THE MEASUREMENT, EVALUATION, AND ENCOURAGEMENT OF TELEPHONE SERVICE QUALITY

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Seventeenth Annual Telecommunications
Policy Research Conference

October 3, 1989

Arlie House, Virginia

September 21, 1989

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ABSTRACT

Telephone service quality is an important but understudied aspect of industry performance. In order to evaluate industry performance in response to new technological opportunities and a new regulatory environment, we must be able to measure quality over time (and across firms), evaluate the many dimensions of service quality in terms of some objective function, and develop incentive mechanisms for encouraging appropriate levels (and mixes) of service quality. Plain old telephone service is far more complicated than typical models suggest, which requires that researchers rigorously analyze the costs and valuations of alternative quality improvements.

Seventeenth Annual Telecommunications Policy Research Conference October 3, 1989
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Research on quality of telecommunications service requires individuals with quantitative, historical, and analytical skills. Measuring quality and estimating its effects on costs and demands represent difficult tasks for engineers, econometricians, and psychologists. Similarly, understanding the institutional contexts within which choices have been made in the past requires a deep understanding of economics, politics, and history. In addition, while theoretical frameworks have identified how different market structures and regulatory constraints affect quality, the links to actual situations have not received much attention. The crucial relationships among empirical researchers, policy analysts, and economic theorists have been described most eloquently by J. von Neumann (1947) in the context of a mathematical discipline:

> . . . there is grave danger that the subject will develop along the line of least resistance, that the stream so far from its source will separate into a multitude of insignificant branches, and that the discipline will become a disorganized mass of details and complexities. In other words, at a great distance from its empirical source, or after much abstract inbreeding, a mathematical subject is in danger of degeneration. At the inception the style is usually classical; when it shows signs of becoming baroque, then the danger signal is up. (von Neumann, 1947, p. 147)

Quality of service research does not yet fit this characterization, but the topic is subject to abstract inbreeding. Theoretical work has enabled economists to isolate key implications of quality improvements, but there has been little success in finding empirical correlates for testing various models. Published quantitative research is nearly nonexistent for the pre-and post-divestiture telecommunications industry.[1]

The purpose of this paper is to provide an overview of the measurement, evaluation, and encouragement of telephone service quality. First, the paper surveys the theoretical literature exploring the production and valuation of quality. Then the various dimensions of local telephone service quality are identified. With so much data being collected, it is somewhat surprising to find so little analysis and interpretation of that data. Third, to improve the evaluation of service quality, we propose an approach which develops weights for different service dimensions. Finally, we consider practical ways to encourage

[1] Branch (1979) equates investments in equipment modernization with increased service quality. However, he attempts no independent measure of quality. Since two different modernization plans might be equally costly, but have different implications for consumer welfare, the link to quality valuation is essential. Similarly, Lawton's (1988) literature survey on telecommunications modernization includes a twenty-three page bibliography listing many studies of depreciation practices and cost allocation studies, but not a single citation on service quality.

appropriate levels of telephone quality. As the telecommunications industry undergoes regulatory and technological upheavals, the impact of service quality on costs and demands warrants additional analyses and evaluation.

1. THE THEORY OF SERVICE QUALITY

The inclusion of a quality variable enriches and complicates economic analysis. Since regulatory agencies monitor numerous dimensions of quality, collapsing these into a single index represents both a regulatory option and a theoretical necessity. Later we examine regulatory disadvantages to the adoption of pass-fail criteria for multiple service characteristics (such as signal clarity and dial tone response). Thus, regulators might choose to utilize a single index by creating a unique objective function which gives weights to different service quality dimensions. From the standpoint of economic research, simplification of the quality choice problem may be necessary just to make the analysis tractable. After reviewing previous analyses, we apply some of the key results to the regulatory situation in local telephone service.

1.1 Quality Choice with and without Regulation

Analysts have long been aware of regulatory problems arising from quality-of-service issues. For example, regulating price without obligating the firm to meet demand can lead to non-price rationing: one dimension of service quality deteriorates (as some customers are not served or reliability falls). Thus, additional choice variables tend to come under regulatory purview. In the mid-seventies, economists analyzed the basic issue of quality regulation in monopoly situations (Spence, 1975; Sheshinski, 1976; and Kihlstrom and Levhari, 1977). The following conclusions emerged from these studies.

(1) Monopoly power can affect quality choice under a number of circumstances: (a) if the level of output affects the cost of quality; (b) ..."if the good is used in variable proportions in firm or household production;" (c) "if some characteristic of the good facilitates...price discrimination;" (d) if "...the marginal valuation of quality depends on the quantity consumed." (Schmalensee, 1979, p. 193).

The first and fourth points are clear from the first order conditions for the monopoly and welfare maximizing firms. Marginal valuation (price) is a function of output (X) and dimensions of product quality (Z_1, Z_2)

$$P_x(X,Z_1,Z_2)<0; \quad P_i(X,Z_1,Z_2)>0, \quad i=1,2$$

Production costs depend on output and levels of product quality, where

$$C_x(X,Z_1,Z_2)>0$$

$$C_i(X,Z_1,Z_2)>0, \quad i=1,2$$

Take the sum of producer and consumer surplus as the index of welfare

$$V(X,Z_1,Z_2) = \int_o^X P(V,Z_1,Z_2)dv - C(X,Z_1,Z_2)$$

Assuming an interior solution, the first order conditions equate marginal benefits with marginal costs for each choice variable:

$$V_x = P(X,Z_1,Z_2) - C_x = 0$$

$$V_i = \int_o^X P_i(V,Z_1,Z_2)dv - C_i = 0, \ i = 1,2$$

Quality is increased to where the valuation of additional quality improvements equals the additional cost of the quality improvement. Alternatively, the average valuation of quality improvement equals the cost per unit output of that improvement.

However, a monopolist bases decisions on marginal costs and marginal revenues: choices are based on the marginal revenue from quality improvements associated with the marginal consumer rather than the increase in valuations experienced by all the consumers. In the absence of perfect price discrimination, inframarginal consumers are not counted in the monopolist's maximization problem.

Analytically,

$$\pi(X,Z_1,Z_2) = P(X,Z_1,Z_2)\cdot X - C(X,Z_1,Z_2)$$

$$\pi_x = M(X,Z_1,Z_2) - C_x, \text{ where } M(\ ) = P + P_x\cdot X$$

$$\pi_i = P_i(X,Z_i)X - C_i, \ i = 1,2$$

Both Spence and Sheshinski analyze this model for a single quality dimension, noting that two factors tend to lead to nonoptimal quality choice by an unregulated monopolist: nonseparability of quality and quantity in the cost function and dependence of marginal valuation of quality on the quantity consumed (on the demand side)

Early researchers emphasized the importance of how quality changes shifted the demand curve -- if improvements rotated demand outward from the initial price intercept, the size of the market may have increased (as when a new set of demanders enters the market, where the demanders have with marginal valuations comparable to those of initial consumers). Or, the initial demanders might just demand more units than before (at a given price). In each case

$$P_{xi}>0$$

The downward sloping demand function ($P_x<0$) is less steep at a given output level. In such situations, output and quality can be viewed as complements.

However, if quality improvements makes the demand curve steeper,

$$P_{xi}<0$$

the average valuation of quality will be greater than the marginal valuation, which tends to result in a monopolist supplying less than optimal level of quality.

Consider, for example, telephone access and usage as individual goods, each with different quality characteristics: dial tone delay for access can be reduced by improved switching capabilities; signal clarity, on the other hand, depends on the lines connecting users, including fiber optic facilities. Improved dial tone response probably does not expand the demand for access, making such quality improvements "substitutes" for increased output: the demand (marginal valuation) becomes steeper with quality improvements. On the other hand, signal clarity might be particularly important for business users, who can build their own communications networks if a high noise to signal ratio begins to interfere with voice or data transmissions. Thus, improved quality for usage can be viewed as a "complement" for increased output: demand rotates from the price intercept with quality improvements. Obviously, complex cross effects are possible, but this stylized characterization illustrates some of the complexities facing managers and regulators.

(2) Public service commissions have problems incorporating quality into the regulatory process, partly because quality is a public good if it must bundled with the basic service.

When a quality attribute is a "public good", its availability to one customer makes it available to all. Yet different customers will have different marginal valuations for the quality dimension. Both equity and efficiency may be enhanced if there is any way to distinguish among consumers, charging those who value the characteristic. Kihlstrom and Levhari (1977) modeled the efficiency conditions for quality as a public good. In some markets, the same service price is charged to all types of customers (whether or not the quality is valued as highly by a particular customer): such bundling can cause inefficiencies. For example, the bundling of access and usage implies that customers with different calling patterns will involve cross-subsidies: one customer paying for the costs incurred to increase quality for another. Here, the bundling of access and usage creates public good problems within a given customer class. The problem is no less severe for a single dimension of quality and different customer classes. Business demanders may have fundamentally different uses for communications channels than residential customers. For example, signal clarity and undisturbed connections are far more important for high speed data transmission than for conversation purposes.

These different valuations raise difficult problems for regulators. Pricing needs to reflect both the alternatives available to telephone subscribers and the costs imposed on the system when quality dimensions valued by a segment of subscribers are made available to all.

(3) Rate of return regulation can induce resource allocation improvements not only in terms of increased output, but also vis a vis quality choices; AJ distortions can also be exacerbated if quality is labor intensive.

Researchers have identified circumstances under which rate of return regulation (RORR) could enhance welfare. Spence showed that if quality were capital intensive, (and would otherwise be under-provided), RORR expanded the use of capital -- increasing both output and quality. Recall that quality should be raised if $P_{xi}<0$ for the monopolist. Note that the theory of rate base regulation suggests that a bias in quality improvements is possible.

Alternatively, price regulation which expanded output could have an impact on quality. Some of these stories involved leaving the quality choice completely up to the firm, but such a situation could yield a Cournot outcome (firms taking price as given and adjusting quality, and regulators taking quality as given and mandating a price). Both consumers (whose agents are the regulators) and the monopolist could be made better off under an alternative regime. Spence (1975, p. 424) suggests that this is one reason why quality standards should accompany price regulation.

Sherman and Visscher (1979) analyzed a wider range of rate designs than contained in the original Averch-Johnson formulation. They conclude:

> "The price structure problem is not confined to welfare losses caused by simple pricing inefficiencies of well-defined products or services, however. In some cases the right product or service characteristics may not even be priced, because a rate-of-return regulated firm will emphasize certain elements that might be priced and will deemphasize others." (p. 128-129).

Sherman and Visscher argue that, for example, the Civil Aeronautic Board's regulation of airlines pricing lead to a level of service quality that might have been inefficient (and the absence of different price/quality combinations). They emphasize that not only will the input mix (and technologies) be affected, but the output mix can be suboptimal--in terms of wrong qualities and inappropriate bundling of services. Thus, the definition and pricing of service characteristics become important aspects of the regulatory process which affect the decisions of the monopoly producer and consumers of the service.

(4) A multiproduct firm faces an additional set of quality choices, in which bundles are created to maximize profits subject to various regulatory constraints.

A recent contribution by Besanko, Donnenfeld and White (1988) showed how minimum quality standards, maximum price regulation, and rate of return regulation affect welfare. The basic model involves two groups of customers, one of which (type I) has a higher total and marginal willingness to pay than the other. Quality is observed but the heterogenous preferences for product quality cannot be observed. In the absence of perfect discrimination, the monopolist offers all customers two different price-quality combinations: self-selecting price quality bundles. By assuming a separable cost function for quality, BDW conclude that the monopolist offers group I the socially optimal quality, but the second group receives a suboptimal quality offering: "The magnitude of the distortion depends on the size of each group of consumers and the difference in each group's marginal willingness-to-pay for quality." (p. 414)

BDW find that minimum quality standards (MQS) and maximum price regulation (MPR) raise the quality offered to consumers who prefer low quality goods--reducing the distortion which characterizes monopoly price-quality choices. Their results illustrate how a multiproduct monopolist (such as a local cable company) might alter the price and channel offering mix for "basic" and "premium" services. MQS can correct the distortion facing type II customers. Alternatively, MPR which reduces the price to type I customers counteracts the unregulated monopolist's incentive to reduce the quality in the second bundle in order to raise the price for the first bundle. In the case of telephones, the definition of "basic service" becomes important -- since different dimensions of quality (party line vs. single line or size of area for non-toll calls) have different costs and capital intensities.

The impact of rate of return regulation (RORR) is much more complicated (even in their simple characterization of costs and valuations) because the production technology must be specified in greater detail. If quality is capital-intensive, the implicit reduction in effective cost of capital leads the RORR firm to choose more capital. "This in turn slackens the self-selection constraint and leads to an increase in quality for the low-quality good as well. Hence, the firm reacts to RORR by upgrading the entire quality schedule," (p. 424). If quality is capital intensive, RORR has mixed effects, since it increases quality offered to both groups. Consumers who prefer low quality goods are better off (the distortion is reduced) but consumers who prefer high quality goods face an increased distortion.

It should be noted that different demand or cost conditions would affect the BDW conclusions. Nevertheless, their analysis sheds light on the quality choices offered when self-selecting bundles of services are offered by firms. Are these "possibilities" important from the standpoint of determining the types of regulations most conducive to efficiency? Unless we step back from the mathematical details of these models, we may miss their relevance, or overemphasize something that ought not concern decision-makers. Empirical research is far from obtaining indications of inefficiencies. Nevertheless, the results which emerge from these models suggest that regulation (and deregulation) can yield perverse outcomes.

1.2 Implications when Quality is Multidimensional

Let us consider a simple case where two service characteristics are monitored by regulators: dial tone response (Z_1) and call completions (Z_2). The Florida Public Service Commission has a rule that 95% of all calls shall receive a dial tone within 3 seconds. The surveillance methods for determining compliance are problematic (peak hours? as a proportion of all calls?)[2] However, even after appropriate monitoring procedures have been adopted, determining the benefits and costs of exceeding the standard is complicated. For a second dimension of quality, intra-office call completions, 95% of all calls to numbers with the same first 3 digits as the caller must be completed.

We will assume that regulators attempt to maximize welfare, subject to the telephone company's budget constraint (total revenues are no less than total costs). Alternatively, regulators may be engaging in satisficing behavior, but we will assume welfare maximization. Spence (1975) pointed to the specification of minimum quality standards in the context of price regulation, arguing that it could stem from underprovision of quality in that situation. His and Sheshinski's analyses are further reinforced in a multiquality context by Besanko, Donnenfeld and White (1988). If regulators do not encourage a telco to exceed the stated standard, they must believe that marginal benefits are equal to the marginal costs when the standards are just met.

This condition for optimality is depicted in Figure 1, where $Z_1 = .95$ and $Z_2 = .95$ in equilibrium (point E). Note that output is adjusted for the different production possibility frontiers shown in the Figure (so that P = MC). The perceived levels of benefits are also shown (again, measured in dollar terms). Point A (94,94) involves resource costs of $100: additional costs of $10 yield equal additional benefits (at point E). However, beyond E, further improvements in quality cost more than they are worth. Thus, if the marginal cost of additional output is just equal to the marginal valuation (price) of that output, the marginal efficiency conditions are satisfied.

The above is an extremely simplified characterization of the opportunity set and relative valuations of quality. First, we are implicitly assuming separability in production, so that the cost of additional output is independent of the levels of both quality attributes. In addition, since the shift from A to E implies higher quality overall, the marginal valuation for output will be greater at E, if output is not increased. So we must let output expand to the point where price equals marginal production cost. If marginal production cost is constant, price will not change. Anyone familiar with single quality, single output models is aware of how complicated the analysis becomes if there are cost interdependencies (as when higher Z_1 affects marginal production costs).

If point E (95,95) is optimal today, need it remain so in the future? Even if preferences remain unchanged, income elasticities for output and quality, changing customer mixes, and technological changes will tend to yield a new optimal point. For example, if the cost of shifting from E to B is $8 rather than the $20 shown in the figure, then regulators should encourage further quality improvement. However, if the benefit is primarily via inframarginal consumers, a profit-maximizing firm subject to price control will not have an incentive to enhance quality. Either the regulators will have to mandate new minimum quality standards, or quality incentives must be established--rewarding

[2] Another issue is whether 90% receiving a dial tone within 2 seconds might be preferable to 95% within 3 seconds, but since the former probably implies greater than 95% in 3 seconds, we take the duration of the delay as given.

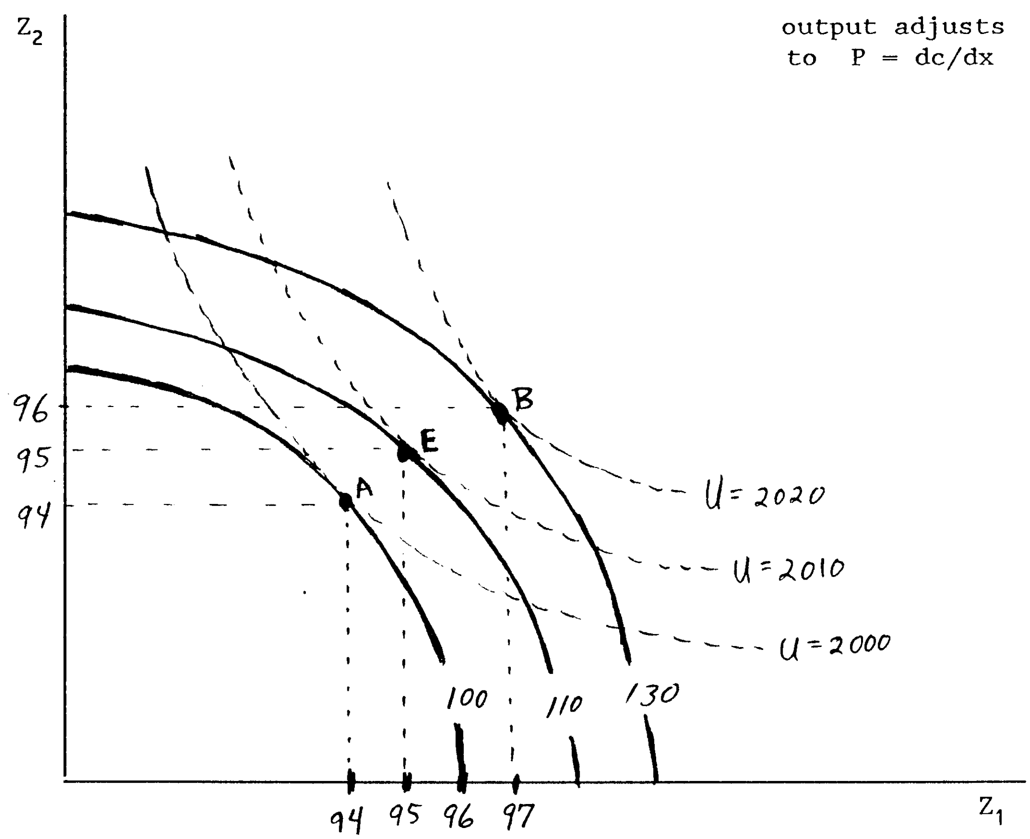

Figure 1

Welfare Maximization for Two Quality Attributes

telcos which achieve higher standards.

Clearly, the regulatory information requirements become burdensome: commission staffs must become familiar with the underlying production technologies and cost structures. In addition, they must know the preferences of consumers, and capture those preferences in some objective function relating higher levels of quality to dollar benefits. Given the dramatic technological changes in this industry (and state employee staffing problems), the knowledge of changing cost trade-offs is unlikely to reside in state regulatory commissions. Furthermore, if the "correct" benefit levels for the three indifference curves were 2000, 2005, and 2007, the commission ought to be loosening, rather than tightening, minimum quality standards (moving from E to A).

Figure 2 illustrates the issue we focus on in this study. At point E, the marginal rate of substitution (MRS) between Z_1 and Z_2 does not equal the marginal rate of transformation (as reflected in the slope of the production possibility frontier). For simplicity, we assume constant MRS. Compared with the preferences depicted in Figure 1, at point E, the relative valuation of Z_1 is greater in Figure 2. The MRS is roughly minus one in Figure 1, indicating that (95.5, 94.5) is valued about equally with (94.5, 95.5). However, in Figure 2, the former is preferred to the latter: additional Z_1 is valued relatively more than additional Z_2. The MRS depicted in Figure 2 is -2.5. So if Z_1= 96, Z_2 could fall to 92.5 to obtain the same benefit as point E.

The conclusion is elementary: for the same resource cost ($110), higher benefits would be obtained at point X, than are obtained at point E. How can a regulatory incentive system encourage a telco to modify its quality mix: increasing quality for dimensions which are relatively more highly valued? The following sections describe a methodology for determining weights for the various dimensions of telephone service quality. Firms are then presented with the regulatory objective function--and allowed to trade-off high cost (low valued) quality dimensions for low cost (highly valued) quality dimensions. In the context of the simple example, if (95, 95) yielded an "acceptable" overall level of quality, then the firm would be able to achieve the same quality score with lower costs: at point M (97, 90). One scoring function which would signal the telco to modify its quality mix would be $Q = Z_2 + (5/2)Z_1$, and the minimum quality "score" is Q = 665.

The telco has lower costs at M but has a score of 665 (based on the formula. Alternatively, a higher quality standard (score) could be set, driving the firm to point X--so customers achieve greater satisfaction without an increase in outlays on quality. However, recall that the increase in demand will require an expansion of output, and corresponding marginal production costs could change.

The main point is that a more comprehensive treatment of quality by regulators could yield benefits to customers, with some of the savings providing an incentive to firms. The associated measurement problems are not simple: aggregating quality characteristics to calculate a single "score" requires some confidence in the value elicitation process, and determining the appropriate "score" requires an understanding of the changing technological opportunities.

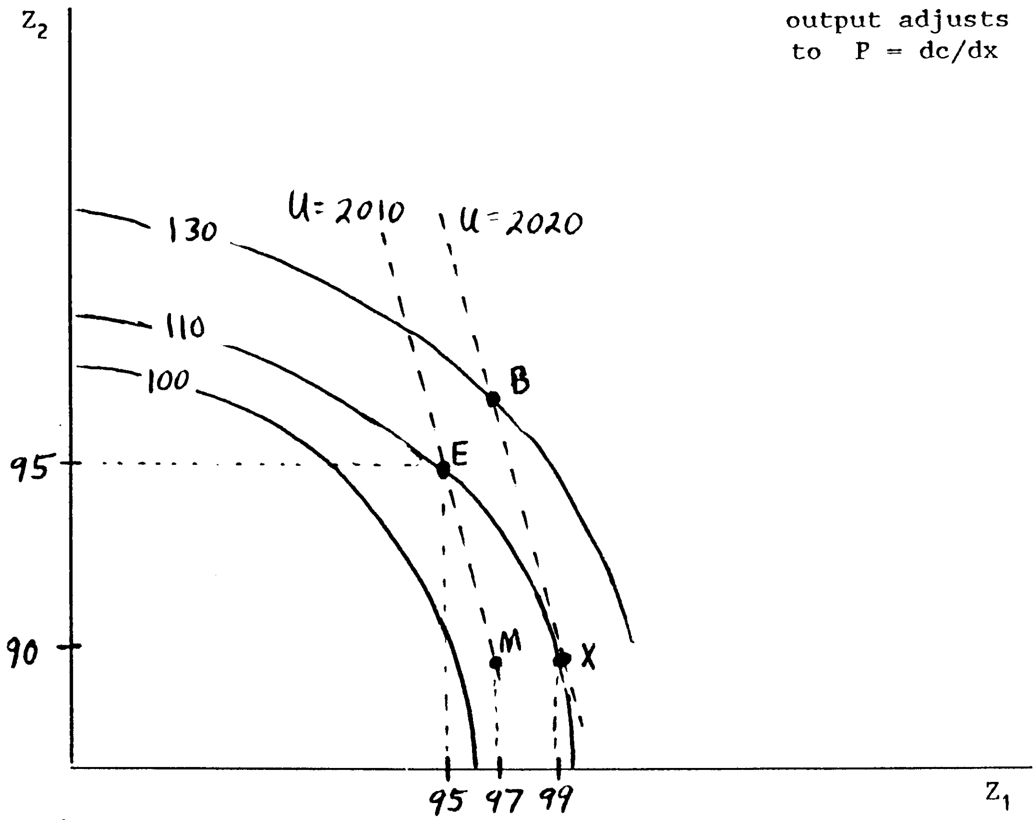

Figure 2

New Relative Valuations of Quality Attributes

In addition, telcos face different costs (urban-rural differences and different historical patterns of investment--yielding different technological opportunities). Different customer mixes (or different income levels for those customers) may also imply different relative valuations for the various quality dimensions (and for additional output, compared with improved quality scores). However, on this latter point, we find in our empirical work remarkable agreement among experts at different telephone companies regarding the relative importance of different quality dimensions. We now turn to that work.

2. MEASUREMENT OF SERVICE QUALITY

2.1 Dimensions of Service Quality

The Florida Public Service Commission evaluates local telephone companies on the basis of dial tone delay, meeting telephone installation appointments and thirty-six other performance standards. Companies measure various technical characteristics and maintain detailed records of company performance. Although these rules (or standards) can be further grouped into nine clusters, creating a single index of quality is not a simple task. The National Association of Regulatory Utility Commissioners recommends a similar set of standards.[3] However, the weights to be given individual rules have not been established.

In a sense, the absence of a reasonable weighing scheme means that service quality for a particular dimension could be too high--given the incremental costs and benefits of moving from, say 94% to 95% for a particular standard. Alternatively, exceeding present standards for some dimensions of quality might yield substantial additional consumer benefits relative to the incremental costs of surpassing the standard. Given the billions of dollars associated with maintaining service quality standards nationwide, it is important that analysts identify ways to deal with quality in a more systematic and rigorous fashion.

A complete listing of the thirty-eight FPSC quality standards is shown in Table 1. The nine broad categories (clusters) are (1) dial tone delay, (2) call completions, (3) answer time (eg. for operators, directory assistance, repairs, or business office), (4) directory service, (5) intercept services (eg. changed numbers, vacation disconnects), (6) availability of service (three day primary service and meeting appointments), (7) 911 service, (8) repair service (eg. 24 hour restoral), and (9) public telephone services (involving sixteen separate components). Clearly, aggregating these different categories into a single quality index is no simple process.

There are a number of other ways quality of service might be determined. Consumers could be surveyed directly regarding quality of service. For example,

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[3]Telephone utilities have done some work in the area. For example, the book Engineering and Operations in the Bell System (R.F. Rey, editor, 1983) from Bell Laboratories describes processes for evaluating service and company performance. The analysts note that complex network interfaces occurring at company boundaries create new problems for performance evaluation (p. 683-84). The absence of references to regulatory standards is an interesting omission from this comprehensive source-book, since these standards are supposed to be used to evaluate performance.

Table 1
38 PSC RULES WITH PUBLISHED STANDARDS OF PERFORMANCE

Rule Cluster 1: Dial Tone Delay

1. Dial Tone Delay: 95% of all calls shall receive a dial tone within 3 seconds.

Rule Cluster 2: Call Completions

2. Intra-office: 95% of all calls to numbers with the same first 3 digits as your own shall be completed.
3. Inter-office: 95% of all calls to numbers with different 3-digit codes but within your home exchange shall be completed.
4. EAS: 95% of all calls to different home exchanges must be completed.
5. Intra-company DDD: 95% of all toll calls within your local company's service area shall be completed.

Rule Cluster 3: Answer Time

6. Operator Answer Time: 90% of all toll calls to a toll office shall be answered within ten seconds after the start of an audible ring.
7. Directory Assistance: 90% of all calls to Directory Assistance shall be answered within twenty seconds after the start of an audible ring.
8. Repair Service: 90% of all calls to Repair Service shall be answered within 20 seconds after the start of an audible ring.
9. Business Office: 80% of all calls to Business Offices shall be answered within 20 seconds after the start of an audible ring.

Rule Cluster 4: Adequacy of Directory and Directory Assistance

10. Directory Service: A directory conforming to PSC rule 25-4.040 shall be published within 12-15 months since the last published directory.
11. New Numbers: 100% of all new or changed listings shall be provided to directory assistance operators within forty-eight hours after connection of service, excluding Saturdays, Sundays, and holidays.

Rule Cluster 5: Adequacy of Intercept Services

12. Changed Numbers: 90% of all calls to numbers that have been changed shall be answered automatically within 20 seconds.
13. Disconnected Service: 100% of all calls to numbers to disconnected numbers shall be answered within 20 seconds by a recording informing the caller that the number reached is not in service.
14. Vacation Disconnects: 80% of all calls to numbers temporarily disconnected at the customer's request shall be answered within 20 seconds.
15. Vacant Numbers: 100% of all calls to vacant numbers shall be answered within 20 seconds by a recording informing the caller that the number reached is not in service.
16. Disconnects Non-Pay: 100% of all calls to numbers disconnected due to non-payment shall be answered within 20 seconds by a recording informing the caller that the number is not in service.

Rule Cluster 6: Availability of Service

17. 3-Day Primary Service: 90% of requests for Primary Service in any Calendar month shall normally be satisfied within an interval of three working days after the receipt of application.
18. Appointments: 95% of appointments kept that are set within time frames of 7-12 A.M., 12-5 P.M., or 5-9 P.M., or for a specific hour of the day.

Rule Cluster 7: 911 Service

19. 911 Service: 95% of all calls to 911 Service answered within 10 seconds.

Rule Cluster 8: Repair Service

20. 24 Hour Restoral: 95% of all customers shall have service restored within 24 hours of reporting trouble.
21. Appointments: 95% of Repair Service appointments kept that are set within time frames of 7-12 A.M., 12-5 P.M., or 5-9 P.M., or for a specific hour of the day.
22. Rebates -- Over 24 Hours: 100% of customers whose service is interrupted for more than 24 hours shall be given pro-rated rebates.

Rule Cluster 9: Public Telephone Service

Sub-Cluster 9a: Functioning of Public Telephones

23. Serviceability: 100% of public telephones must meet all service standards applicable to service to other customers.
24. Telephone Numbers: 100% of all public coin phones must have identified station telephone numbers.
25. Receive Calls: 100% of all pay phones -- except in prisons, schools, and hospitals -- must be able to receive incoming calls.
26. Dial Instructions: 100% of all public telephone stations should have legible and clear dialing instructions, including notice of the lack of availability of local or toll service.

Sub-Cluster 9b: Enclosure of Public Telephones

27. Accessibility to Handicapped: 100% of all stations installed since January 1, 1987 must be accessible to the handicapped.
28. Cleanliness: Normal maintenance shall include inspection and reasonable effort shall be taken to insure cleanliness and freedom from obstructions of 95% of all coin stations.
29. Lights: 100% of all public telephones must be lighted during hours of darkness when light from other sources is inadequate to read instructions and to use the instrument.

Sub-Cluster 9c: Coin Operations of Public Telephones

30. Pre-Pay: 100% of all coin-operated public telephones allow Pre-Pay. They provide a dial tone, require coin deposit prior to dialing (except for calls to operator or 911 as discussed 32 and 33 below), and automatically return any deposited amount for calls not completed.
31. Coin Return: 100% of all coin stations shall return any deposited amount if a call is not completed, except messages to a Feature Group A access number.
32. Coin Free Access - Operator: 100% of all public telephones shall have coin free access to the Operator.
33. Coin Free Access - 911: 100% of all public telephones shall have coin free access to 911 Service.
34. Coin Free Access - Directory Assistance: 100% of all coin stations shall allow coin free access

or coin return access to Local Directory Assistance.

35. Coin Free Access - Repair Service: 100% of all coin stations shall allow coin free access or coin return access to Repair Service.

36. Coin Free Access - Business Office: 100% of all coin stations shall allow coin free access or coin return access to the Business Office.

Cluster 9: Public Telephone Service (Continued)

Sub-Cluster 9d: Directory Security of Public Telephones

37. Directory Security: 100% of all coin stations have directories available. When there are three or more coin stations in one area, there must be a directory for the local calling area for every two stations. Otherwise, there must be a directory for every station.

Sub-Cluster 9e: Address/Location of Public Telephones

38. Address/Location: 100% of all public telephones have their locations posted, and the identifications of locations coordinated with the appropriate 911 or emergency center.

a National Regulatory Research Institute Report (Mount-Campbell et al., 1978) provides a survey design for obtaining opinions from telephone subscribers. Trends in consumer perceptions can be captured via such surveys. In addition, customer complaints made directly to the utility or to the FPSC provide another index of the acceptability of quality service levels (see Appendix A which lists types and numbers of complaints in Florida, 1987). However, customer-initiated evaluations can be spurred by other factors--an on-going rate case, a spate of consumer activism, or developments beyond a firm's control (as with AT&T divestiture causing customer confusion during the transition period).

As a supplement to such data, trends in the nine clusters (or thirty-eight categories) provide an indication of the technical aspects of telephone service. However, too many sub-indices makes any overall external evaluation unmanageable. Firms do not have a simple task in determining their own quality of service. See, for example, Militzer (1980) who describes AT&T's internal evaluation process in some detail. Note that AT&T distinguishes between service measurements (reflecting operations characteristics perceivable to customers) and performance measurements (reflecting whether corporate technical objectives are being met). A key question is what weights should be given the various rules or standards.

The most significant published source on the measurement of service quality is a recent volume edited by B. Cole (in press), containing papers by state and national regulators and telecommunications specialists. Kraushaar's and Curry's papers in this volume survey the effect of the Bell System breakup on service quality. They tentatively conclude that quality has not declined following the breakup, and may even have increased. However, they point to potential problems, including the lack of comparable technical measures across regulatory jurisdictions and over time. In addition, the absence of an overall index of quality hampers the performance evaluation process.

2.2 Customer vs. Expert-Based Measurement

The welfare-maximizing PSC is actually interested in using an evaluation scheme that reflects <u>customers'</u> preference weights. Given this, researchers could ask the concerned parties (i.e. consumers) to identify current quality and to make trade-offs between levels of performance on the different rules. The alternative to asking consumers is to ask experts who possess the technical knowledge necessary to make trade-offs between rules. This study used experts within the FPSC and telcos, but it was stressed to respondents that their answers should reflect the consumers' interests. This amounts to modeling the experts' perceptions of what is most important to consumers. Although the experts' perceptions may be inaccurate, this approach was deemed a reasonable solution to the problem. In addition, a telecommunications engineer is more likely to be aware of the consequences of changes in these variables on system performance. In particular, interdependencies among rules would be understood by the technically trained individual.

We have argued elsewhere (Buzas, Lynch, and Berg, forthcoming) that, despite their relevance, customer-based measures of importance cannot be treated as the ultimate criterion for several reasons:

(1) Consumers may lack the technical expertise necessary to evaluate certain dimensions. In some cases, they simply may not understand the technical terminology (e.g. Call Completions Intra-office, Inter-office, EAS and Intra-company DDD). Other dimensions may be "credence" attributes (Darby and Karni 1973), the values of which cannot be determined even after experiencing their levels.

(2) Due to the monopolistic nature of the industry, consumers do not have the opportunity to experience service from firms providing different profiles of strengths and weaknesses across the various dimensions. Thus, they lack the covariation information necessary to abstract the values of the dimensions -- as in Meyer's (1987) analysis of the process by which consumers learn multi-attribute preferences.

(3) Because customers have not had to make choices among competing services, they have not had occasion to think about the tradeoffs between different dimensions. Research has shown that when prior opinions about tradeoffs do not exist, revealed weights are highly unstable and susceptible to minor changes in the elicitation procedures (Feldman and Lynch 1988; Fischhoff, Slovic and Lichtenstein 1980).

3. EVALUATION OF SERVICE QUALITY

3.1 Weights for Dimensions and Customer Classes

The dominant approach to monitoring quality in regulated monopolies is to set performance standards on various objective and technical dimensions of service quality (e.g., Model Telecommunications Service Rules, National Association of Regulatory Utility Commissioners 1987). The critical feature of regulation by standard is that essentially continuous variations in performance on any dimension are degraded into a two-category (pass/fail) classification (Fischhoff 1984).

In the competitive marketplace, firms offer price-quality combinations and potential consumers choose the bundles that maximize their net benefits. Even though identifying the level of quality is not a simple process, consumers generally "know what they like", and the resulting pattern of demand and market shares is often viewed as meeting some optimality criteria. However, for public utilities, mandated entry barriers or the direct regulation of technical features of the service cut short the evolutionary process arising from competitive markets. The question then, is how to evaluate quality in the context of a regulated industry, like local telephone service.

3.2 The Approach Selected: Hierarchical Conjoint Analysis

In order to design an experimental set of profiles capable of estimating the parameters of expert regulators' objective functions, it was first necessary to determine the general form of $\hat{Q} = f(x_1, x_2, \ldots, x_{38})$. Nine telecommunications experts at the Florida Public Service Commission completed a series of pretests designed to determine 1) whether the various technical dimensions combined additively or configurally to determine judgments of overall service quality, and 2) whether the partial effect of each dimension on overall judgments was linear or curvilinear. The pretests employed "functional measurement" methodology (Anderson 1982; Lynch 1985).

Experts were asked to judge the quality of service provided by a series of hypothetical companies by pairs of the 38 technical dimensions. Stimuli were defined by a series of two-factor repeated measures designs. In each design, the two dimensions each varied over four levels. If historical data showed observations both above and below the standard for a given dimension, we chose high and low levels of that dimension in accord with the historical range. For several dimensions, though, no company had ever failed to pass the standard. For these dimensions, we chose the lowest level in pretests to be 1% or 2% below the standard.

Additive or Multiplicative

We first tested whether pairs of dimensions combined additively or configurally to affect experts judgments of quality. We considered it possible that experts' might combine the 38 dimensions in accord with a conjunctive decision rule, whereby a company would be judged acceptable if it passed all standards, but would be judged unacceptable if it failed even one standard (Einhorn 1971; Fischhoff 1984). Alternatively, a few dimensions might be judged to be so important that failing standards on these dimensions might cause other dimensions to be ignored, and an unacceptable overall rating to be assigned. Other configural objective functions considered plausible *a priori* were multiplicative and multilinear rules (Keeney and Raiffa 1976) and averaging rules that give disproportionate weight to negative information (Anderson 1974; Lynch 1979). The absence of significant interactions between dimensions ruled out all of these configural rules, implying that an additive combination rule was appropriate. This conclusion was supported both by group level tests and analyses of individual level data.

Linear or Nonlinear

Next we turned to analyses intended to determine whether the effect of each cue on overall quality were linear or nonlinear. Since each rule has a published standard for performance, it was possible that experts dichotomized performance into two levels: Pass or Fail. This would imply for example, that for the intra-office call completions standard cited above, a score of 94% would be just as bad as one of 80%, since both are below the standard. Similarly, a score of 96% would be just as good as one of 100%. We tested for nonlinearities of this form or of alternative forms by ANOVA tests of whether the main effects of each attribute in the two factor designs exhibited any significant deviation from the linear relationships. Results showed no significant residual from linearity within the ranges considered. A one percentage point change in performance on a given dimension caused the same degree of improvement in overall evaluation, regardless of whether improvement was from 80% to 81% or from 99% to 100%. Moreover, this was approximately true even when the change caused the company to move from not meeting the standard to meeting it exactly.

Functional Form

Taken together, these pretests implied that experts' overall quality judgments could be appropriately modeled by a weighted linear composite equivalent to equation 1:

$$(1)\quad \hat{Q}_j = a + w_1 * (x_{j1} - x_{1*}) + w_2 * (x_{j2} - x_{2*}) + \ldots + w_{38} * (x_{j38} - x_{38*}),$$

where a is a constant, w_i is the weight for the i-th criterion, and $x_{ji} - x_{i*}$ is the deviation of the j-th company's performance from the standard on the i-th criterion.

Hierarchical conjoint analysis was developed to circumvent problems with two more commonly used variants of conjoint analysis (Louviere 1984; Louviere and Gaeth 1987). In this approach, a large number of dimensions are broken down into hierarchical "clusters", and profiles are judged that are described only on the dimensions included in that cluster. Each cluster includes only a small number of related dimensions, so that respondents do not have to integrate an overwhelming amount of information at any one time. In the present context, these "rule clusters" were: Dial Tone Delay (1 dimension); Call Completions (4 rules); Answer Time (4 rules); Adequacy of Directory and Directory Assistance (2 rules); Adequacy of Intercept Services (5 rules); Availability of Service (2 rules); 911 Service (1 rule); Repair Service (3 rules); and Public Telephone Service (16 rules). Because the Public Telephone Service cluster included so many dimensions, it was further broken down into 5 "sub-clusters", as described in Table 1.

Determining the weights involved three steps. First, we calculated the weights of a one percentage point change in compliance on the evaluation of performance within each cluster of rules (Table 1). Experts rated different combinations of performance levels within each cluster of rules on a scale from 1 to 10. There were 13 questionnaires of this type - one for each cluster of rules. For example, in the questionnaire for Answer Time, subjects judged 8 profiles formed by a 1/2 fractional factorial design (Winer 1973), in which the four factors varied over the following levels: Operator Answer Time, 89% and 100%; Directory Assistance, 89% and 99%; Repair Service Answer Time, 75% and 98%; and Business Office, 67% and 100% (Winer 1973). Based on these ratings, we calculated the weights of a one percentage point change on the evaluation of performance for the cluster of rules. In general, the evaluation of the j-th company for the k-th rule cluster of i rules is given by $y_{jk} = g_k(x_{j1(k)}, x_{j2(k)}, \ldots, x_{ji(k)})$. In the present application, pretesting determined that the function was linear in form.

Second, we determined the relative importance of the clusters of rules. Experts were asked to rate combinations of <u>evaluations</u> of performance on the clusters on a scale from 1 to 10. That is, they were shown profiles formed by a fractional factorial design, in which factors varied over levels of cluster evaluations, such as 1 and 10 for Answer Time and 2 and 10 for Intercept Services. There were two questionnaires of this type. One related performance on the five Public Telephone sub-clusters to overall performance on Public Telephone Service (see Table 1). The other related performance on the 9 rule clusters to the evaluation of overall service quality. Based on these ratings, we next calculated the weights of a <u>one percentage point change in cluster evaluation</u> on the overall evaluation. The tradeoffs between performances on the K clusters were given by $\hat{Q}_j = h(y_{j1}, y_{j2}, \ldots, y_{jK})$.

Lastly, we calculated the weight a one percentage point change in performance on overall evaluation using the weights of a one percentage point change on cluster evaluation and the weights of a point change in cluster evaluation, i.e. $\hat{Q}_j = f(x_{j1}, x_{j2}, \ldots, x_{j38}) = h(y_{j1}, y_{j2}, \ldots, y_{jK}) = h[g_1(x_{j1(1)}, x_{j2(1)}, \ldots, x_{ji(1)}), g_2(x_{j1(2)}, x_{j2(2)}, \ldots, x_{ji(2)}), g_K(x_{j1(I)}, x_{j2(I)}, \ldots, x_{ji(K)})]$. Since the functions h and g were linear, this involved multiplying the weights from the first and second steps above.

<u>Application to a Hypothetical Company</u>

Exhibit 1 shows the company score and rule for 38 dimensions of telephone service quality. For each percentage point above the "rule," additional points are earned by the company -- depending on the weight accorded to the particular dimension: greatly exceeding a low-valued dimension is less valuable than slightly exceeding the most highly valued dimension.

In the example, an overall score of 8.21 is achieved, compared with a 6.10 for <u>just matching</u> each current FPSC rule. How to interpret this in practice remains up to the Commission and its staff. But the single score approach has a number of favorable features.

4. ENCOURAGEMENT OF SERVICE QUALITY

Although the actual use of service quality data in the regulatory process has not been examined by analysts, the topic is clearly important. Our own contribution attempts to identify a single service quality index which could be used to rank firms and to reward those with superior performance over time. Since the competitive marketplace is unavailable to signal preferred price-quality bundles, regulators must simulate such a process. Note that the role of service quality is reduced if regulators create so many dimensions of quality that comparisons become cumbersome, if not impossible. Thus, current practice of specifying minimum performance standards has severe limitations. An index giving weights to each standard would assist both firms and regulators.

4.1 Perverse Incentives of Pass/Fail Standards

Technical standards themselves are clear and precise, but two major classes of problems arise in their use to monitor and reward quality. First, by evaluating performance relative to a pass/fail cutoff, distinctions among various levels of sub-standard and super-standard performance are ignored. As a consequence, companies are given targets to achieve, but little incentive to

EXHIBIT 1

EXAMPLE OF COMPREHENSIVE EVALUATION FOR HYPOTHETICAL COMPANY

CRITERIA	(A) COMPANY SCORE	(B) RULE	(C) (A-B)	(D) WEIGHT OF 1% CHANGE	(CXD) GAIN OR LOSS
1) Dial Tone Delay	100%	95%	+ 5.0	.097	+0.4850
2) Call Completions					
Intra-Office	99.9%	95%	+ 4.9	.087	+0.4753
Inter-Office	99.2%	95%	+ 4.2	.084	+0.3528
EAS	99.9%	95%	+ 4.9	.058	+0.2842
Inter-Company-DDD	96.8%	92%	+ 4.8	.041	+0.1968
3) Answer Time					
Operator	95.7%	90%	+ 5.7	.012	+0.0684
Directory Assistance	96.3%	90%	+ 6.3	.005	+0.0315
Repair Service	79.1%	90%	-10.9	.008	-0.0872
Business Office	66.3%	80%	-13.7	.004	-0.0548
4) Directory					
Directory	100%	100%	0.0	.058	0.0
New Numbers	94.9%	100%	- 5.1	.014	-.0714
5) Intercept Services					
Changed Numbers	100%	90%	+10.0	.008	+0.0800
Disconnected	100%	100%	0.0	.015	0.0
Vacation Disconnects		80%	0.0*	.002	0.0*
Vacant Numbers	100%	100%	0.0	.009	0.0
Non-Pay		100%	0.0*	.016	0.0*
6) Availability of Service					
3-Day Primary Service	100%	90%	+10.0	.030	+0.3000
Appointments	100%	95%	+ 5.0	.046	+0.2300
7) 911 Service		95%	0.0	.117	0.0
8) Repair Service					
24-Hour Restoral	94.1%	95%	- 0.9	.018	-0.0162
Appointments	94.4%	95%	- 0.6	.023	-0.0138
Rebates	78.6%	100%	-21.4	.003	-0.0642
9a) Functioning of Public Telephones					
Servicability	97.8%	100%	- 2.2	.027	-0.0594
Telephone Numbers	100%	100%	0.0	.015	0.0
Receives Calls	100%	100%	0.0	.013	0.0
Dial Instructions	100%	100%	0.0	.022	0.0
9b) Enclosure of Public Telephones					
Handicapped	100%	100%	0.0	.003	0.0
Cleanliness	100%	95%	+ 5.0	.002	+0.0100
Lights	96.8%	100%	- 3.2	.004	-0.0128

EXHIBIT 1 (cont'd)

CRITERIA	(A) COMPANY SCORE	(B) RULE	(C) (A-B)	(D) WEIGHT OF 1% CHANGE	(C)X(D) CXD GAIN OR LOSS
9c) Coin Operations					
Pre-Pay	100%	100%	0.0	.009	0.0
Coin Return	98.6%	100%	- 1.4	.005	-0.0070
Coin Free Access Operator	NA	100%	0.0*	.002	0.0*
Coin Free - 911	100%	100%	0.0	.003	0.0
Coin Free Directory	100%	100%	0.0	.001	0.0
Coin Free Repair	98.9%	100%	- 1.9	.001	-0.0019
Coin Free Business	99.6%	100%	- 0.4	.001	-0.0004
9d) Directory Security	97.1%	100%	- 2.9	.002	-0.0058
9e) Address/Location	99.6%	100%	- 0.4	.017	-0.0068

Overall Evaluation = Base (6.1000) + 0.4850 + 0.4753

+ ... -.0058 - 0.0068

= 8.2123

exceed these targets. If standards were set by formal economic analysis at the point where the marginal benefits of improvements were equated to the marginal costs along each dimension, meeting the standards exactly would enhance consumer welfare. In practice, though, the levels of standards often arise from a chaotic set of political and social forces (Fischhoff 1984). Moreover, even when standards are set initially at levels that equate marginal benefits and costs, technological change makes it likely that exceeding present standards for some dimensions might yield substantial additional consumer benefits relative to the current incremental costs of surpassing the standards. In these cases, the typical cutoff-based system may dysfunctionally fail to reward superior performance.

The proposed system overcomes perverse incentives that seem to be present with the current system. In particular, companies previously had no regulatory incentive to exceed standards on <u>any</u> dimension, even if that dimension was one where improvements could be realized at low cost, and where a small improvement would lead to a sizeable consumer welfare gain. Thus the prevailing system provides no incentive to respond to new technological opportunities. The proposed system should lead a company to act in ways that enhance both its own self-interest and the interests of consumers. The system provides incentives to improve on those dimensions where a) gains to the overall comprehensive score -- and presumably to consumer welfare -- are greatest, b) and where those gains can be achieved at the lowest possible cost to a company.

4.2 Specification of an Objective Function

The second major problem regulators face is how to <u>combine</u> information on multiple dimensions of service quality into an overall assessment. In Florida as in other states, this has been left to the discretion of the regulators, who must integrate complex information on a very large number of dimensions using unaided (intuitive) judgment. The exact nature of the objective function is left unspecified.

Even expert regulators face an unenviable task as they attempt to combine intuitively information on the many dimensions along which telephone companies are evaluated. Research in behavioral decision making across a wide variety of tasks has demonstrated convincingly a syndrome of dysfunctional consequences when decision makers experience information overload. Ironically, the decision makers themselves are largely oblivious to these consequences. Indeed, their confidence in their judgments about an object increases as they have more information about the object (Payne 1982), even when the added information is normatively irrelevant (Ronis and Yates 1987).

The large number of rules on which regulators have information may cause them to "manage by exception." By focusing on the rules that a company fails, regulators essentially ignore dimensions on which the company being evaluated has exceeded the standards. If the marginal benefits of improvement are greater for the latter (passed) than for the former (failed) dimensions, it follows that by "managing by exception," regulators create incentives for resource misallocation by companies.

4.3 Concluding Observations

Identifying relative trade-offs among different dimensions of quality is just a first step in a comprehensive research agenda. How are relative costs affected by changes in the different dimensions of quality? Engineering studies ought to allow us to identify marginal costs, although some inputs are likely to affect multiple quality dimensions -- leading to some difficulties in disentangling the impacts of shared inputs.

No less difficult is the demand side of the equation. How does the marginal valuation of quality depend on the quantity consumed? Would society prefer quality improvements or higher rates of telephone penetration? Which types of quality are substitutes and which are complements for output? And what is the relevant output, access or usage? Furthermore, when the parent of regulated firm has unregulated subsidiaries, quality enhancements of the regulated service may have implications for the demand (or costs) of outputs produced by unregulated subsidiaries. Such interdependencies might be as simple as the creation of goodwill (via advertising or outstanding service) or as complicated as the design of interface protocols. We have a long way to go before sophisticated theory is able to assist regulators in establishing multiple standards and/or a single weighted score which will signal the correct level and mix of qualities.

Measurement without theory or theory without measurement: both situations leave decision-makers without a basis for choosing from among a wide variety of output-quality combinations. When there were no competitive offerings, the absence of a consistent view of price quality trade-offs probably lead to inefficiencies and inequities. However, the potential costs of mistakes by firms and oversight groups today is enormous. At present, economists are only beginning to scratch the surface of a very complicated set of issues. The approach suggested here is no panacea, but hopefully the conjoint analysis will stimulate creative ways to measure, evaluate, and encourage quality in telecommunications.

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Appendix A

Customer Initiated Complaints

The Division of Consumer Affairs of the FPSC receives, investigates, and resolves consumer complaints regarding gas, electricity, water, and telephone utilities. Since it received 44,189 complaints during 1988, but recorded and investigated only 5,857 cases, significant screening occurs at the FPSC. For example, a complaint about high prices would not be logged in, but service problems would be "counted" and studied. The Division presents testimony on complaint activity during rate hearings. References to poor service are sometimes made in published decisions.

Commissioners also hear testimony on the technical standards from the Division of Communications. To measure the level of service provided by telecommunications firms, over half a million test calls were made in the service territories of the major local operating companies. These were used to measure all completions, dial tone delay, and other performance characteristics of the local system. The staff also evaluated such items as answer time, installation intervals, directory assistance and billing accuracy. Thus data on the 38 characteristics described are also introduced during the regulatory hearing process.

The attached listing shows the complaints logged in during 1988, indicates whether they were justified, and provides bottom line indices: percent change from the previous year and the number of justified complaints per 1,000 customers. Such information represents a potentially useful data base -- as consumer perceptions regarding quality of service could be linked to telco outlays in particular areas. So far as we know, this issue has not been addressed in the past, so it represents a potentially promising research avenue.

TELEPHONE INDUSTRY COMPLAINTS 1988

	COMPLAINTS LOGGED IN 1988				COMPLAINTS CLOSED IN 1988			
					Justification			Percent
	Service	Billing	Total	Major Type	Yes	No	Some	Justified
Alltel	45	13	58	Serice Problems	26	16	17	44%
Centel	123	49	172	Delay Connect	82	44	44	48%
Florala	5	0	5	Party Line	2	0	2	50%
GTE	399	137	536	Service Problems	211	196	133	39%
Indiantown	2	0	2	Service Problems	0	2	0	0%
Long Distance	170	836	1006	Alt. Operator Service	624	194	175	63%
N.E. Florida	6	3	9	Delay Connect	2	7	1	20%
Pay Telephone	93	41	134	Service Standards	70	25	24	59%
Quincy	2	3	5	Service Problems	0	3	1	0%
St. Joseph	10	4	14	Service Problems	5	7	3	33%
Southern Bell	1318	451	1769	Delay Connect	688	577	477	40%
Southland	1	9	1	Service Problems	1	0	0	100%
United	158	88	246	Delay Connect	59	93	79	26%
Vista-United	0	2	2	Miscellaneous Billing	0	1	0	0%
Industry Total	2332	1627	3959	Delay Connect	1770	1165	956	45%

TELEPHONE INDUSTRY COMPLAINTS 1988
Continued

	1988			
	Total Received	Percent Change From '87	Complaints Per 1000 Customers	Justified Per 1000 Customers
Alltel	58	-23%	1.281	0.618
Centel	172	-29%	0.773	0.373
Florala	5	-38%	3.183	1.273
GTE	536	-26%	0.353	0.141
Indiantown	2	100%	1.066	0.000
Long Distance	1006	24%	-	-
N.E. Florida	9	29%	1.872	0.416
Pay Telephone	134	116%	-	-
Quincy	5	67%	0.627	0.000
St. Joseph	14	-46%	0.724	0.259
Southern Bell	1769	11%	0.462	0.180
Southland	1	-50%	0.364	0.364
United	246	-4%	0.285	0.069
Vista-United	2		0.637	0.000
Industry Total	3959	4%	0.432	0.166