 depicts this phenomenon. A permanent increase in demand advances the placement of the increments of capacity needed to accommodate growing demand. For example, with the base line demand **D**, the first new increment of capacity would be added in year ten. The permanent increase in demand advances the deployment of the first new capacity reinforcement by roughly three years, and this advancement applies to all subsequent reinforcements in this example. In effect, a time dimension has been added to the incremental cost calculation.

Mathematically, the incremental cost calculation becomes:

$$\textit{Unit Incremental Cost} = \frac{PV(C_1) - PV(C_0)}{PV(V_1) - PV(V_0)} \qquad \textbf{(1)}$$

where PV denotes present value.[2]

A. Cost Determination/Attribution

The incremental investment necessary to accommodate a new increment of demand can often be broken into two components: (1) a component that varies directly with volume (often linearly) and (2) a non-volume-sensitive component. In many situations of interest, the volume-sensitive cost has the following convenient representation.[3]

$$Unit\ Cost_{Volume-Sensitive} = \frac{Cost\ of\ Capacity\ Module}{Effective\ Capacity} \qquad \textbf{(2)}$$

For example, if the cost of an extra 100 units lump of capacity in Figure 1 is \$100 and the effective capacity is 100,[4] the unit volume sensitive cost is \$1/unit.

In fact, Equation 2 can be an exact solution to Equation 1. Referring again to Figure 1, mathematical proofs have been offered in a number of special cases: (1) the demand increment is a constant increase (e.g., 10 additional units) over baseline demand and the initial baseline demand (the y intercept in Figure 1) is uniformly distributed between 0 and the effective capacity of the

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[2] At first glance, the notion of present value of demand in the denominator of the equation seems strange, because present value deals with the time value of money and units of demand are not money. The calculation has more intuitive appeal when it is restated in terms of cost per unit of demand, which is a monetary figure. That is $\frac{PV(C)}{PV(V)} = \frac{d_i C_i}{d_i V_i} = f_i \frac{C_i}{V_i}$, where d_i is the discount factor for year i and $f_i = \frac{d_i V_i}{d_i V_i}$. That is, the unit incremental cost is the weighted average of the annual unit costs, where the weights vary with the annual volumes and the discount factors.

[3] This term is also known as the average incremental cost and the Boiteux price in the economics literature. See Rolla Edward Park, *Incremental Costs and Efficient Prices with Lumpy Capacity: The Single Product Case*, The Rand Corporation, June 1989. For a non-mathematical discussion of capacity costs see Richard D. Emmerson, *op. cit.*, pp. 145-189.

[4] In some cases, the effective capacity is less than the physical capacity of the lump, e.g., there may be defective units and/or some units may be needed for administrative purposes. Thus, the "spare capacity" represented by the difference between total physical capacity and effective capacity is part of the volume-sensitive cost. Specifically, the volume sensitive cost is (1/u) times the cost that would apply if all the physical capacity were available, where u is the ratio of effective capacity to total physical capacity.

lump,[5] (2) the demand increment is a linear increase in the rate of growth (slope) over baseline demand (e.g., the baseline demand is growing by 10 units per year and new demand is growing by 15 units per year) and again the initial baseline demand is uniformly distributed between 0 and the effective capacity of the lump,[6] and (3) the initial baseline demand is zero and a constant permanent increment of demand occurs sometime between time 0 and the time when the first unit of capacity would be added in the baseline case.[7]

Although Equation 2 is not always an exact solution to Equation 1, the unit volume sensitive cost is widely used in practice, both because of its simplicity and the fact that the underlying calculation and associated data are easily verifiable. Such practical use is also supported by Emmerson's finding that the approximation to the exact solution is reasonably close when the underlying assumptions are relaxed.[8]

There is, however, a particular special case where the unit cost calculation in Equation 2 is not a close approximation. In situations where only a single lump of new capacity is expected over

[5] The assumption that the initial baseline demand is uniformly distributed between 0 and the effective capacity has the following practical interpretation. Demand is being served on a number of facilities that deploy the lumps of capacity additions (e.g., line cards in a switch are deployed over all the switches in a service territory) and at any point in time, the actual utilization of a particular lump of capacity is somewhere between 0 and the maximum capacity. The theoretical result is the average over the lumps in question.

[6] J. Lee and V. Schmid-Bielenberg, "Marginal Cost and Capacity Cost," Attachment I of Viktor Schmid-Bielenberg, "Bellcore's Switching Cost Information System (SCIS) Cost Model: A Practical Approach to a Complex Problem," in William Pollard, ed., Marginal Cost Techniques for Telephone Services: Symposium Proceedings, The National Regulatory Research Institute, 1991, pp. 85-123.

[7] Richard D. Emmerson, "Capacity Cost," Indetec Corporation, 1994.

[8] Emmerson, 1994, *op. cit.* Emmerson's article credits Professor Baumol with originating the capacity cost solution during a early 1970s FCC cost proceeding.

the remaining life of an existing facility and an increase in demand advances the date at which the replacement takes place, an exact solution of Equation 1 is the following:[9]

$$Unit\ Cost_{Volume-Sensitive} = \frac{(Cost/s) \times r\ e^{-rT_I}}{1 - e^{-rT_L}} \tag{3}$$

In Equation 3, s is the slope of line representing volume growth in Figure 1, r is the discount rate, T_I is the length of time until the new module of capacity is expected to be added and T_L is the remaining life of the facility in question. Because the situation addressed by Equation 3 is of an intermediate duration, it is generally not applicable to the types of long-run studies currently used to set regulated prices, e.g., the use of approaches such as TELRIC for setting unbundled element prices.

A key feature of Equation 2 is that volume-sensitive costs are based on full utilization of all capacity (up to the level of effective capacity). In contrast, Figure 1 demonstrates that capacity is not always fully utilized; for each additional lump of capacity, full utilization only occurs at the time the next increment is about to be added.[10] Consequently, a firm that included only the volume sensitive costs in its prices would not fully recover its costs.

Identification and measurement of these *non-volume-sensitive costs* proceeds by comparing the firm's total cost to serve the volume in question with the cost that would be recovered by charging the unit cost produced by Equation 2 to the new volume in question.

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[9] Specifically, the exact solution assumes (1) linear volume growth in the base case, (2) a permanent increase in demand occurs at the time the calculation is performed, and (3) the continuous versions of present value formulas are used. Equation 3 is derived from Equation 1 under these assumptions plus assuming that the demand increment is small. The numerator represents the increase in costs that results from advancing the time the new module is installed. The denominator is the fraction of the total present value of a permanent increase in demand that occurs during the remaining life of the facility.

[10] For example, Emmerson, 1994, shows that the average amount of spare capacity in situations depicted in Figure 1 is one-half of the capacity of an additional module.

$$C_{NVS} = [PV(C_1) - PV(C_0)] - Unit\,Cost_{Volume-Sensitive} \times [PV(V_1) - PV(V_0)] \qquad \textbf{(4)}$$

This volume-insensitive cost can be of one of two types, depending on the cost problem being studied. First, if the volume in question is considered a single service, the non-volume-sensitive cost is a *product-specific fixed cost*. For example, the total peak capacity of a switch can be viewed as a single service: unbundled local switching. As discussed earlier, such costs are recovered over the total volume of the service in question, although not necessarily with uniform mark-ups over the volume-sensitive cost. Second, in other studies, the same volume could be viewed as an input to two or more services, e.g., local switching capacity is used for local as well as long distance calling. In this case, the volume-insensitive cost is a *shared fixed cost*. Economic principles require that this cost be recovered in the prices charged for the several services, although again there is no requirement that that recovery be uniform or that particular services as a whole be required to recover specific proportions of this cost.

Just as Equation 2 serves as a practical tool for identifying the unit volume-sensitive cost, an equally simple equation has become prominent in practical cost studies for identifying the non-volume-sensitive cost. Let a be the average capacity utilization and u be the utilization at effective capacity. Then

$$Average\,Unit\,Cost_{Non\,Volume-Sensitive} = \frac{[Cost\;of\;Capacity\;Module]}{[Physical\;Capacity]} \times \left[\frac{1}{a} - \frac{1}{u}\right] \qquad \textbf{(5)}$$

As described earlier, the FCC's TELRIC approach calls for uniform recovery of this non-volume-sensitive cost, i.e., the average unit non-volume-sensitive costs identified in Equation 5 are added to the volume-sensitive cost. The result of this calculation is to replace utilization at effective capacity with actual utilization in the calculation shown in Equation 2 (and noting that Effective Capacity = *u* x Physical Capacity).

$$Average\,Unit\;Cost\;=\frac{Cost\;of\;\;Capacity\;Module}{a\times Physical\,Capacity} \qquad \textbf{(6)}$$

Alternatively, if such volume-insensitive costs are to be assigned to another unit of demand, e.g., subscriber lines, multiplying Equation 5 above (the average non-volume-sensitive cost per unit) by actual usage (a x physical capacity) produces the total dollar value of the spare usage capacity. Dividing this intermediate result by number demand units produces per unit mark-up necessary to recover the spare capacity cost. That is,

$$Non\,Volume-Sensitive\,Cost\,/\,DemandUnit=(Cost\;of\;\;Capacity\;Module\,/\,DemandUnit)\times[1-\frac{a}{u}] \quad \textbf{(7)}$$

One final special case can occur where excess capacity exists in each and every lump of investment depicted in Figure 1. This phenomenon is different from previous cases where spare capacity exists for some period of time until demand consumes the spare capacity and a new unit is purchased. Certain switching equipment items, e.g., line termination equipment, are designed with dual-limiting capacities—total lines and total peak period usage.[11] For example, a particular line module at a given line concentration ratio ("LCR")[12] may have capacity for 500 lines and 1500 hundred call seconds ("CCS") in the busy hour. If the average peak usage per line is less than 3

[11] In general, both lines and peak usage can cause additional resources to be incurred and the relative contribution of these demand drivers to total cost will vary across switches. Thus, switch models that assume constant proportions, such as those used in a number of proxy cost models can produce inaccurate results. See, for example, Atkinson, et al. Opt. Cit., ¶ 50.

[12] Concentration is the consequence of terminating more subscribers to a given line peripheral than can possibly use the equipment at the same time. A proper concentration ratio is selected based on expected traffic demand (CCS is the primary cost driver) such that an acceptable grade of service is provided.

CCS, then the switch will have excess usage capacity for every one of the 500 lines that are served by the module. If the switch in question serves primarily lower-volume residential customers that generate only 2.5 CCS in the peak, only 1250 of the 1500 of usage capacity would be in use when line capacity exhausts.[13] Each additional line on average introduces 0.5 CCS of excess capacity for this LCR configuration.

This situation occurs for frequently-replicating equipment like line modules because switch vendors typically offer only a finite number of engineered configurations (LCRs) for such dual-limiting equipment. Therefore, both capacities will rarely exhaust simultaneously. Switch engineers must decide whether to buy enough equipment to have a reserve margin (i. e., spare usage capacity), or deload[14] the equipment, such that proper service is still provided. For economic reasons the former is usually chosen.

Accordingly, traffic-sensitive line termination equipment, when engineered properly, should have some reserve margin included in its usage capacity as specified in switch manufacturers engineering rules. This reserve margin is designed to accommodate occasional peaks in usage demand and some forecast of usage growth. As such, total usage demand on each line termination module should be less than total usage capacity provided by each line termination module.

Consequently, if only the volume-sensitive cost as determined by Equation 2 is charged for

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[13] The alternative scenario of above average peak usage would cause usage capacity to exhaust before the full 500 lines had been served. However, as we understand it, the incremental investments necessary to accommodate lines are not lumpy, so that serving fewer than 10,000 lines would not result in any unused investments.

[14] If the switch is engineered with an LCR that has capacity less than demand, then the maximum number of lines per peripheral cannot be utilized. Otherwise, the quality of service would be compromised. This condition is referred to as *deloading.* In these situations, the excess CCS capacity is zero. However, traffic engineers rarely design switches in this manner.

usage, the full usage cost would not be recovered for every line interface throughout the switching system. Rather than accommodating this residual cost through a mark-up on usage (as described earlier), it should be assigned based on its cost driver—line terminations. Multiplying Equation 2 (Capacity cost per CCS) by the difference between capacity and demand per line (3 CCS – 2.5 CCS = 0.5 CCS) produces the excess capacity investment per line termination.

The reserve margin built into the engineering of traffic-sensitive equipment contributes to the overall cost efficiency of the switching system. If the reserve margin were not provided, then any savings in switch investment would be more than offset by increased expenses for operations and administration when usage demand meets or exceeds usage capacity. When this occurs, subscriber lines must be deloaded from existing line interface equipment on to new line interface equipment to avoid degradation in service. These activities must be done on an on-going basis whenever traffic demand exceeds capacity. Operations and administrative expenses associated with such deloading activities are typically very expensive and, as such, are avoided whenever possible in Local Exchange Companies ("LECs"). The reserve margin concept included in the engineering of traffic sensitive equipment helps minimize the need for deloading activities in a switching system, resulting in a more cost efficient switch.

This proper costing approach recognizes that each new line, not the usage (CCS) per line, introduces the excess usage capacity cost. In other words, the non-traffic-sensitive cost per line should appropriately include the excess capacity cost, (but not the volume-sensitive usage cost), because line terminations, not additional usage, cause excess capacity. When new lines are added to the office, as long as the average CCS remains below capacity, their addition collectively brings more excess capacity into the switch, as more line peripherals are required. Additional load brought into the system by adding such low-usage lines will not cause excess capacity to be incurred. To the contrary, additional usage per line will consume excess capacity on each peripheral; merely proof that line peripherals are dual limiting. The result would simply be a drop in the excess capacity investment per line. The presence of excess capacity that does not exhaust because of usage may suggest that there is no incremental cost associated with usage, i.e., increased usage would not cause the addition and/or advancement of investment to accommodate that increase in demand. This could well be the case for particular switches. More generally, however, the incremental volume-sensitive cost determined by Equation 2 is appropriate for at least two reasons. First, when incremental costs are the basis for usage prices, they are generally aggregated beyond the serving area of a single switch. Within such an aggregation there will be high volume as well as low volume users and the price charged to high volume users should recover at least the volume-sensitive costs. Second, even for low volume users, charging too low a price could stimulate demand beyond the point where the usage constraint binds.

B. Improper Determination of Capacity Costs

As described in the previous sections, the capacity cost approach rigorously links a change in the volume of service produced by a firm to the amount and timing of extra capacity required to accommodate that new volume. Approaches which (1) overlook the fact that capacity needs have increased and/or (2) do not rigorously link the cost driver (volume increase) to the capacity resource will produce incorrect costs.

For example, consider the demand increase depicted in Figure 1. Even though demand increases immediately in this example, the next module is not added for some time into the future. If a cost study improperly truncated its measurement of cost before the next increment of capacity were added, it would produce the erroneous conclusion that only additional maintenance expenses were needed to accommodate the new demand. This conclusion is wrong because only in the case when capacity does not exhaust over the planning horizon, e.g., when absolutely no additions are needed, will the incremental cost equal out-of-pocket expenses only.

An example of the second faulty study would be one that started with the historical costs for current capacity, and then allocated these costs to services in a more or less arbitrary fashion. The fundamental problem with such a top-down approach is that there is no rigorous determination of whether an *increase* in volume causes the need for additional capacity in the future. A top-down study might provide plausible estimates of average costs for large aggregates of services (particularly where the embedded technology is similar to the technologies used in the future), but it cannot identify costs that vary with particular business decisions. Such a study is only at best an approximation and cannot be relied upon to address the many specific business decisions that can be handled by a properly implemented capacity cost assessment.