The measurement and encouragement of telephone service quality

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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 studies suggest, requiring researchers to rigorously analyse the costs and valuations of alternative quality improvements.

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An earlier version of this study was presented at the Seventeenth Annual Telecommunications Policy Research Conference, Arlie House, VA. Helpful comments by David Sappington and Thomas E. Buzas are gratefully acknowledged. Support was received from the Public Utility Research Center. However, the views expressed do not necessarily represent those of sponsoring organizations.

[1]Branch equates investments in equipment modernization with increased service quality, but he attempts no independent measure of quality: B. Branch, 'Quality of service and the allowed rate of return: American Telephone and Telegraph', *Journal of Economics and Business*, Vol 32, 1979, pp 86–88. Since two different modernization plans might be equally cost-

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The purpose of this article is to provide an overview of the measurement, evaluation and encouragement of telephone service quality. First, the article 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 those data.[1] Third, to improve the evaluation of service quality, we propose an approach which develops weights for different service dimensions. Finally, this study considers practical ways to encourage appropriate levels of telephone quality. The only other comprehensive policy analysis of which we are aware is by Noam,[2] who describes how to link financial incentives to service quality performance. As the telecommunications industry undergoes regulatory and technological upheavals, the impact of service quality on costs and demands warrants additional analyses and evaluation.

The theory of service quality

The inclusion of a quality variable enriches and complicates economic analysis. Regulatory agencies monitor numerous dimensions of quality, but collapsing these into a single index represents a useful complement to current utilization of pass–fail indicators. As will be seen, there are numerous regulatory disadvantages to the pass–fail criteria for multiple service characteristics (such as signal clarity and dial tone response). Thus regulators might adopt 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 might 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.

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

0308-5961/92/030210-15

Rulemaking. Then each unbundled rate element would become a BSE, and ESPs would be free to combine BSEs as they see fit. The concept of a BSA would not exist. Such bundled rate elements could go into effect as early as October 1991, after expiration of the MFJ restriction effectively prohibiting an unbundled local transport element.

- Require mandatory interconnection of alternative access carriers in LEC central offices on reasonable economic and technical terms. The MFS petition and the New York interconnection order provide a framework for doing this.
- Permit increased flexibility for the LECs to respond to competition for services (ie BSEs) for which they face effective competition. In so doing, the FCC should consider a core/non-core distinction in which core BSEs – such as the unbundled local switching sub-elements – are subject to price cap regulation, and non-core BSEs – such as local transport – are subject to competition with no regulated prices.[49]

Favourable action on these recommendations would indicate that distorted policies which maintain cross-subsidized prices and monopoly provision of BSEs and bundled BSAs are no longer consistent with the telecommunications infrastructure needed to pave the way for all citizens to enter the information age. It may be in the BOCs' economic interest for FCC regulation to discourage competition in basic services and maintain the status quo – but it is no longer in the public interest.

[49]For more information on promulgating this option in the case of AT&T see John R. Haring and Evan R. Kwerel, *Competition Policy in the Post-Equal Access Market*, OPP Working Paper No 22, Federal Communications Commission, Office of Plans and Policy, Washington, DC, February 1987, pp 28–30.

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-1970s economists analysed the basic issue of quality regulation in monopoly situations.[3] The following conclusions emerged from these studies.

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'.[4]

Two factors tend to lead to non-optimal quality choice by an unregulated monopolist: non-separability of quality and quantity in the cost function and dependence of marginal valuation of quality on the quantity consumed. (See Appendix 1.)

Economists have shown the importance of specifying how quality changes shift the demand curve. For example, a quality improvement which increased the size of the market could be characterized as a rotation of demand outwards from the initial price intercept: a new set of demanders enters the market, where the demanders have marginal valuations comparable to those of initial consumers. Alternatively the initial demanders might just demand more units than before (at a given price). In each case the downward-sloping demand function is less steep at a given output level. In such situations output and quality can be viewed as complements. However, if quality improvements make the demand curve steeper, the average valuation of a quality improvement will be greater than the marginal valuation of that improvement, 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 fibre-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.

Public service commissions have problems incorporating quality into the regulatory process, partly because quality is a public good if it must be 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 some way to distinguish among consumers, charging more to those who value the (higher-cost) characteristic more. Kihlstrom and Levhari

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ly, but have different implications for consumer welfare, the link to quality valuation is essential. Similarly, Lawton's literature survey on telecommunications modernization includes a 23-page bibliography listing many studies of depreciation practices and cost allocation studies, but not a single citation on service quality: R.W. Lawton, *Telecommunications Modernization: Issues and Approaches for Regulators*, Report 87-14, National Regulatory Institute, Columbus, OH, 1988. Cole's new collection of analyses has chapters by several authors which address quality-of-service issues: B. Cole, ed, *After the Breakup: Assessing the New Post AT&T Divestiture Era*, Columbia University Press, New York, NY, 1991.

[2]Eli Noam, 'The quality of regulation in regulatory quality: a proposal for an integrated incentive approach to telephone service performance', in M.A. Einhorn, ed, *Price Caps and Incentive Regulation in Telecommunications*, Kluwer, Dordrecht, the Netherlands, 1991.

[3]Michael A. Spence, 'Monopoly, quality, and regulation', *Bell Journal of Economics*, Vol 6, No 2, 1975, pp 417–429; Eytan Sheshinski, 'Price, quality and quantity regulation in monopoly situations', *Economica*, Vol 43, 1976, pp 127–137; Richard E. Kihlstrom and David Levhari, 'Quality, regulation and efficiency', *Kyklos*, Vol 30, Fasc 2, 1977, pp 214–234.

[4]Richard Schmalensee, 'Market structure, durability and quality: a selective survey', *Economic Inquiry*, Vol XVII, April 1979, p 193.

modelled the efficiency conditions for quality as a public good.[5] When the same 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. If the only option is a Cadillac, some who would prefer smaller cars are priced out of the market, and others receive less of a benefit from their purchases. In addition, the bundling of access and usage for customers with different calling patterns causes cross-subsidies – one customer paying for the costs incurred to increase quality for another. In this case the bundling of access and usage creates public-goods problems within a given customer class. The problem is no less severe for a single dimension of quality and different customer classes, or for multiple dimensions of quality. 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.

Rate-of-return regulation can induce resource allocation improvements not only in terms of increased output, but also *vis-à-vis* quality choices; distortions can also be exacerbated if quality is labour 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 underprovided), RORR expanded the use of capital – increasing both output and quality.[6] Sherman and Visscher analysed a wider range of rate designs than contained in the original Averch-Johnson formulation. They concluded: '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.'[7] Sherman and Visscher argue that, for example, the Civil Aeronautic Board's regulation of airlines' pricing led to a level of service quality that might have been inefficient (and to an 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 sub-optimal – 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. Defining and pricing the functions available under Open Network Architecture (ONA) illustrates the complex problems raised by this issue.

A multiproduct firm faces an additional set of quality choices in which bundles are created to maximize profits subject to various regulatory constraints. Besanko, Donnenfeld and White have examined how minimum quality standards, maximum price regulation and rate-of-return regulation affect welfare.[8] Their basic model involves two groups of customers, one of which (type I) has a higher total and marginal

[5]Kihlstrom and Levhari, *op cit*, Ref 3.
[6]Spence, *op cit*, Ref 3.
[7]Roger Sherman and Michael L. Visscher, 'Rate-of-return regulation and price structure', in Michael A. Crew, ed, *Problems in Public Utility Economics and Regulation*, Lexington Books, Lexington, MA, 1979, pp 128–129.
[8]David Besanko, Shabtai Donnenfeld and Lawrence J. White, 'The multiproduct firm, quality choice, and regulation', *Journal of Industrial Economics*, Vol 36, June 1988, pp 411–429.

willingness to pay than the other. Quality is observed but the heterogeneous 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, Besanko, Donnenfeld and White conclude that the monopolist offers group I the socially optimal quality, but the second group receives a sub-optimal 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.'[9] A higher-quality offering to this other group would begin to attract type I customers, reducing an unregulated monopolist's profits.

The same authors find that minimum (pass–fail) quality standards (MQS) and maximum price regulation (MPR) raise the quality offered to the type II 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 television 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 versus single line or size of area for non-toll calls) have different costs and capital intensities.

The impact of RORR is much more complicated (even for Besanko, Donnenfeld and White's 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.'[10] 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 obtain an excessive level of quality.

It should be noted that different demand or cost conditions would affect these conclusions. Nevertheless, Besanko, Donnenfeld and White's 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? Nevertheless the results which emerge from these models suggest that regulation (and deregulation) can yield perverse outcomes.

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 three seconds.[11] For a second dimension of quality, intra-office call completions, 95% of all calls to numbers with the same first three digits as the caller must be completed.

[9] *Ibid*, p 414.
[10] *Ibid*, p 424.
[11] The surveillance methods for determining compliance are problematic (peak hours? as a proportion of all calls?). However, even after appropriate monitoring procedures have been adopted, determining the benefits and costs of exceeding the standard is complicated. Another issue is whether 90% receiving a dial tone within two seconds might be preferable to 95% with three seconds, but since the former probably implies greater than 95% in three seconds, we take the three-second delay as the relevant duration.

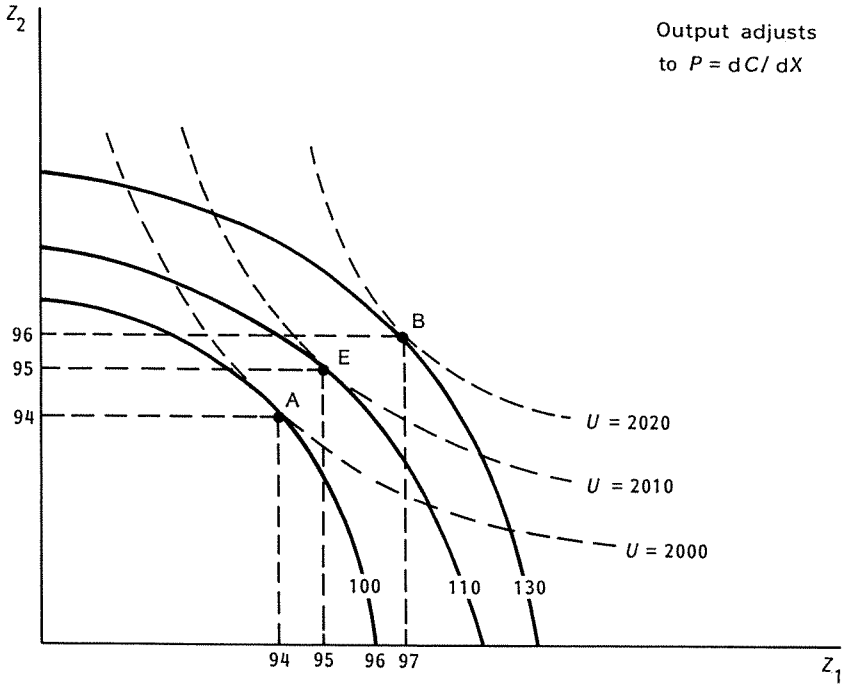

Figure 1. Welfare maximization for two quality attributes.

Presumably regulators attempt to maximize welfare, subject to the telephone company's budget constraint (total revenues are not less than total costs). 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 $Z_1 = 0.95$ and $Z_2 = 0.95$ in equilibrium (point E). The curve (frontier) labelled 110 represents the different quality combinations that can be feasibly produced with an outlay of \$110. The shape of the frontier implies that for a fixed level of outlays, improvements in the Z_1 quality attribute require reductions in Z_2 quality. Three different production possibility frontiers are depicted, representing \$100, \$110 and \$130 worth of resources going into the production of the two types of quality. Note that output is adjusted for the different production possibility frontiers shown in the figure (so that price, P, equals marginal cost, MC).

The perceived levels of benefits are also shown in Figure 1, using three social indifference curves (again measured in dollar terms). Again the shape reflects trade-offs, but these curves represent consumer preferences: if Z_1 is reduced from 95 to 94, the consumers would be equally well off if Z_2 were increased to about 97. Consumers would remain on the curve corresponding to $U = 2010$. If both quality dimensions are reduced (from E to A), then consumers are worse off ($U = 2000$, where U is utility or some dollar valuation). 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.[12]

If point E (95,95) is optimal today, need it remain so in the future? Even if preferences are known and remain unchanged, income elasticities for output and quality, changing customer mixes and technological

[12]Note that this 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 ouput 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.

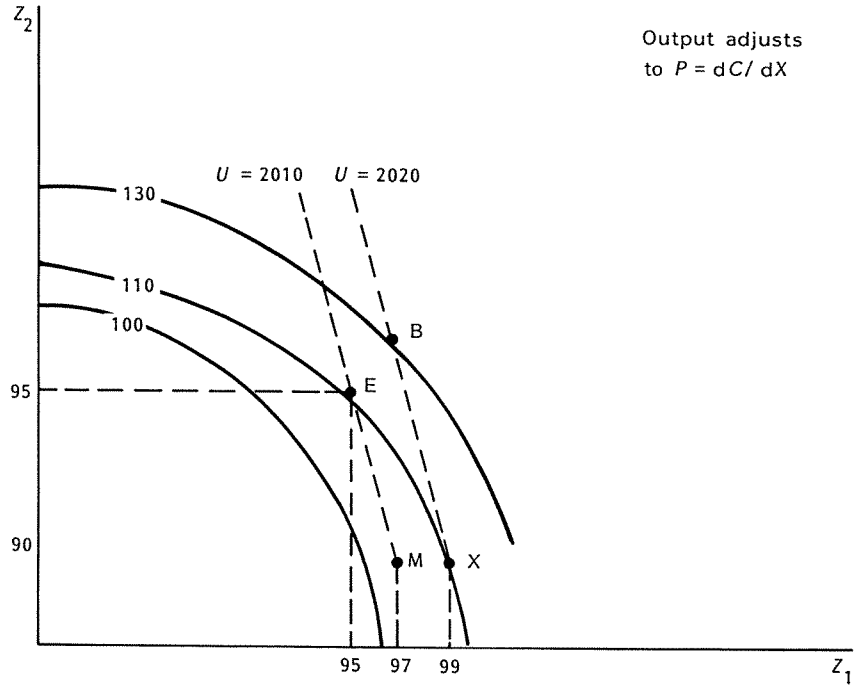

Figure 2. New relative valuations of quality attributes.

changes will tend to yield a new optimal point. For example, if the cost of shifting from E to B were $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 pass–fail quality standards, or quality incentives must be established – rewarding 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).[13] 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? One regulatory approach resulting in the achievement of point X would be to change the pass–fail standards to $Z_1 \geq 99$ and $Z_2 \geq 90$. An alternative appoach would give the telco greater flexibility in selecting least-cost ways to achieve $U = 2020$.

The following sections describe a methodology for determining

[13]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. At E the MRS is -1 in Figure 1, indicating that (95.5,94.5) is valued 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.

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 $Q = 332.5$.

The telco has lower costs at M but has a score of 332.5 (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 shared 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.

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 the 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.

Measurement of service quality

Dimensions of service quality

To illustrate current procedures, let us consider the Florida Public Service Commission. The FPSC evaluates local telephone companies on the basis of dial tone delay, meeting telephone installation appointments and 36 other performance standards. Companies measure various technical characteristics and maintain detailed records of company performance. The National Association of Regulatory Utility Commissioners recommends a similar set of standards.[14] However, the weights to be given individual rules have not been established. Although the FPSC rules (or standards) can be further grouped into nine clusters, creating a single index of quality is not a simple task.

In a sense, the absence of a reasonable weighting 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 (benchmark). 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.

[14]Telephone utilities have done some work in the area. For example, *Engineering and Operations in the Bell System* (ed R.F. Rey, AT&T Bell Laboratories, Murray Hill, NJ, 1983) 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 (pp 683–684). 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.

A complete listing of the 38 FPSC quality standards is shown in Appendix 2. 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 services, (8) repair service (eg 24-hour restoral), and (9) public telephone services (involving 16 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, a National Regulatory Research Institute report provides a survey design for obtaining opinions from telephone subscribers.[15] Trends in consumer perceptions can be captured via such surveys.[16] 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 3, which lists types and numbers of complaints in Florida, 1988). However, customer-initiated evaluations can be spurred by other factors – an ongoing 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).

Customer versus expert-based measurement

The welfare countours depicted in Figures 1 and 2 reflect social preferences. Thus researchers could ask the concerned parties (ie 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 modelling the experts' perceptions of what is most important to consumers. This approach was deemed a reasonable solution to the problem since 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[17] that, despite their relevance, customer-based measures of importance cannot be treated as the ultimate criterion for additional reasons:

- Consumers may lack the technical expertise necessary to evaluate certain dimensions. In some cases they simply may not understand the technical terminology (eg Call Completions Intra-office, Inter-office, EAS and Intra-company DDD). Other dimensions may be 'credence' attributes,[18] the values of which cannot be determined even after experiencing their levels.
- 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 analysis of the process by which consumers learn multi-attribute preferences.[19]

[15]C.A. Mount-Campbell, D. Slyper and S. Ahn, *Quality of Telephone Service: Summary Report*, National Regulatory Research Institute, Columbus, OH, 1978.

[16]Since the regulatory process tends to be adversarial, the usefulness of surveys for rewarding or penalizing firms is unclear. Drops in a 'popularity poll' which resulted in a reduced allowed rate of return could be subject to legal challenge by the regulated firm. Regulators operate under legal standards of due process and legislative mandates. They collect information on technical features of telephone service such as dial tone delay and noise on the line. Thus regulatory rules related to quality pertain to objective features of the service. These 'objective' indicators of quality are presumably related to subjective valuations – although the links have not been carefully examined in any regulatory jurisdictions. However, Bolton and Drew found that the link between actual service improvements and customer perceptions is tenuous. In a GTE field experiment, test exchanges were modernized, and static greatly reduced: 'customers at the test sites perceived greater increases in static directly after network upgrades and all customers [including those *without* upgrades] perceived decreases in static six months later': R.N. Bolton and J.H. Drew, 'A longitudinal analysis of the impact of service changes on customer attitudes', *Journal of Marketing*, Vol 55, 1–9 January 1991, p 5. The results of this GTE field experiment raise serious questions about using consumer surveys when the stakes can involve tens of millions of dollars.

[17]Thomas E. Buzas, John G. Lynch and Sanford V. Berg, 'Issues in telephone service quality', in Cole, ed, *op cit*, Ref 1.

[18]M.R. Darby and E. Karni, 'Free competition and the optimal amount of fraud', *Journal of Law and Economics*, Vol 16, 1973, pp 67–86.

[19]R.J. Meyer, 'The learning of multiattribute judgment policies', *Journal of Consumer Research*, Vol 14, 1987, pp 155–173.

- Because customers have not had to make choices among competing services, they have not had occasion to think about the trade-offs between different dimensions. Research has shown that when prior opinions about trade-offs do not exist, revealed weights are highly unstable and susceptible to minor changes in the elicitation procedures.[20]

Evaluation and encouragement of service quality

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.[21] 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.[22]

In the competitive marketplace firms offer price–quality combinations and potential customers 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.[23]

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 judgements of overall service quality, and (2) whether the partial effect of each dimension on overall judgements was linear or curvilinear. The pretests employed 'functional measurement' methodology.[24]

Experts were asked to judge the quality of service provided by a series of hypothetical companies by pairs of the 38 technical dimensions. A series of two-factor repeated measures designs allowed the two dimensions each to be varied over four levels reflecting the historical range of performance. The empirical tests found a lack of interactions between dimensions.[25] Furthermore, the evaluations along individual dimensions were linear. A 1% 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.

Taken together, the analysis implied that experts' overall quality judgements could be appropriately modelled by a weighted linear composite equivalent to:

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

[20]J.M. Feldman and J.G. Lynch, Jr, 'Self-generated validity and other effects of measurement on belief, attitude, intention, and behavior', *Journal of Applied Psychology*, Vol 73, 1988, pp 421–435; B. Fischoff, P. Slovic and S. Lichtenstein, Knowing what you want: measuring labile values', in T. Wallsten, ed, *Cognitive Processes in Choice and Decision Behavior*, Earlbaum, Hillside, NJ, 1980.

[21]*Model Telecommunications Service Rules*, National Association of Regulatory Utility Commissioners, Washington, DC, 1987.

[22]B. Fischhoff, 'Setting standards: a systematic approach to managing public health and safety risks', *Management Science*, Vol 30, 1984, pp 823–843.

[23]See K.H. Militzer, 'Macro versus micro input/output ratios', *Management Review*, Vol 69, June 1980, pp 8–15, which 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.

[24]N.H. Anderson, *Methods of Information Integration Theory*, Academic Press, New York, NY, 1982; J.G. Lynch, 'Uniqueness issues in the decompositional modeling of multiattribute overall evaluations: an information integration perspective', *Journal of Marketing Research*, Vol 22, 1985, pp 1–19.

[25]The tests are reported in Thomas E. Buzas, John G. Lynch and Sanford V. Berg, *Regulatory Measurement and Evaluation of Telephone Service Quality*, Working Paper, Public Utility Research Center, University of Florida, Gainesville, FL, 1991. For a description of antecedents to hierarchical conjoint analysis, see J.J. Louviere, 'Hierarchical information integration: a new method for the design and the analysis of complex multiattribute judgement problems', in T. Kinnear, ed, *Advances in Consumer Research*, Vol 11, Assocation for Consumer Research, Provo, UT, 1984; and J.J. Louviere and D.J. Garth, 'Decomposing the determinants of retail facility choice using the method of hierarchical information integration: a supermarket illustration', *Journal of Retailing*, Vol 63, 1987, pp 25–48.

Table 1. Example of comprehensive evaluation for a hypothetical company.

Criteria	Company score (%) (A)	Rule (%) (B)	Change (A–B)(%) (C)	Weight of 1% change (D)	Gain or loss (C × D) (E)
1 Dial tone delay	100	95	+ 5.0	0.097	+0.4850
2 Call completions					
Intra-office	99.9	95	+ 4.9	0.087	+0.4753
Inter-office	99.2	95	+ 4.2	0.084	+0.3528
EAS	99.9	95	+ 4.9	0.058	+0.2842
Inter-company DDD	96.8	92	+ 4.8	0.041	+0.1968
3 Answer time					
Operator	95.7	90	+ 5.7	0.012	+0.0684
Directory assistance	96.3	90	+ 6.3	0.005	+0.0315
Repair service	79.1	90	−10.9	0.008	−0.0872
Business office	66.3	80	−13.7	0.004	−0.0548
4 Directory					
Directory	100	100	0.0	0.058	0.0
New numbers	94.9	100	− 5.1	0.014	−0.0714
5 Intercept services					
Changed numbers	100	90	+10.0	0.008	+0.0800
Disconnected	100	100	0.0	0.015	0.0
Vacation disconnects		80	0.0	0.002	0.0
Vacant numbers	100	100	0.0	0.009	0.0
Non-pay		100	0.0	0.016	0.0
6 Availability of service					
Three-day primary service	100	90	+10.0	0.030	+0.3000
Appointments	100	95	+ 5.0	0.046	+0.2300
7 911 service		95	0.0	0.117	0.0
8 Repair service					
24-hour restoral	94.1	95	− 0.9	0.018	−0.0162
Appointments	94.4	95	− 0.6	0.023	−0.0138
Rebates	78.6	100	−21.4	0.003	−0.0642
9a Functioning of public telephones					
Serviceability	97.8	100	− 2.2	0.027	−0.0594
Telephone numbers	100	100	0.0	0.015	0.0
Receives calls	100	100	0.0	0.013	0.0
Dial instructions	100	100	0.0	0.022	0.0
9b Enclosure of public telephones					
Handicapped	100	100	0.0	0.003	0.0
Cleanliness	100	95	+ 5.0	0.002	+0.0100
Lights	96.8	100	− 3.2	0.004	−0.0128
9c Coin operations					
Pre-pay	100	100	0.0	0.009	0.0
Coin return	98.6	100	− 1.4	0.005	−0.0070
Coin-free access operator	NA	100	0.0	0.002	0.0
Coin-free 911	100	100	0.0	0.003	0.0
Coin-free directory	100	100	0.0	0.001	0.0
Coin-free repair	98.9	100	− 1.9	0.001	−0.0019
Coin-free business	99.6	100	− 0.4	0.001	−0.0004
9d Directory security	97.1	100	− 2.9	0.002	−0.0058
9e Address/location	99.6	100	− 0.4	0.017	−0.0068

Overall evaluation = Base (6.1000) + 0.4850 + 0.4753 + ... − 0.0058 − 0.0068 = 8.2123

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

Table 1 shows the hypothetical company's 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 *just matching* 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 favourable features. A single service quality index 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 importance of service quality in the actual hearing process is reduced if regulators create so many dimensions of quality that comparisons become cumbersome, if not impossible. Thus the current practice of specifying minimum performance standards has severe limitations given our findings about preferences. An index giving weights to each standard assists both firms and regulators.

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 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.[26] Moreover, even when standards are set initially at levels that equate marginal benefits and costs, technological change makes it more 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 fail to reward superior performance appropriately.

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 *any* 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 little 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, and (b) where those gains can be achieved at the lowest possible cost to a company.

Specification of an objective function

The second major problem regulators face is how to combine 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) judgement. The exact nature of the objective function is left unspecified.[27]

Even expert regulators face an uneviable task as they attempt to combine intuitively information on the many dimensions along which

[26]Fischhoff, *op cit*, Ref 22.

[27]Another significant published source on the measurement of service quality is a recent volume edited by Cole (*op cit*, Ref 1), 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 break-up on service quality. They tentatively conclude that quality has not declined following the break-up, 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.

telephone companies are evaluated. Research in behavioural 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 judgements about an object increases as they have more information about the object[28] even when the added information is normatively irrelevant.[29]

The large numbers 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.

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 might 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. To what extent do aggregate indicators mask localized failures?[30] 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 a 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 services) 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. However, the approach reported here provides a starting point which can be further refined. The key point is that it is useful to have an explicit scoring function which can be used to reward good performance.

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 in telecommunications, the absence of a consistent view of price–quality trade-offs probably led to some inefficiencies and inequities. However, the potential costs of mistakes by firms and oversight groups today are 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 service quality in telecommunications.

[28]J.W. Payne, 'Contingent decision behavior', *Psychological Bulletin*, Vol 92, 1982, pp 382–402.
[29]D.L. Ronis and J.F. Yates, 'Components of probability judgment accuracy: individual consistency and effects of subject matter and assessment method', *Organizational Behavior and Human Decision Processes*, Vol 40, 1987, pp 193–218.
[30]Noam, *op cit*, Ref 2, p 17.

Appendix 1

Monopoly and welfare-maximizing outcomes

Economic models of output and quality determination support the conclusions summarized in the first section of the text. Items (a) and (d) of the first conclusion can be derived from the first-order conditions for the monopoly and welfare-maximizing firms. Earlier studies only considered one dimension of quality, but we consider two in order to emphasize trade-offs between the two characteristics of the good. Marginal valuation (price) is a function of output (X) and dimensions of product quality (Z_1, Z_2):

$$P_x(X,Z_1,Z_2) < 0;\ P_i(X,Z_1,Z_2) > 0, i = 1,2 \quad \text{(A1)}$$

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

$$C_x(X,Z_1,Z_2) > 0;\ C_i(X,Z_1,Z_2) > 0, i = 1,2 \quad \text{(A2)}$$

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

$$V(X,Z_1,Z_2) = \int_0^x P(V,Z_1,Z_2)\mathrm{dV} - C(\mathrm{X},Z_1,Z_2) \quad \text{(A3)}$$

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

$$V_x = P(X,Z_1,Z_2) - C_x = 0;$$
$$V_i = \int_0^x P_i(V,Z_1,Z_2)\mathrm{dV} - C_i = 0,$$
$$i = 1,2 \quad \text{(A4)}$$

For welfare maximization, each dimension of 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 across customers equals the cost per unit output for achieving 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,

$$\pi(X,Z_1,Z_2) = P(X,Z_1,Z_2)\cdot X - C(\mathrm{X},Z_1,Z_2) \quad \text{(A5)}$$

$$\pi_x = M(X,Z_1,Z_2) - C_x, \text{ where } M() = P + P_x\cdot X \quad \text{(A6)}$$

$$\pi_i = P_i(X,Z_i)X - C_i, i = 1,2 \quad \text{(A7)}$$

Thus the unregulated monopolist considers the marginal rather than the average impact of quality change – leading to underprovision of quality if improvements make the demand curve steeper.

Appendix 2

Florida Public Service Commission 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 three seconds.

Rule cluster 2: call completions

2. Intra-office: 95% of all calls to numbers with the same first three digits as your own shall be completed.
3. Inter-office: 95% of all calls to numbers with different three-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 10 seconds after the start of an audible ring.
7. Directory assistance: 90% of all calls to directory assistance shall be answered within 20 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 48 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 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 discon-

nected 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. Three-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 shall be kept that are set within time frames of 7–12 am, 12–5 pm or 5–9 pm, or for a specific hour of the day.

Rule cluster 7: 911 service
19. 911 service: 95% of all calls to 911 service shall be 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 shall be kept that are set within time frames of 7–12 am, 12–5 pm or 5–9 pm, 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 telephones must have identified station telephone numbers.
25. Receive calls: 100% of all pay telephones – 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 dialling 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 1 January 1987 must be accessible to the handicapped.
28. Cleanliness: Normal maintenance shall include inspection and reasonable effort shall be taken to ensure 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 must allow pre-pay. They must provide a dial tone, require coin deposit prior to dialling (except for calls to operator or 911 as discussed in 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.

Sub-cluster 9d: directory security of public telephones
37. Directory security: 100% of all coin stations must 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 staion.

Sub-cluster 9e: address/location of public telephones
38. Address/location: 100% of all public telephones must have their locations posted, and the identifications of locations must be coordinated with the appropriate 911 or emergency centre.

Appendix 3

Customer-initiated complaints to the Florida Public Service Commission, 1988

The Division of Consumer Affairs of the FPSC receives, investigates and resolves customer complaints regarding gas, electricity, water and telephone utilities. Since it received 44 189 complaints during 1988, but recorded and investigated only 5857 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 services 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

Appendix Table 1. Telephone industry complaints, 1988.

	Complaints logged in 1988						Complaints closed in 1988				
	Service	Billing	Total	Change from 1987 (%)	Complaints per 1000 customers	Major type	Justification Yes	No	Some	Justified per 1000 customers	Per cent justified
Alltel	45	13	58	–23	1.281	Service problems	26	16	17	0.618	44
Centel	123	49	172	–29	0.773	Delay connect	82	44	44	0.373	48
Florala	5	0	5	–38	3.183	Party line	2	0	2	1.273	50
GTE	399	137	536	–26	0.353	Service problems	211	196	133	0.141	39
Indiantown	2	0	2	100	1.066	Service problems	0	2	0	0.000	0
Long Distance	170	836	1006	24	–	Alt operator service	624	194	175	–	63
NE Florida	6	3	9	29	1.872	Delay connect	2	7	1	0.416	20
Pay Telephone	93	41	134	116	–	Service standards	70	25	24	–	59
Quincy	2	3	5	67	0.627	Service problems	0	3	1	0.000	0
St Joseph	10	4	14	–46	0.724	Service problems	5	7	3	0.259	33
Southern Bell	1318	451	1769	11	0.462	Delay connect	688	577	477	0.180	40
Southland	1	9	1	–50	0.364	Service problems	1	0	0	0.364	100
United	158	88	246	–4	0.285	Delay connect	59	93	79	0.069	26
Vista-United	0	2	2	0	0.637	Miscellaneous billing	0	1	0	0.000	0
Industry total	2332	1627	3959	4	0.432	Delay connect	1770	1165	956	0.166	45

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.

Appendix Table 1 shows the complaints logged in during 1988, indicates whether they were justified and provides bottom-line indices: percentage change from the previous year and the number of justified complaints per 1000 customers. Such information represents a potentially useful database – as consumer perceptions regarding quality of service could be linked to telco outlays in particular areas. As far as we know, this issue has not been addressed in the past, so it represents a potentially promising research avenue.