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DECISION ANALYSIS APPLIED TO ELECTRIC UTILITY RATE DESIGN

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The National Regulatory Research Institute
2130 Neil Avenue
Columbus, Ohio 43210

By

ROBERT K. KOGER
NORTH CAROLINA UTILITIES COMMISSION

JOHN R. CANADA
NORTH CAROLINA STATE UNIVERSITY

EARL R. MACCORMAC
DAVIDSON COLLEGE

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EXECUTIVE SUMMARY

Introduction

This research report demonstrates how decision analysis can be used to bring more structured and logical decision making to the complex matter of electric utility ratemaking. It also provides the results of a nationwide survey of regulators and utility rate managers regarding the weights (importance) they place on ratemaking objectives.

The aspect of electric utility ratemaking, which deals with apportioning costs and structuring rates among customers, has been a problem for the electric utility industry since its inception. It has become increasingly controversial in the last decade because of the rapid rise in the nominal price of electricity. Prior research has determined that there is no one "correct" method of costing, but that the selection of a costing method depends on one's pricing or ratemaking objectives. However, pricing objectives in the electric utility industry are multiple and often conflicting.

The Analytic Hierarchy Process, a decision analysis technique, is used to address the problem of weighting priorities among pricing objectives. A normative model is developed for use by decision makers and national and regional preference values are determined. Such values afford an individual decision maker a reference standard for comparison purposes. Also, responses from various regions of the country are compared to determine sensitivity of pricing objectives to system operating characteristics.

Background

During the 1970s, the design of electric utility rates became a national issue for study--primarily because it was perceived that a different means of pricing could help restrain the rapidly increasing costs of electric power. Of the various studies of rate design, the most prominent and comprehensive one was carried out under the auspices of the Electric Power Research Institute at the request of the nation's state utility regulators. This study produced many important findings, as well as focused needed attention on certain controversial areas of ratemaking. However, it did not adequately address the problem concerned with determining and meeting a decision maker's pricing objectives.

The concept of pricing by objective is not new to the electric utility industry. For example, electric utilities for years practiced market building techniques such as declining block rates, discount rates for electric heating, etc. [25]. Pricing objectives, however, need to be viewed from the broader perspective of strategic planning. Utility executives use strategic planning and strategic goals to guide decisions in a consistent manner. This helps to coordinate action and move a company in a desired direction. Pricing by objectives can determine the extent to which strategic goals are met [25]. For example, prior to the

1970s, increased sales growth for many utilities resulted in lower per-unit costs and higher profits. In today's environment of high costs and difficult financing for capacity additions, generating plant construction for many utilities impairs returns to stockholders as well as impacts ratepayers adversely. Therefore, a utility in such a situation might choose a goal of reducing sales in order to try to maintain or increase profits.

The Survey

The demonstration of a means of explicitly setting priorities or weights for multiple ratemaking objectives was a major purpose of this research. Within this broad purpose, two subpurposes were also undertaken. One subpurpose was to arrive at regional and national weighted pricing objectives of electric utility rate managers and state utility regulators. The other was to examine these weighted objectives in terms of what possible ratemaking changes they might require if implemented. These purposes were pursued by polling regulators and utility rate managers nationally on their ratemaking objectives. The polling was done in the context of a pairwise comparison procedure necessary for use with a decision analysis technique called the Analytic Hierarchy Process (AHP) [17]. Next, the results of the analysis were examined to ascertain the degree of impact that different operating characteristics of utilities might have on the ratemaking objectives. This was done by segregating the responses on a regional basis. From these analyses, some judgments could be made on suitable rate design changes to meet a decision maker's explicitly determined ratemaking objectives, given various circumstances.

Application of Decision Analysis

Given a simple decision problem, it is easy enough to consider in an informal, in-the-head analysis all the various factors that may impact the problem [21,22]. The complexity of the allocation of costs and design of electric utility rates, however, is such that an informal analysis is very difficult to do well.

Decision analysis is a term used to describe a formal and systematic approach to problem solving. Decision analysis developed in the last 25 years and is a discipline for use in the analysis of important and complex decisions. It resulted from the combining of the fields of systems analysis and statistical decision theory.

There have been a variety of decision analysis methods developed which are designed to assist a decision maker in logically choosing among multiple alternatives or objectives. In this research, the Analytic Hierarchy Process was employed. The AHP was initially developed by Saaty in 1972 and has been used in a number of decision problems [31].

The AHP was chosen for this research for several reasons including ease of use in obtaining preferences from a large group of decision makers across the country. More importantly, it appears to have a definable mathematical foundation and its hierarchical framework appears to structurally follow the way the mind works in considering a multitude of elements which comprises a complex situation. Like various other decision analysis methods, it is applicable in areas where attributes with nonstandard measurements must be compared with each other or with attributes defined in monetary or other standard values. An example of such an attribute, having no standard measurement, would be the ratemaking objective, fairness.

The AHP is simple to use in practice, particularly with ready-made microcomputer programs now available. A brief technical description of the AHP procedure follows. The general approach of the AHP is to decompose the problem by hierarchical levels (determined by the relationships of the elements within the problem). The shape of the structure tends to be pyramidal, but this hierarchy is not an exclusively disjunctive tree structure. Higher placed nodes (goals) are allowed to dominate a multiplicity of lower placed nodes in the structure. Pairwise comparisons of elements on the same level are made with respect to the elements or nodes in the level directly above them. The degree of preference or intensity of the decision maker in the choice for each pairwise comparison is measured and these measurements are placed in a matrix of comparisons.

Use of the AHP in Electric Utility Ratemaking

As stated earlier, there are multiple electric utility ratemaking objectives, and they are often conflicting. After an extensive review of the various ratemaking objectives, it was determined that they could be combined and formulated into five with certain ones having important subelements. They are as follows:

(1) revenue requirements--the effectiveness of rate design in ensuring recovery of all reasonably incurred costs;

(2) simplicity--ability of rate design to be understandable to consumers;

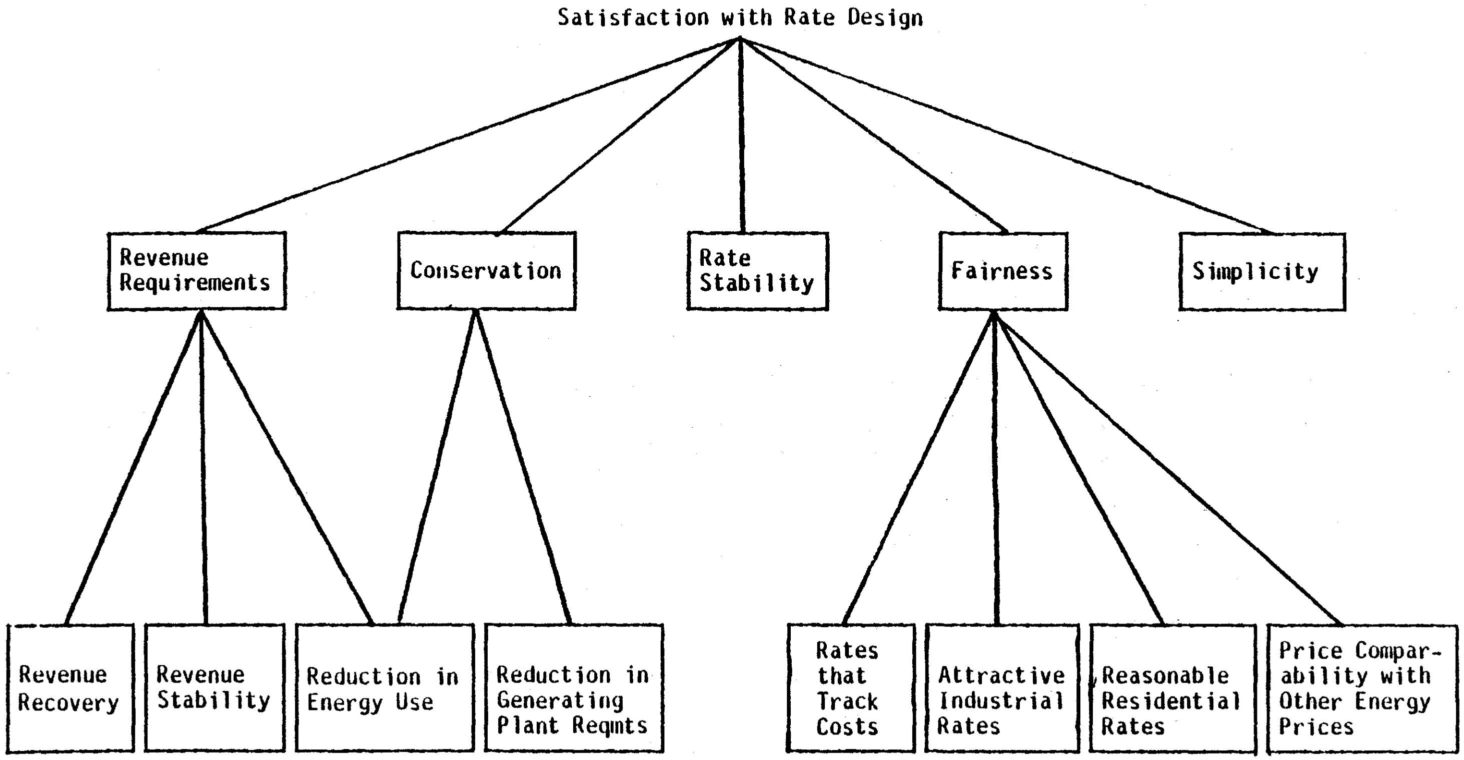
(3) stability--effectiveness of rate design in minimizing large adverse price changes to customers;

(4) conservation--ability of rate design to effect conservation of resources utilized in production of electric power; and

(5) fairness--effectiveness of rate design in providing rates which are considered "fair" between and among customers and customers classes.

The ratemaking objectives on which the questionnaire was based can be shown in the hierarchical framework on the following page.

From observation of the hierarchy, it can be seen that the second level of elements consists of the five major ratemaking objectives.



Hierarchy of ratemaking objectives

These are interpreted to mean that rates would be designed to promote each according to its importance in terms of satisfying the overall rate design objectives of the decision maker. For example, if the conservation objective were determined to have a 100% weight, then rates that promote conservation should receive complete consideration without regard to any other factor. This would not likely be the case, however. A more reasonable expectation would be that each objective would receive some weight and a prioritization of ratemkaing objectives would have to be established.

On the third level of the hierarchy are the subelements or the more narrowly defined objectives which relate directly to the second level objective. By obtaining the preference weights of the subelements, a further refinement of a decision maker's preferences are available for use in arriving at a rate design which meets his objectives. The percentage weights that regulators and utility executives placed on these objectives at the time of the survey are shown below. A more complete discussion of regional findings and the weighted subelements are given in the report.

National weighted ratemaking objectives

Objectives	Weights	
	Regulators	Utilities
Revenue Requirements	35.3%	48.1%
Conservation	16.5%	8.0%
Stability in Rates	13.4%	17.4%
Fairness	25.7%	19.7%
Simplicity	9.1%	6.8%

As can be seen, there is a degree of conformity found between regulators and utility rate managers on several of the major objectives. Both regulators and utility rate managers place the greatest weight on designing rates to meet revenue requirements with the second highest for each being the fairness objective. The utility respondents did, however, place relatively more weight on the revenue requirements objective. The most substantial difference between the two groups lies in their judgments of the weight to be attributed to the conservation objective. Regulators would assign about twice as much important to this objective as would the utility representatives. This likely means that utility respondents are more skeptical about the positive impacts conservation can have on the utility system and its customers. It is particularly interesting to observe how these weights vary on a regional basis, given the different operating circumstances of the utilities. This report attempts to draw some tentative conclusions from these variances by regions.

Summary

This research is unique in its effort to introduce decision analysis techniques into electric utility ratemaking at the initial stage of determining and weighing pricing objectives. By implementing the decision analysis technique demonstrated herein, decision makers should be able to more logically and correctly arrive at ratemaking decisions. The explicit determinations of ratemaking objectives should facilitate discussions regarding which objectives are to be strived for and what trade-offs among ratemaking objectives may be necessary. Furthermore, the ratemaking weights resulting from the national and regional survey should be useful in guiding individual decision makers. Finally, the recent development of a micro computer based program for the simple and and direct application of the AHP to decision problems should encourage and facilitate its use in electric utility ratemaking.

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Foreword

The bylaws of The National Regulatory Research Institute state that among the purposes of the Institute are:

> ...to carry out research and related activities directed to the needs of state regulatory commissioners, to assist the state commissions with developing innovative solutions to state regulatory problems, and to address regulatory issues of national concern.

This report helps meet those purposes, since the subject matter presented here is believed to be of timely interest to regulatory agencies and to others concerned with electric utility regulation.

Douglas N. Jones
Director
June 1, 1985

ACKNOWLEDGMENTS

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1. INTRODUCTION

1.1 Statement of Purposes

The contents of this paper were selected from a more lengthy research paper prepared by the authors. The original research had two major, interrelated purposes. One was to demonstrate that decision analysis can be used to bring more structured and logical decision making to the complex matter of electric utility ratemaking.[1] (Decision analysis is a term used to describe a formal and systematic approach to problem solving.) The other was to close two significant and related gaps in utility ratemaking research left by prior work. Completion of this latter purpose was shown also to satisfy the first. The gaps in the ratemaking process referred to and addressed by this research can be described in general terms as follows:

(1) The absence of a procedure for explicitly weighing choices among multiple and often conflicting pricing objectives and

(2) The absence of an effective procedure for "blending" marginal and accounting costs in a way which could meet the economic efficiency pricing objective.

The importance of these will become clearer subsequently. The authors, however, believe that the first issue, or the development of a procedure for explicitly arriving at ranked and weighted choices among pricing objectives, is of much greater interest. Therefore, the second part of the research results are discussed only briefly in this paper.

1.2 Previous Research

During the 1970s, the design of electric utility rates became a national issue for study--primarily because it was perceived that a different means of pricing could help restrain the rapidly increasing

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1 Ratemaking, as used in this paper, refers to the determination of the level and form of rates to customers and customer classes. It does not include the determination of the overall revenue requirement of the utility.

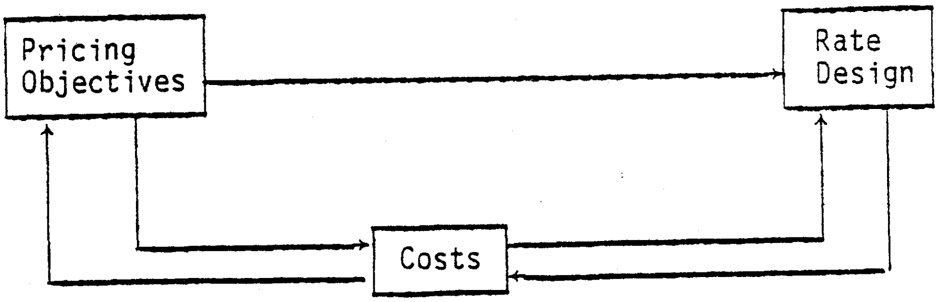
costs of electric power. Of the various studies of rate design, the most prominent and comprehensive one was carried out under the auspices of the Electric Power Research Institute at the request of the nation's state utility regulators. In the electric utility industry, it is generally referred to as the Rate Design Study (RDS) or as the Electric Utility Rate Design Study (EURDS). The RDS involved countless experts from all areas of the electric utility industry, consumed millions of dollars, and took approximately seven years to complete following its initiation in 1975 [11]. The RDS produced many important findings, as well as focused needed attention on certain controversial areas of ratemaking. However, it did not adequately address the problems referred to above which are concerned with determining and meeting a decision maker's pricing objectives.

1.3 Concept of Pricing by Objective

Prior to discussion of determining priorities and/or meeting given pricing objectives, some discussion of why pricing objectives are relevant is required. The concept of pricing by objective is not new to the electric utility industry. For example, electric utilities for years practiced market building techniques such as declining block rates, discount rates for electric heating, etc. [25].

Pricing objectives, however, should be viewed from the broader perspective of strategic planning. Utility executives use strategic planning and strategic goals to guide decisions in a consistent manner. This helps to coordinate action and move a company in a desired direction. It should be observed that regulators may have different goals. In any case, pricing by objectives can determine the extent to which strategic goals are met [25]. To elaborate with a brief example, prior to the 1970s, increased sales growth for many utilities resulted in lower per unit costs and higher profits. In today's environment of high costs and difficult financing for capacity additions, generating plant construction for many utilities impairs returns to stockholders as well as impacts ratepayers adversely. Therefore, a utility in such a situation might choose a goal of reducing sales in order to try to maintain or increase profits.

In the electric utility industry, however, ratemaking tends to be somewhat circular in nature, and outcomes of certain actions tend to be difficult to predict. Pricing affects demand for electricity; demand affects costs; and costs affect pricing. Furthermore, pricing objectives can act either exogenously or interdependently in the ratemaking process because given pricing objectives may or may not be affected by costs. For example, the decision to meet a noncost-based pricing objective, such as to help poor people through a "lifeline" rate, would (by definition) not be affected by cost considerations. Yet providing rates below costs may affect customer demand which could change overall system costs.[2] The diagram shown below illustrates, in simplified form, the role of pricing objectives in the ratemaking process.



To explain the feedback effects further, assume the hypothetical situation discussed previously. That is, a particular utility may have an important goal to increase or maintain profits by reducing electricity sales. With this goal, conservation in usage might be effectively induced by simply instituting inverted rates--the more one uses, the more one pays on a per unit basis. An alternative ratemaking decision which might also cause a reduction in sales would be to base rates on marginal costs (under current cost conditions, marginal costs exceed accounting costs for most utilities). By charging rates that reflect marginal or incremental costs of supplying power as opposed to rates based on average

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2 Selling power below cost to this group may result in increases in their demand which might affect peak demand for the system and increase generation costs.

(accounting) costs,[3] the result is likely to be higher rates in periods when power is more costly to produce. This should lead users with more elastic demands in those time periods to reduce their demand. This, in turn, should result in better utilization of the existing facilities and reduce the need for additional plant. As a consequence, costs per unit would be expected to stabilize or fall.[4]

In the converse situation, induced conservation, based on noncost-based inverted rates or on incorrectly calculated marginal costs, could adversely affect the company by causing demand to decrease more than the economics of the situation dictates. Excess or idle generating plant could result, causing higher unit costs and lower profits. In this situation, the initial objective of reducing growth might have to be modified and a new objective of reducing excess generating plant adopted. Also, it should be kept in mind that, at the same time this goal is being pursued, there are other goals and objectives that would be expected to require consideration. Furthermore, they may be conflicting. For example, another objective might be to maintain pricing stability; i.e., to avoid frequent shifts in rates to consumers. Still another objective, on which regulators might focus, is the question of fairness of the rates among customers. In other words, would these rate design changes be equitable to each of the customer classes?[5]

If more than one objective is to be considered (and that is likely to be the normal situation for a decision maker), the question arises as to what kinds of trade-offs should be made among those objectives. In

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3 Marginal cost measures the change in total cost due to a unit change in the output produced. It can also be referred to as the opportunity cost. Average cost is equal to the total cost divided by the number of units. As used in ratemaking practices, average costs reflect all historic investments at their original price less depreciation. Consequently, there is no rigorous link between a utility's marginal costs and a utility's average costs (also referred to as accounting or embedded costs) [17].

4 This, of course, sets forth part of the argument put forward by proponents of marginal costing.

5 For costing and ratemaking purposes, customers are grouped into classes. The three major classes are industrial, commercial, and residential. Also, a class may contain subclasses as "all-electric" heating customers.

order to consider appropriate trade-offs, however, priorities must first be assigned to the various objectives, even if done on an implicit or intuitive basis. In the absence of any formalized decision analysis procedure for ratemaking, it appears that these decisions are generally being made that way currently. Research on the human mind, though, has shown that it is very doubtful that all the issues in complex problems can be adequately considered on an intuitive or implicit basis.

Given this further explanation of pricing objectives, the purposes of this research can now be more fully stated.

1.4 Ascertaining Ratemaking Priorities

The demonstration of a means of explicitly setting priorities or weights for multiple ratemaking objectives addressed one significant research gap and comprised a major purpose of this research. Within this broad purpose, two subpurposes were also undertaken. One subpurpose was to arrive at regional and national weighted pricing objectives of electric utility rate managers and state utility regulators. The other was to examine these weighted objectives in terms of what possible ratemaking changes they might require if implemented. These purposes were pursued by polling regulators and utility rate managers nationally on their ratemaking objectives. The polling was done in the context of a pairwise comparison procedure necessary for use with a decision analysis technique called the Analytic Hierarchy Process (AHP) [31]. Next, the results of the AHP were examined to ascertain the degree of impact that different operating characteristics of utilities might have on the ratemaking objective. This was done by segregating the responses on a regional basis. From these analyses, some judgments could be made on suitable rate design changes to meet a decision maker's explicitly determined ratemaking objectives, given various circumstances.

1.5 Meeting the Efficiency Objective Through Traditional Costing Practices

A single pricing objective, economic efficiency, was next singled out to study how it might be met within the context of traditional costing and ratemaking practices. This constituted the second major and specific purpose of this research. The justification for placing particular emphasis on this pricing objective was twofold. First, it can be argued that its achievement would result in meeting several other specific pricing objectives--namely, the objectives of fairness, conservation, and revenue requirements. Second, the assumption of its primary importance was consistent with the emphasis placed on it by the RDS. The RDS was prompted by a desire to hold rates down [25], and it was assumed that the achievement of economic efficiency is closely identified with that goal by many ratemaking experts.

This research then made a second important assumption--that a large majority of utilities and regulators desire to and will continue to follow traditional accounting costs in electric utility ratemaking. These two assumptions, however, presented a contradictory situation. The achievement of economic efficiency is generally considered to be possible only if goods or services are priced at their marginal costs. There is no theoretical basis for believing that economic efficiency would result from basing rates on traditional accounting costs. Nonetheless, this research addressed the questions of whether and how this contradiction can be circumvented. Specifically, it determined whether there is a means to integrate marginal costing into traditional costing practices, preserving the apparent values inculcated by decision makers to traditional costing but yet obtaining the advantages of marginal costing. (As indicated earlier, the details of this part of the research will not be covered fully in this paper. However, a brief summary of it is given in the context of a decision analysis framework developed in Chapter 6.)

1.6 Costing Practices

The results of the national survey show that basing rates on costs-of-service is considered to be a very significant ratemaking or pricing objective. The RDS determined, however, that there is no single correct costing method for attributing costs of providing electric service to customers or customer groups, but that the costing method chosen depends on one's pricing objectives.[6] For example, if a decision maker believes that fairness and equity dictate that embedded costs of plant should be considered in determining the distribution of revenue requirements (hence, rates) among customers, then a traditional accounting costing procedure would be more appropriate. On the other hand, if the decision maker's primary objective is economic efficiency, then he should consider choosing a marginal costing procedure. (Many would also argue that rates based on marginal costs are the most fair.)[7]

Even after this initial costing decision is made, further complex costing decisions remain. For example, there are several competing costing methodologies for attributing costs of jointly used plant under both the traditional accounting and marginal costing procedures. The choice of any of these methods can have a material effect on the level of revenue requirements attributed to each of the customer classes.

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6 "For some, admitting the subjectivity of choosing a methodology for measuring costs and of choosing additional goals for rates may be a disillusioning loss of innocence that erodes their confidence that an objective standard can be discovered for equitable pricing of electricity" [24].

7 "Clearly there are possible areas of public policy in which conceptions of fairness may conflict with economic efficiency. But it is by far the greater wisdom to recognize that, for the most part, the major departures from economic efficiency in our public policies today are also demonstrably unfair; and that, for the most part, movement in the direction of economic efficiency is also compatible with increased fairness. It is fair, as a general proposition, to impose costs on people in so far as they impose costs on society" [19].

1.7 General Plan of Work

One decision that had to be made early in the preparation of this study was how much explanatory or background material to include on the general subjects of utility operations, ratemaking, and decision analysis. It was decided that sufficient information should be given to enable persons less experienced in these areas, as well as those more familiar with the subject, to critically evaluate this research and make use of its results. A brief history of electric utility pricing, the central aspects of ratemaking, and some limited details on the operations of an electric utility are provided in Chapter 2. Readers more knowledgeable about the electric utility industry may want to give less attention to this chapter. A discussion of decision analysis is contained in Chapter 3.

The plan of work followed the general sequence set out earlier in describing the principal areas to be studied. For convenience of discussion, the research can be considered to be divided into two major areas with the first area receiving the emphasis in this paper on the reporting of its results. The first part of the research examined the general aspects of decision analysis, application of the Analytic Hierarchy Process to ratemaking, and an analysis of the results of the nationwide survey of decision makers' ratemaking preferences. The possible effects of emphasizing various pricing objectives on utilities with different operating characteristics are also discussed.

The second part of the research which is not covered in detail in this paper builds upon the previously discussed assumptions that one pricing objective is paramount (economic efficiency) and that it must be met through primary reliance on traditional accounting costs. A specific area of utility costing was then examined in detail from the standpoint of attaining this objective--the matter of attributing the costs of jointly used production plant among customer classes (the most controversial area of costing). Both marginal costing and accounting costing for attributing costs to customer classes were examined including the individual alternative costing methods within each of these major costing methodologies. This was accomplished by applying each to a group of synthetically created but representative utilities. From these applications, conclusions were drawn on the effects of various operating characteristics on costing outcomes. As a result of this research, a procedure was suggested for integrating marginal costing results into the traditional ratemaking practices for the purpose of meeting the economic efficiency objective.

The importance of which costing method is selected can hardly be overstated in terms of the impact that these cost allocation decisions have on the relative level of rates for the three major customer classes. On a nationwide basis, hundreds of millions of dollars of revenue requirements are subject to being shifted from one customer class to another depending on the cost allocation method chosen by the utilities and/or their regulators.

1.8 Questions to Be Answered

This research attempted to answer the following questions:

1. Can decision analysis materially aid a decision maker in the complex and controversial matter of setting electric utility rates?

2. Is it possible to utilize a decision analysis technique to explicitly determine the weighted priorities among multiple and conflicting electric utility ratemaking objectives?

3. What effects do different utility operating characteristics have on the selection of ratemaking objectives?

4. Under the assumption that a decision maker desires to strive to design rates to meet the economic efficiency objective, can it be done through primary reliance on traditional costing methodologies in setting customer class revenue requirements?

5. Under the same assumptions of assigning primary important to the economic efficiency objective, what effect do different system demand and supply characteristics have (a) on the choice of a traditional costing method chosen to meet the economic efficiency objective, and consequently, (b) on the revenue requirements attributed to the individual customer classes?

1.9 Contributions of This Research

This research was unique in its effort to introduce decision analysis techniques into electric utility ratemaking at the initial stage of determining and weighing pricing objectives. By implementing the decision analysis technique demonstrated herein, decision makers should be able more logically and correctly to arrive at ratemaking decisions. The explicit determinations of ratemaking objectives should facilitate discussions regarding which objectives are to be strived for and what tradeoffs among ratemaking objectives may be necessary. Furthermore, the ratemaking weights resulting from the national and regional survey should be useful in guiding individual decision makers.

2. OVERVIEW OF ELECTRIC UTILITY RATEMAKING

2.1 History of Electricity Price Changes

When Thomas Edison first started generating and distributing electric energy for lights in New York City in 1882, it is possible that he had the vision to anticipate that the use of electricity would permeate our total society and cause major changes in the way we live and work. However, it is unlikely that he could have foreseen the problems that would occur in the pricing of electricity--at least, not in the degree of complexity or intensity that has occurred in the last decade.

Electric utility pricing, or rate design, has always been a significant concern to those who were trying to administer or regulate the sales of electric power. As a whole, the great majority of consumers appeared to be generally satisfied with utility pricing for most of the decades following the first sales of electricity. It is no wonder. The following graph, Figure 2.1, illustrates how both the nominal and real prices declined from 1892 through about 1970. The prices for power were as little as one-fifth the prices at the turn of the century [32]. On a real basis the comparisons were even more dramatic.

The public, of course, has a short memory, and when prices began to rise rapidly in the early 1970s, loud outcries of protests spread throughout the nation.

2.2 Reasons for Price Increases

There are several reasons for the sharp upturn in prices that began in the 1970s and is still continuing. The economies of scale that had been achieved through larger and more efficient generating facilities became effectively exhausted by the 1970s. The rate of inflation rose and hovered at double-digit levels in the 1970s, and to compound this problem, the time for construction of generating plants doubled and tripled, taking up to 15 years in some instances [20, 32]. This is significant because many regulatory commissions require utilities

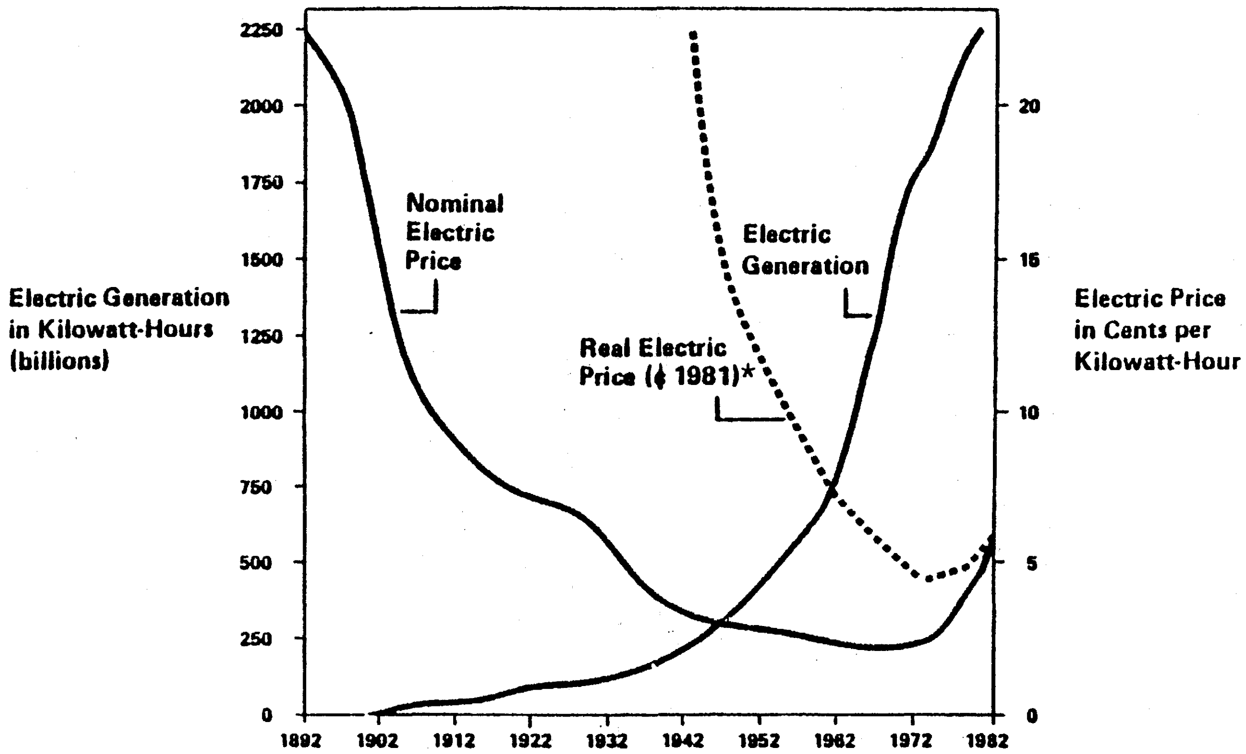

Figure 2.1 Generation and price

*Real electric prices are shown in 1981 cents.
SOURCE: U.S. Department of Energy. 1983. The Future of Electric Power in America: Economic Supply for Economic Growth; Report of the Electricity Policy Project. DOE/PE-0045, June.

to include the cumulative financing costs of these plants in their overall capital cost as opposed to treating the carrying costs as part of yearly current expenses. New safety and environmental constraints, of course, were responsible for a significant portion of these delays. As a result of all these factors, the cost of new production facilities skyrocketed [20,32]. Coal- and nuclear-fueled generating plants that were planned and built in the 1960s and early 1970s at $100 to $400 per kilowatt (kW) of capacity seem cheap today compared to the high costs per kW of similar and more recent plants. Some nuclear plants with expected completion dates within the 1985-1987 time frame will cost $4,000 per kW or $4 billion for a 1000-megawatt plant. Such large increases in cost of total plant in service have created major ratemaking problems for the utilities involved. In addition to the increases seen in cost of plant facilities, the average cost of total fuel used in production of electricity has risen by approximately 500% since the Arab oil embargo of 1973 [2].

These rapid cost increases forced utilities to begin to request large and frequent rate increases in the 1970s, but consumers were not ready to see them granted. During the years of steadily falling electricity prices, people and industry significantly increased their electricity usage, one reason being that they had come to expect stable or declining rates. Suddenly, they were faced with electric utility costs which represented a more significant portion of their net income. In the past 10 years, typical electric bills have increased from 1.64% to 2.5% of median family income [14]. As customers began to experience the continuous requests for rate increases in the 1970s, they became concerned and formed "grass roots" campaigns and customer interventions in many states to try to hold down the level of utility rates. This led to heightened regulatory and legislative activity and resulted in nationwide interest in rate design. One manifestation was a call by many, both within and without the electric utility industry, to examine the traditional pricing methodologies that had been followed for years. Both the efficiency and the fairness of the means of pricing came under question.

2.3 Key Decisions by Regulators

In the overall determination of an electric rate case, a regulatory commission must make three key decisions:

(1) The overall level of revenues the utility should be allowed to collect;

(2) How the overall level of revenues should be apportioned to each class of customers; i.e., how much to collect from each class; and

(3) The structure or design of rates within a class that will yield the revenues determined appropriate for that class.

In the period prior to the 1970s, regulatory bodies dealt almost exclusively with decision number (1) above--the determination and setting of an overall level of revenues. By default, this left the allocation of revenue requirements among classes and the design of rates largely to the utilities. The public had little interest because of the steadily declining cost in the unit price of electric power. All of this changed with the frequent rate increase requests. Decisions (2) and (3), regarding who pays and how, began to become major concerns of consumers and regulators [20].

2.4 Optimum Production Plant Design

In examining rate design questions, it is important to understand the economics involved in selecting the optimum types, or mix, of generating plant facilities to be used in transforming an energy source such as coal, uranium, oil, etc., into electricity, and in turn, how this selection can affect the cost responsibility of customers or customer classes. The nonfeasibility of storing electric power makes it necessary for output to follow the time-varying fluctuations of demand season by season, day by day, and hour by hour. This means that utilities must build enough capacity to meet the highest demand they face and must cycle plants on and off in order to follow the time pattern of demand. The time of system peaks tends to occur the smallest fraction of the time while a base level demand must be provided almost continuously. The production facilities that are the most fuel efficient in terms of fuel cost are the most capital intensive. The ones that are the least capital intensive tend to have the highest fuel costs. Therefore, electric utility systems should use a mix of production technologies with various fuel efficiencies and capital costs to minimize costs [8].

The optimum mix of generating facilities would, of course, depend on the daily, weekly, and yearly total system loads for any particular utility. Total load is defined as the sum of all the customers' demands. The load tends to be lowest at night, when most people are asleep, and highest during the day, when most appliances are in use and more factories are in production. In warmer parts of the United States, where widespread air conditioning exists, the peak load usually occurs in late afternoons on hot summer days. In cooler climates, the yearly peak tends to occur on cold winter days [13]. Some systems in more moderate climates experience relatively balanced summer and winter peaks.

A large utility might have a hundred separate generating units in service at the time of system peak. To better understand how a system might be dispatched from a cost standpoint, consider the following example utility system as shown in Table 2.1.

The units are listed in Table 2.1 in ascending order of costs to operate. Units 1 and 2, the large nuclear and coal units, are the cheapest to run and are operated around the clock on a baseload basis. Units 6, 7, and 8 are peaking units and are only operated during the peak hours of the day, which in this case is the afternoon as shown in Figure 2.2. Units 3, 4, and 5 are considered intermediate units. Their fixed costs and variable costs are more in balance. They are generally started up in the morning and shut down in the evening. Figure 2.2, which is not to scale, illustrates an economic dispatch of the units throughout the day.

2.5 Impact of Load Factor

It is important to understand the concept of load factor in costing. If it is assumed for further illustrative purposes that the total load is made up of just two customer classes, residential (A) and industrial (B), it is informative to study the implications of each class's load factor. For XYZ Utility, the system peak week is shown in Figure 2.3 and is exemplary in terms of relative load factors of most utility systems.

Table 2.1 XYZ Utility

Unit	Capacity (MW)	Fuel	Oper. Cost (¢kWh)
1	1000	Nuclear	0.9
2	800	Coal	1.6
3	300	Coal	2.4
4	200	Res. Oil	5.5
5	150	Res. Oil	6.0
6	50	#2 Oil	10.0
7	50	#2 Oil	10.0
8	50	#2 Oil	10.0

SOURCE: Electricity, 1982, EPRI, Palo Alto, California.

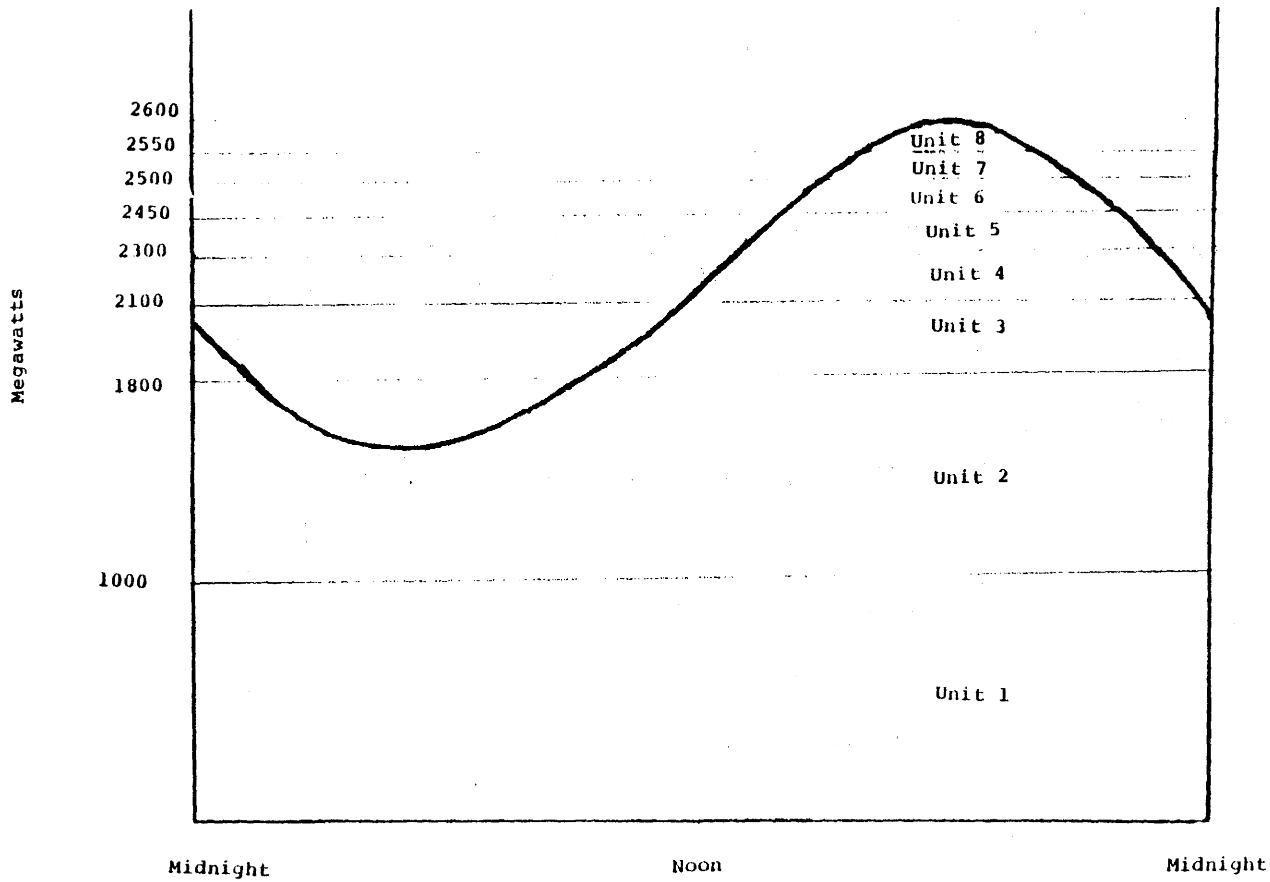

Figure 2.2 Generator dispatch procedure

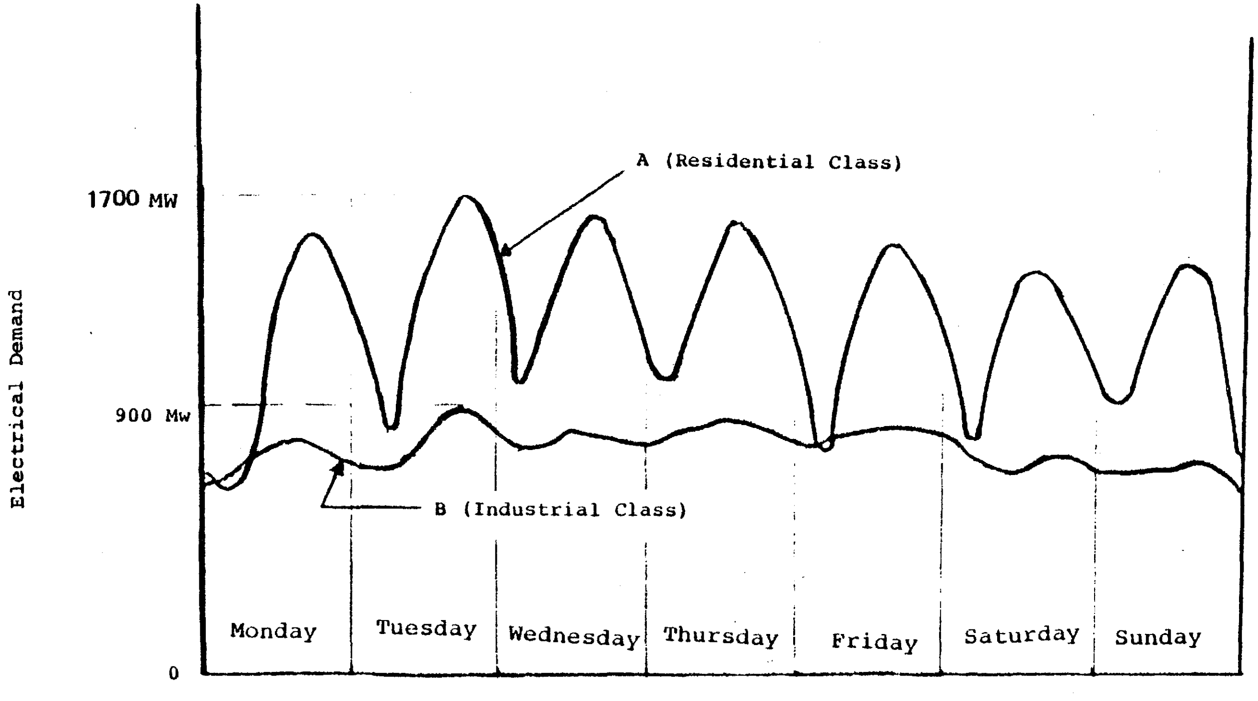

Figure 2.3 Low and high load factors

SOURCE: Electricity. EPRI, Palo Alto, CA, 1982.

On Tuesday, the system peaks with the residential class having a maximum demand of 1700 megawatts and the industrial class, 900 megawatts. The residential class curve (A) illustrates a class with a low load factor (load factor is average load divided by peak load), fluctuating throughout the week with sharp afternoon peaks. The industrial class load curve (B) shows a much higher load factor. This situation normally results because of the industrial class's greater utilization of power on an around-the-clock basis. In this example, serving the residential customer class with its low load factor requires the installation of almost twice as much generating capacity as the industrial class, but the residential class does not purchase twice as much electricity. This higher ratio of fixed costs to sales makes it very obvious that the per unit costs of serving the lower load factor class (in this case, the residential class) is greater [13].

2.6 Translating Cost to Rates

In the early years of electric generation and distribution, rates were initially set on a flat charge basis and calculated on the number of electric lights connected or number of rooms in the house or building. This simple concept soon became obsolete as wider usages of electricity developed and low-cost metering devices became available. It should be noted that even some of these simple flat rates recognized time of use in that they did not count bedrooms in computing the room total [30]. With meters, more cost discriminating rate schedules could be formulated. These rate schedules attempted to recognize the cost characteristics of electrical usage, which classically are customer costs, "demand" costs, and energy costs. Customer costs are those costs that can specifically be identified to vary with the number of customers on a system. Demand costs are those costs that can be identified with meeting the maximum rate of electrical usage, and since plant must be built to meet the maximum demand at any time during the year, demand costs are comprised of the annual fixed costs of the plant facilities that are required to meet that rate of usage. Energy costs are those costs which can specifically be identified to vary with number of kilowatt-hours (kWhs) produced.

The above breakdown of cost characteristics of service is necessary in attempting to determine cost responsibility by customer or customer class. To charge solely on some average per unit basis (such as kWh) would be discriminatory against high load factor customers as shown earlier because the unit costs to serve them are lower. Also, it might not be economically possible to maintain a system of substantial price discrimination to such customers; at least it would not have been in the past. Because of their size, large industrial customers have always had the option of installing their own generating units and have exercised this option when it appeared that they could generate power more cheaply for themselves. The threat of such actions has tended to hold rates to industrial classes closer to costs. However, as time has passed, the economies of scale associated with the installation of larger and larger centralized generating units have gradually precluded the economic installation of generating units for exclusive use at most industrial sites, hence lessening the possibility of industrial customers opting off the system. Nevertheless, for the most part there appears to be a general belief by most rate designers that a customer class whose usage permits more efficient utilization of the system's facilities should share in the related savings through recognition in its rates.

2.7 The Problem of Joint Costs

It should now be clear that the first major complication in basing rates on costs is caused by the nonstorageable nature of electric power. The consequence of not being able to store electric power is that the cost of power varies over time due to the changing electrical demands of the customers and the different facilities that are called on to meet those demands at any time. In the traditional costing approach, the second major complication involves the problem of joint costs. There is fairly good agreement on how to assign cost responsibility for the energy cost component and some general agreement in assigning cost responsibility for the customer cost component which is relatively much less significant. However, personnel from utility firms, consulting organizations, and regulatory bodies have consistently failed to agree on a costing methodology for allocating peak demand-related costs.

2.8 Accounting versus Marginal Costing Methodologies

There are two major costing approaches for determining cost responsibilities imposed by customers on the system for use in the design of electric utility rates. One approach is the traditional methodology which has been discussed briefly. This methodology looks at historically incurred costs. It is also referred to as the embedded cost approach, or as an accounting or average cost-based (AC) methodology. The distinguishing feature of this methodology is that it attempts to apportion cost responsibility for previously incurred nondepreciated book costs of plant (plus annual operating expenses) to customers or customer classes. In contrast, the marginal costing (MC) approach attempts to determine what it would cost to provide additional units of power. It looks at current or future costs. All historically incurred costs are considered to be "sunk" costs and, consequently, irrelevant. Decisions made which resulted in the incurrence of those costs are no longer subject to being changed and therefore are alleged to be of no significance in setting rates that would provide accurate price signals to consumers.

2.9 Problems with Either Method

In application to the electric utility industry, both of these general costing approaches suffer deficiencies. One problem with traditional costing has already been mentioned--the judgments involved in allocating costs of jointly used plant. The judgments in this process are of substantial importance given that the electric utility industry is the most capital-intensive industry in the United States economy and that a major portion of a utility's system investment is in jointly used generating plant [32]. Consequently, customer class rate levels can be significantly affected by choice of allocation method. For this reason, rate analysts and regulators have historically focused attention on finding an appropriate method(s) to use to allocate the cost responsibility of production plant. There have been at least 29 different accounting cost methods suggested for allocating production-related plant facilities, with some dating back to the early

1900s [12]. This may somewhat exaggerate the problem in that there appears to be three or four basic methods with the rest being variations of them, but as long as there is more than one method, or no agreement on which method is correct under a particular set of circumstances, the problem remains.

It should be noted, however, that neither can proponents of marginal costing agree on one universally acceptable method to be used in computing additional or incremental costs of service. Furthermore, marginalists must struggle with the problem of not having total marginal costs equate to the overall costs which the utility may recover under regulation. By law throughout the nation, rates set by regulatory agencies are established to produce a total revenue requirement which is based on providing a utility an opportunity to earn a fair return on its embedded not-yet-depreciated investment in plant plus an allowance for reasonable operating expenses. Consequently, the estimated revenues to be produced by marginal cost-based rates are unlikely to equate to the total system revenue requirements as found to be fair and reasonable by the regulatory agency under which the utility operates. Many traditionalists maintain that this problem of having to scale marginal costs up or down to eliminate the revenue discrepancy renders the use of marginal costing for electric utility ratemaking theoretically unsupportable.[8] The use of any accounting cost methodology in apportioning costs to customer classes should, by definition, add up to the total revenue requirements because these procedures all begin with this total figure.

8 To counter this criticism, marginalists have suggested reconciliation procedures which would minimize the effects of deviations from marginal costs.

2.10 Importance of Pricing Objectives

Given the disagreements over how to determine cost responsibility, it is not surprising that since the early days of electric distribution, pricing on the basis of cost responsibility was not the only ratemaking objective considered in the design of rates. Even if costs could have been accurately determined, other ratemaking objectives would have required recognition. In fact, some observers have suggested that the "great rate debate" which flared in the 1970s between the proponents of marginal cost pricing and advocates of embedded costs or traditional ratemaking was really an argument over ratemaking objectives.

> The debate generated substantially more heat than light, and produced more emotion than credible analysis. Advocates of embedded costs were known to remark that the only good marginalist was a dead marginalist. Devoted marginalists, attempting to convert their embedded cost adversaries, assumed all but true believers in marginalism were heathens.
>
> As the dust settles, it is easier to view the rate debate as a tradeoff among often conflicting ratemaking objectives. Rates are designed to meet numerous objectives; efficiency, equity, continuity, revenue stability, etc. The marginalists sought an increase in efficiency, by designing rates which closely track the structure of incremental cost. The traditionalists saw this as a violation of the equity and continuity rate objectives. [3]

The final RDS report on "Costing for Ratemaking" [25] concluded that all costing methodologies are based on underlying assumptions which attempt to reflect real-world costs and that there is no single "right" costing method. It does go on to add that this does not mean one cannot derive costs and apply them to ratemaking questions. Instead, it states that one should clearly enumerate and rank his ratemaking objectives from which he then "can derive costing methods (or mixes of costing methods) which best meet those objectives" [25].

This subjectivity of costing should properly raise a cloud of doubt over all cost studies submitted either by utilities or intervenors in formal rate cases because of the potential bias which may be incorporated into the studies. For example, can their pricing objectives be ascertained? What pricing objectives does a particular cost study enhance or deter?

The number, the lack of a unit of common measure, and the complexity and inexactness of their meanings make it extremely difficult to consider and make tradeoffs among the ratemaking objectives. The RDS tried to address these questions: Why have utility pricing objectives and what are the appropriate pricing objectives? It did not provide any assistance on how pricing objectives should be ranked or weighted.

In 1961 Bonbright listed eight ratemaking objectives which have largely become accepted by regulators and utility managers. They are as follows:

> 1. The related, practical attributes of simplicity, understandability, public acceptability, and feasibility of application.
> 2. Freedom from controversies as to proper interpretation.
> 3. Effectiveness in yielding total revenue requirements under the fair-return standard.
> 4. Revenue stability from year to year.
> 5. Stability of the rates themselves, with a minimum of unexpected changes seriously adverse to existing customers.
> 6. Fairness of the specific rates in the apportionment of total costs of service among the different customers.
> 7. Avoidance of undue discrimination in rate relationships.
> 8. Efficiency of the rate classes and rate blocks in discouraging wasteful use of service while promoting all justified types and amounts of use:
> a. In the control of the total amounts of service supplied by the company and
> b. In the control of the relative uses of alternative types of service. [25]

Bonbright stated that three pricing objectives are primary: (1) the revenue requirement or fair-return standard, (2) the fairness of rates in apportioning cost responsibility, and (3) the optimal-use objective which says that wasteful use of service should be discouraged while all "beneficial" uses should be promoted.

In 1978 Congress reacted to rising electric utility rates by passing the Public Utility Regulatory Policies Act (PURPA). PURPA set forth three purposes, or ratemaking objectives, for the pricing of electricity: (1) conservation, (2) efficiency, and (3) equity [25]. These do not include all relevant objectives such as revenue adequacy, but they obviously reflect the concern regarding higher rates and the belief that adherence to these pricing objectives or purposes would help hold rates down. There are very close parallels between the objectives of Bonbright and PURPA's stated purposes. In fact, each of the PURPA purposes appears to be included within the list of ratemaking objectives set forth by Bonbright. There have been additional pricing objectives offered by others. Some of these are (1) cost minimization, engineering efficiency, (3) income redistribution, and (4) below-cost rates for essential needs (life-line rates) [25]. Chapter 4 reviews the various pricing objectives in detail.

2.11 Efficiency as a Ratemaking Objective

The efficiency objective requires further discussion now. As stated in the introduction, attempting to find a means to achieve the efficiency objective through a traditional costing approach constitutes a major aspect of this research. This objective or some form of it has received the most concentration in recent years. As indicated earlier, it could be strongly argued that it was the search for efficiency that prompted the seven-year nationwide rate design study described earlier. There is, however, disagreement over the definition of efficiency. In this paper it will be defined as economic efficiency. Under this definition, efficiency means setting rates that would tend to promote the optimum use of all society's resources. It means providing only those additional increments of power that are priced at a value that is equivalent to the cost of providing them.

By definition, the achievement of economic efficiency in ratemaking requires that a marginal costing methodology be selected. The neoclassical theory of economics is grounded in the theory that pricing on the basis of marginal costs equates to the most efficient allocation of resources. Simply stated, consumers will demand electricity until the price exceeds the marginal value to the consumer of the last unit consumed. If the price for electricity is set below marginal cost, then consumers will demand it beyond the point at which the cost of producing electricity exceeds its marginal value. If the price is set above marginal cost, then less will be demanded and more of other goods will have been consumed than is economically efficient. Conceptually, basing electricity prices upon marginal costs should improve the allocation of the total bundle of resources available to society.

In discussing efficiency as a ratemaking objective, the different perceptions of its meaning make it difficult to ascertain the priority a decision maker would assign to it. Efficiency can mean efficiency in the allocation of resources as defined in the context of marginal cost theory. It can also mean the efficiency of the utility or "utility efficiency." Proponents of this definition of efficiency hold that the appropriate efficiency objective for electricity pricing is the optimal use of the electric utility's facilities and resources. A similar definition of efficiency is the concept of "engineering efficiency" adopted by the Ontario Energy Board in the Ontario Hydro case. The Board described engineering efficiency as the efficient allocation and use of resources in producing and distributing electrical energy. The term also was defined to incorporate operational or technical efficiency of the utility [25].

The latter definitions of efficiency are somewhat vague. One means cited for the achievement of utility efficiency or engineering efficiency is the minimization of a utility's average total cost per kilowatt-hour. However, it is not clear how this minimization might be achieved. To use an extreme example, a decision could be made to arbitrarily limit customer demand to eliminate the need for additional capacity additions. This would likely hold down average KWH costs, but at what total costs to society?

3. APPLICATION OF DECISION ANALYSIS

3.1 Introduction to Chapter

Given a simple decision problem, it is easy enough to consider in an informal analysis all the various factors that may impact the problem [21,22]. The complexity of the allocation of costs and design of electric utility rates, however, is such that an informal analysis is very difficult to do well.

This chapter addresses the matter of applying decision analysis theory to electric utility ratemaking. It begins with a discussion of man as an information processor or decision maker. A discussion of the general decision analysis process follows. Lastly, a relatively new decision analysis technique, the Analytic Hierarchy Process, is reviewed for use in conjunction with determining weights to be assigned to multiple and often conflicting electric utility ratemaking objectives.

3.2 The Limitations of Man as an Information Processor

This section discusses the importance of a formal decision analysis process when dealing with complex matters. The mind's deficiencies in receiving, processing, and integrating complex information and data are described.

Man's capacity to accept input (information) and produce outputs (responses) is limited. Human memory is usually thought of as consisting of two parts: (1) a long-term memory, which houses all our factual knowledge, and (2) a short-term, or working, memory, which holds the information currently being processed. It is generally assumed that our working memory is very limited and can hold only a small subset of the information in our long-term memory. When information or data is no longer being used, it is dropped from working memory [1].

In this discussion, reference will be to short-term memory since that is where decision making takes place. George A. Miller has found through empirical research that humans are normally limited in the number of symbols that they can carry in their short-term memory. The number varies between five and nine with the mean being seven [26]. Besides its limited capacity, any overload of the human processing system normally results in a decrease in response rate. References to, and summaries of, experiments which demonstrate this effect are described in Davis [6]. One such experiment shows that man's ability to respond to musical tones reaches a certain level and then declines sharply as an overload point is reached.

The world provides more input than man can process. To cope, man must filter much of this input. Normally, information is filtered on the basis of the probability of its being important or unimportant. Input or information is filtered by an individual in the following ways: (1) by his referring to his previously established frame of reference, (2) by his following his normal decision procedure, or (3) by making arbitrary choices because of stress of time, etc. In regard to the first, individuals construct means of determining the importance of input on the basis of their experience, background, custom, etc. On the second, decision procedures can serve as filters by identifying relevant data and screening out factors not important to the decision. Making decisions under stress, however, can change the whole filtering mechanism. During such periods, filtering will increase, and only the stimuli perceived to be the most important will be considered [6].

Davis maintains that the frame of reference concept also applies to man's mental processing procedure. He points out that it would be difficult and tedious for a person to establish a new processing routine for each new stimulus received. Instead, and he alleges that this occurs over an extended period of time, the brain establishes a means whereby it can identify and categorize data which correspond with the human understanding of the surrounding environment. Then when input is received, it is theorized that these frames of reference are called into play and, as a result, reduce processing time. The drawback is that this process may work to block data that appear inconsistent with an established frame of reference. This, along with man's inherent limitation on his ability to effectively receive and utilize input data, leads to information perception errors. Man also has deficiencies in integrating information. "Humans are not usually consistent in patterns of choice when faced with different types of information and values" [6].

Decision analysis, and specifically the Analytic Hierarchy Process, which is described subsequently, appears to offer a means to overcome some of the limitations humans have with processing the data and information associated with complex problems.

3.3 Development of Decision Analysis

As stated in Chapter 1, decision analysis is a term used to describe a formal and systematic approach to problem solving. Decision analysis developed in the last 25 years and is a discipline for use in the analysis of important and complex decisions. It resulted from the combining of the fields of systems analysis and statistical decision theory. Systems analysis grew as an offshoot of the engineering field and received attention because of its ability to capture the interactions and behavior of complex situations. Statistical decision theory, on the other hand, was concerned with logical decisions in more straightforward but uncertain situations [7].

The merger of these two concepts resulted in a discipline that can facilitate logical decision making in complex, dynamic, and uncertain situations. It should also be pointed out that decision analysis is a normative approach to decision making and not a descriptive one. Decision analysis incorporates procedures that are designed to help a person make decisions which would maximize attainment of his objectives [7].

There is no guarantee, of course, that a good decision (as defined as being logically approached and made) will produce a good outcome (as judged by the decision maker) or that a bad decision will produce a bad outcome. Most people, however, would prefer to make decisions based on some logic because it is believed that doing such would provide the best chance of producing good outcomes. This is an important point to remember in decision making regarding electric utility rates. Because of the large existing stocks of electrical appliances and equipment presently owned by consumers, responses to many rate changes may occur gradually, and consequently, it may be difficult to fully assess the effects of a certain set of rates within a short time frame. Also, no one has yet formulated a set of criteria for evaluating whether particular ratemaking objectives have been satisfied fully or, if not, to what degree. One must usually rely on the reasonable assumption that logical decision making has a higher probability of attaining one's ratemaking objectives than would otherwise be the case.

Following a formal decision analysis approach should also improve communications among all parties to the decision. By explicitly setting forth the values of probabilities one would place on given actions, it is very possible that some of the disagreement between decision makers might disappear. In any case, the arguments should become better focused.

In summary, decision analysis provides a structure in which complex problems can be broken into parts, analyzed, and put back together in a formal and logical fashion which facilitates their solution. Further, decision analysis helps to alleviate man's limited short-term memory and his corresponding limitation on analysis, integration, and resolution of complex problems involving significant input or information. Also, certain decision solutions may be counterintuitive. Formal structuring of such problems should produce fewer erroneous conclusions.

3.4 Description of General Decision Analysis Procedure

The general decision analysis methodology can be illustrated graphically in Figure 3.1 below.

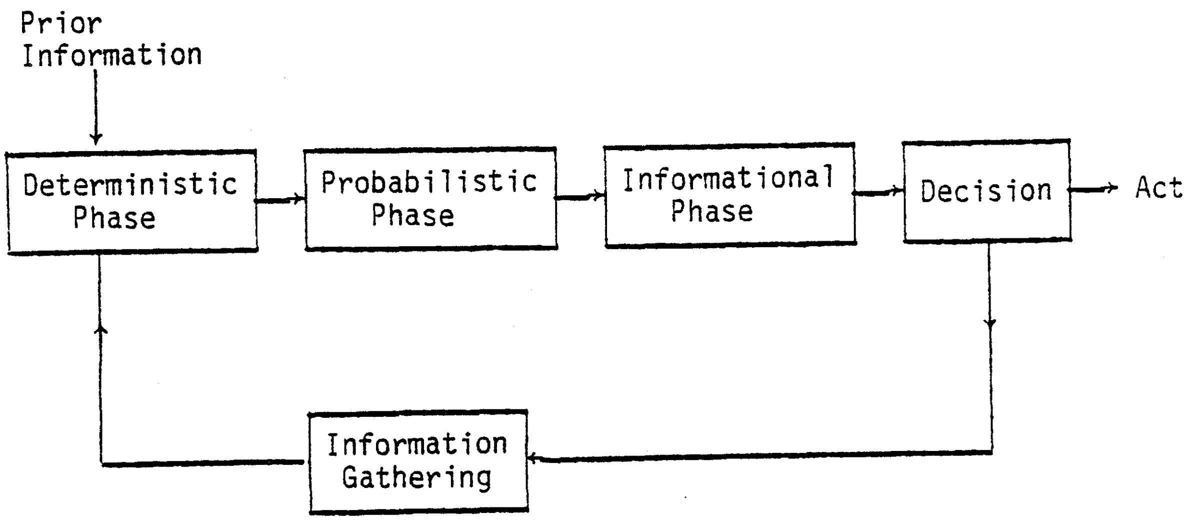

Figure 3.1 Decision analysis cycle

SOURCE: Stanford Research Institute, Decision Analysis Group Readings in Decision Analysis, 1977, Menlo Park, CA.

Not all complex decision problems, of course, would require a decision maker to proceed through each of the three phases: (1) deterministic, (2) probabilistic, and (3) informational. The first phase, deterministic, comprises a system for defining and valuing variables which would affect the decision. No consideration of uncertainty is included in this phase.

The second phase, probabilistic, brings any uncertainty associated with the variables into the analysis by assigning probability values to them. This phase also incorporates the assignment of risk preferences of the decision maker.

The third phase, informational, evaluates the results of the first two phases to determine the economic value of reducing uncertainty in the variables. Comparison of the cost of acquiring additional information with the value to be obtained from it determines whether an iteration of the procedure (as shown in the above diagram) should be made [7].

The deterministic phase of the decision analysis procedure deals with modeling of the problem and its analysis. It generally comprises the following: (1) the identification of alternatives, (2) the establishment of possible outcomes, (3) the selection of system variables, (4) the creation of a structural model, (5) the creation of a value model, and/or (6) the creation of a time preference model. One or more runs on the model(s) can be made to determine sensitivity to decision and to state variables [7]. In this research, the Analytic Hierarchy Process was used in the deterministic context to facilitate the explicit determination of decision makers' preference weightings for multiple and conflicting electric utility ratemaking objectives.

3.5 Analytic Hierarchy Process

There have been a variety of decision analysis methods developed which are designed to assist a decision maker in logically choosing among multiple alternatives or objectives. In this research, the Analytic Hierarchy Process was employed. The AHP was initially developed by Saaty in 1972 and 1973 and has been used in a number of decision problems [31].

The AHP was chosen for this research for several reasons, including ease of use in obtaining preferences from a large group of decision makers across the country. More importantly, it appears to have a definable mathematical foundation, and its hierarchical framework appears to follow structurally the way the mind works in considering a multitude of elements which comprises a complex situation. Like various other decision analysis methods, it is applicable in areas where attributes with nonstandard measurements must be compared with each other or with attributes defined in monetary or other standard values. An example of such an attribute, having no standard measurement, would be the ratemaking objective, fairness.

The general approach of the AHP is to decompose the problem by hierarchical levels (determined by the relationships of the elements within the problem). The shape of the structure tends to be pyramidal, but this hierarchy is not an exclusively disjunctive tree structure. Higher placed nodes (goals) are allowed to dominate a multiplicity of lower placed nodes in the structure. Pairwise comparisons of elements on the same level are made with respect to the elements or nodes in the level directly above them. The degree of preference or intensity of the decision maker in the choice for each pairwise comparison is measured, and these measurements are placed in a matrix of comparisons. The measurements are made on the following preference scale: if "A and B are equally important," assign the number 1 (A is the row value in the matrix and B the column for this particular comparison); if "A is weakly more important than B," assign the number 3 to "A" with respect to "B"; if "A is strongly more important than B," assign the number 5; if "A is demonstrably or very strongly more important than B," assign the number 7; if "A is absolutely more important than B," assign the number 9. The even numbers (2, 4, 6, and 8) are used to represent compromises between preferences. The matrix of comparisons is next constructed with preference weightings measured as above. For inverse comparisons, such as "B to A," the inverse of the ranking for "A to B" is used [31].

To illustrate the AHP briefly herein, Saaty presents a problem in estimating the brightness at four chairs from differing distances from a single light source [31]. The matrix of comparison of judgments with respect to brightness at the four chairs, A, B, C and D was found to be the following (Figure 3.2).

Brightness	A	B	C	D
A	1	5	6	7
B	1/5	1	4	6
C	1/6	1/4	1	4
D	1/7	1/6	1/4	1

Figure 3.2 Comparisons of brightness

By normalizing the principal eigenvector of the above matrix, Saaty arrives at a vector of priorities (0.61, 0.24, 0.10, 0.05) where each value of this vector represents the priority for that row [31].

At this point, Saaty would run a consistency check on the weights given to the preferences. Saaty's definition of consistency is mathematically measured by the approach of the maximum eigenvalue (λ_{max}) of a matrix to the size of the matrix, n. The formula is $(\lambda_{max} - n)/(n-1)$, and it produces a consistency index (C.I.). By computing a random index (R.I.) of a "randomly-generated reciprocal matrix from the scale 1 to 9, with reciprocals forced" and dividing this number into the C.I., the consistency ratio (C.R.) or the degree to which consistency deviates is determined. A consistency ratio of 0.10 or less is considered good [31].

It should be pointed out that this notion of consistency and "allowed" deviation is contrary to the traditional requirement of transitivity of preference. Saaty, however, maintains that absolute or perfect consistency is not required and that the degree of consistency is what is important in most cases. His reasoning is as follows:

> We note that consistency in any kind of measurement cannot be taken for granted. All measurement, including that which makes use of instruments, is subject to experimental error and to error in the measuring instrument. A serious effect of error is that it can and often does lead to inconsistent conclusions. A simple example of the consequence of error in weighing objects is to find the A is heavier than B, and B is heavier than C but C is heavier than A. This can happen particularly when the weights of A, B, and C are close, and the instrument is not fine enough to distinguish between them. Lack of consistency may be serious for some problems but not for others. For example, if the objects are two chemicals to be mixed together in exact proportion to make a drug,

inconsistency may mean that proportionately more of one chemical is used than the other, possibly leading to harmful results in using the drug.

But perfect consistency in measurement, even with the finest instruments, is difficult to attain in practice; what we need is a way of evaluating how bad it is for a particular problem.

By consistency we mean here not merely the traditional requirement of the transitivity of preferences (if apples are preferred to oranges and oranges are preferred to bananas, then apples must be preferred to bananas), but the actual intensity with which the preference is expressed transits through the sequence of objects in the comparison. For example, if apples are twice as preferable as oranges and oranges are three times as preferable as bananas, then apples must be six times as preferable as bananas. This is what we call cardinal consistency in the strength of preference. Inconsistency is a violation of proportionality which may or may not entail violation of transitivity. Our study of consistency demonstrates that it is not whether we are inconsistent on particular comparisons that matters, but how strongly consistency is violated in the numerical sense for the overall problem under study. [31]

3.6 Utility Ratemaking Objectives

The problem of determining the preferences or weights decision makers would assign to electric utility ratemaking goals or objectives required many pairwise comparisons and, hence, under the AHP, involved several matrices. For that reason and for accuracy, a large mainframe computer was used to make all the calculations required in this part of the research. It is recognized, however, that it is sometimes easier to understand the mechanics of a procedure if a simple application requiring no complex computer calculations is first demonstrated. Appendix A outlines the use of the AHP in a decision regarding the purchase of a new car. For readers not having prior contact with the use of the AHP, perusal of this example is recommended.

4. USE OF THE AHP IN ELECTRIC UTILITY RATEMAKING

4.1 Introduction

The Analytic Hierarchy Process has been reviewed briefly in the previous section. This section proceeds to the development of a decision hierarchy and questionnaire, in the AHP format, for ascertaining decision makers' weighted preferences or rankings of electric utility ratemaking objectives.

As stated earlier, there are multiple electric utility ratemaking objectives which are often conflicting. Nevertheless, choices must be made. Presently, decisions which place more weight on one ratemaking objective versus another appear to be made on an implicit rather than an explicit basis by many decision makers. The use of decision analysis, and specifically AHP, should ensure more nearly complete consideration of all factors and alternatives and, furthermore, permit more open discussion of the tradeoffs which must be made among objectives. To decide among ratemaking objectives or how much one should sacrifice one goal to achieve another, regulators and rate managers should have a concept of a utility's present and likely future operating situation.

The pricing policies that develop from consideration of the ratemaking objectives will influence three groups: (1) customers making decisions on what electrical appliances and equipment to buy and when to use them, (2) utility planners making investment decisions among supply alternatives, and (3) investors making decisions on whether to buy the utility's stocks and bonds [25].

In the abstract, a utility rate analyst or regulator is likely to have a given set of ratemaking objectives with certain preferences. As indicated previously, however, the individual circumstances of a particular utility should be taken into account in determining the weightings given to the various objectives or subobjectives by a decision maker. For example, the capacity reserve level of a system could make a difference. If a utility has existing or projected excess generating capacity, it may place less emphasis on the conservation objective than a utility might with thin capacity reserves. Also, the capacity mix of the system could influence ratemaking preferences. For example, assume a system has a large proportion of oil-fired generation (high operating costs). It may concentrate more of its conservation efforts on an attempt to decrease overall usage as opposed to reducing peak demand through shifting load to off-peak hours. Also, a utility's demand curve (as opposed to supply side considerations) may influence the weights given various objectives. Electric utilities' operating characteristics tend to vary across regions of the United States. To test for regional patterns, the questionnaire responses on ratemaking objectives were aggregated on a regional as well as a national basis.

4.2 The Questionnaire

In preparation of the questionnaire, a hierarchy of electric utility ratemaking objectives was determined after extensive literature review and discussions with colleagues. It was determined that the various ratemaking objectives as enumerated by Bonbright, PURPA, and others could be combined and formulated into five major categories with several having important subelements. Efficiency (per se) was not selected as a ratemaking objective to be included in the questionnaire for two reasons. First, there are disagreements on the definition of efficiency and which costing methodology should be followed in pursuing this objective. Second, the meaning of efficiency can be interpreted to include several of the other objectives.[9] The five major ratemaking objectives and a brief definition of each follows:

(1) revenue requirements--the effectiveness of rate design in ensuring recovery of all reasonably incurred costs;

(2) simplicity--ability of rate design to be understandable to consumers;

(3) stability--effectiveness of rate design in minimizing large adverse price changes to customers;

---

9 Of the five objectives set out below, it can be argued that the objective of economic efficiency includes "revenue requirements," "rate stability," and "conservation." As indicated earlier, many would also argue that it includes "fairness."

(4) conservation--ability of rate design to effect conservation of resources utilized in production of electric power; and

(5) fairness--effectiveness of rate design in providing rates which are considered "fair" between and among customers and customer classes.

Several of these objectives have subgoals or subobjectives because their meanings tend to be very broad. In regard to revenue requirements, for example, it is important to determine the relative weights decision makers place on any related subobjectives that could affect revenues. Revenue recovery (adequacy), revenue stability (avoidance of large swings in revenue levels to the utility), and reduction in sales (energy conservation) are possible subobjectives that could impact the revenue requirements goal.

Similarly in regard to conservation, is it more important (and to what degree) to reduce the need for generation plant capacity addition requirements or reduce energy use? Also, the ratemaking objective, fairness, is extremely difficult to define. By asking decision makers to indicate their preferences through pairwise comparisons of a number of factors thought to be related to decision makers' perceptions of fairness, it should be possible to better determine their definition of fairness and also to find out the weights they place on individual elements of ratemaking. With respect to achieving the goal of fairness, the following factors were chosen for determination of their relative weights: (1) rates which reflect "reasonable" residential rates; (2) rates which reflect "attractive" industrial rates; (3) rates that track costs of service; and (4) rates that reflect comparability to prices of other energy forms. The terms "attractive" and "reasonable" as used to describe rates for industrial and residential customers, respectively, were applied with the intention of measuring how much preference, if any, might be given to these customers by regulators and rate managers.

The questionnaire, requesting decision makers to make pairwise comparisons between the ratemaking objectives and subobjectives, respectively, also asked that any disagreement in the choice of objectives be noted. Few expressed any dissatisfaction with the list of objectives or with the hierarchy of objectives as set forth. Some did question the meanings of certain objectives and a few further defined or redefined some of the objectives prior to responding. A very small number of the responders failed to indicate their preferences involving comparisons between other objectives and the objective, "comparability of electric rates to other energy prices," citing lack of relevance. The questionnaire and comments from three anonymous responding decision makers are attached in Appendix B.

4.3 The Hierarchical Framework

The ratemaking objective on which the questionnaire was based can be shown in the hierarchical framework shown in Figure 4.1.

From observation of the hierarchy, it can be seen that the second level of elements consists of the five major ratemaking objectives previously discussed. These are interpreted to mean that rates would be designed to promote each according to its importance in terms of satisfying the overall rate design objectives of the decision maker. For example, if the conservation objective were determined to have a 100% weight, then rates that promote conservation should receive complete consideration without regard to any other factor. This would not likely be the case, however. A more reasonable expectation would be that each objective would receive some weight and a prioritization of ratemaking objectives established.

On the third level of the hierarchy are the subelements or the more narrowly defined objectives which relate directly to the second level objectives. For example, as indicated earlier, the objective, fairness, can have many meanings to people. Two decision makers could assign the same weight to fairness and yet have totally different views on costing allocations to classes or how to reflect fairness in the rate structure. By obtaining the preference weights of the subelements or objectives shown on the third level, a decision maker can obtain a further refinement of his notion of fairness, and he can make better decisions in regard to his total ratemaking objectives. The subelement, energy conservation, can be seen to have a relationship to revenue

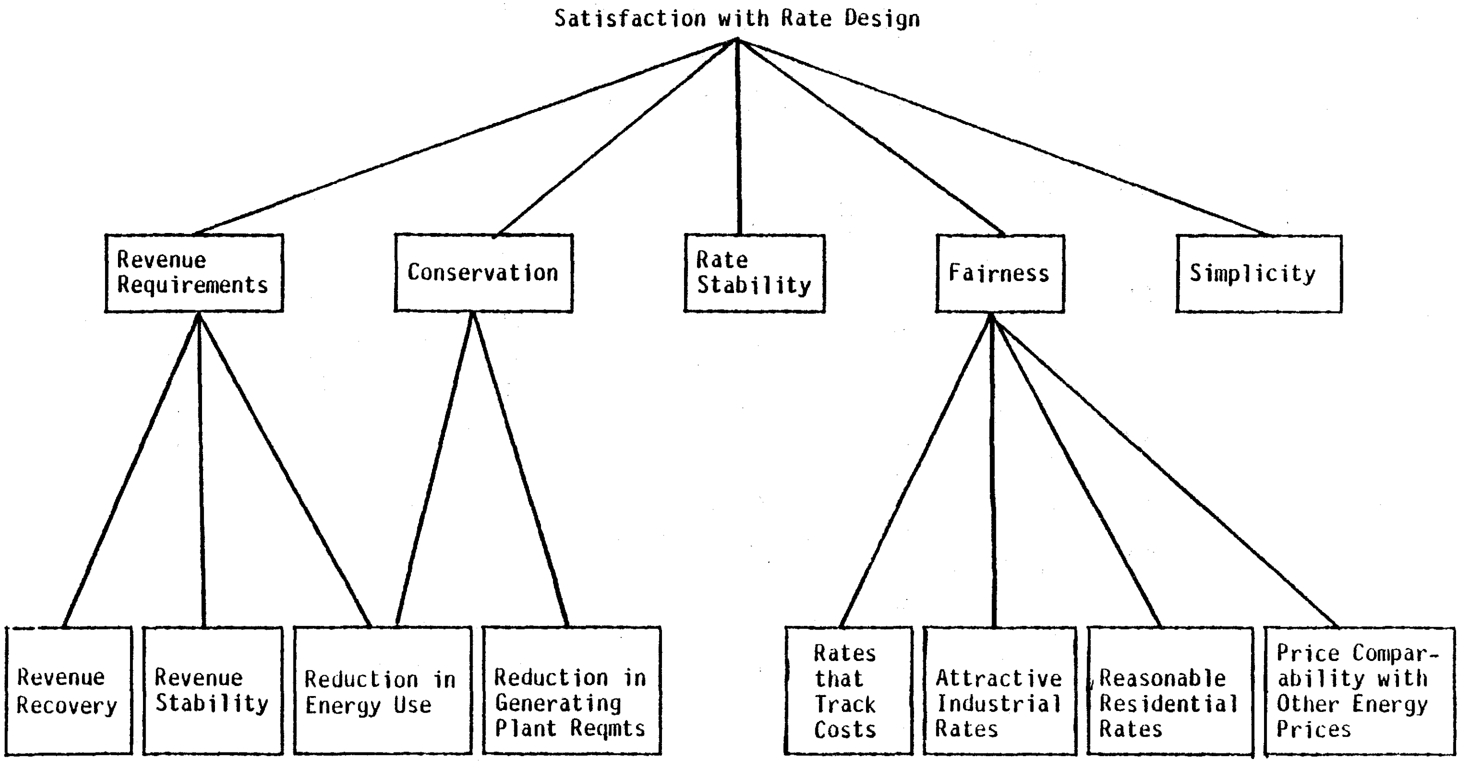

Figure 4.1 Hierarchy of ratemaking objectives

requirements as well as conservation. The reason for its tie-in with revenue requirements is that changes in energy usage can cause significant and immediate changes in revenue requirements. Therefore, it is necessary to consider that relationship in determining the overall set of weights at which a decision maker would arrive through the use of the AHP. The remaining structure should be self-explanatory given the earlier discussion of each element or objective. Neither the objectives of stability nor simplicity have any subelements, and therefore, none is shown.

4.4 Handling of the Questionnaire

The questionnaire, which follows the format suggested by Saaty [31, p. 34], and shown in Appendix B, requested decision makers to make pairwise comparisons corresponding to the hierarchical structure above. In order to obtain as rational and valid results as possible, decision makers were advised that they could send back the questionnaire on an anonymous basis. A few availed themselves of this agreed-upon condition. The questionnaires were coded only to distinguish between regulators and utility respondents. In some cases, postmarks of anonymous respondents were used to segregate them by regions.

To analyze the responses, the Triangle Universities Computation Center (TUCC) facilities were used. A standard TUCC program for calculating eigenvectors and the maximum eigenvalue for each matrix of comparisons of objectives was accessed. The maximum eigenvector for the first matrix provided the weights of the major objectives. Each of the subobjectives was then weighted by the weights of the appropriate major objective(s) to arrive at a weighting for each subobjective or subelement.

The consistency ratio for each matrix of comparisons and an overall consistency ratio for the total hierarchy were also calculated. Responses exhibiting high inconsistency ratios for the hierarchy were not used. In a further analysis of the results of the responses, the revenue requirements and the rate stability objectives in the hierarchy were omitted in order to compare more closely the responses on the remaining objectives. These two objectives impacted the results in such a substantial way that it was difficult to compare the other objectives. Lastly, the responses were complied on a regional basis and on the basis of whether the respondent was a regulator or a utility rate manager.

4.5 Response to Survey

The questionnaires were mailed to 184 state regulators in 49 states and the District of Columbia in June 1982. Members of the North Carolina Utilities Commission were not asked to respond formally; however, one member of the North Carolina Commission assisted in a pretest of the questionnaire, and that response is included. A total of 89 regulators from 46 states completed and returned the questionnaire. Four responses were thrown out because of high inconsistency. One response was returned too late to be included in the analysis. Whereas Saaty states that a target consistency ratio (C.R.) of not greater than 0.10 is desirable, the individual C.R.'s of the four rejected were 0.833, 1.060, 0.722, and 1.389. The remaining responses were judged to be acceptable even though some were somewhat high. However, because of a desire to consider the responses on a regional basis and a desire to have as many responses as possible in some of the regions, these were left in the total. The average consistency ratio of the 83 remaining responses analyzed was 0.164. This figure is higher than desired but still appears to be in a reasonable range based on other similar studies reviewed. For example, this C.R. is not out of line with the C.R.'s in several studies reported by Saaty.

The Nebraska Commission responded that it did not regulate electric utilities. This reduced the number of commissioners to 179. Consequently, 89 out of 179, or approximately 50% of the regulators in the United States (not counting the remaining North Carolina commissioners), who have jurisdiction over electric utility rates responded. The responses were treated as being statistically representative of the total population of state regulators. In other words, the responses were considered to have been returned on a random basis, and those who failed to respond did it through inadvertence. In discussing the results with Dr. Larry Nelson of the North Carolina State University Statistics Department, consideration was given to the standard practice of attempting to sample 5% of those not responding to ensure that this assumption is valid. However, because of the large response and because of the anonymity of several of the respondents, it was determined not to make such a sampling. Based on some random contacts, it is believed that the ones not responding did so out of inadvertence and that the total population can be represented, within statistical limits, by the respondents. On this basis, 95% confidence limits on the preference weights were calculated.[10]

The questionnaire was also mailed to 104 of the larger utilities in the United States. Sixty-five responses, or approximately 63% of those surveyed, responded by returning the completed questionnaire. Two responses were rejected because of their high consistency ratios, 0.731 and 0.523. Again, a few others had somewhat high C.R.'s, but they were left in the total for the reasons given earlier. The number of states served by the utilities from which the 63 remaining responses were received totaled 41. The average consistency ratio of the 63 responses was 0.149. This is slightly higher than the 0.10 strived for but is somewhat lower than that of the regulators. The responses were treated as being statistically representative of the total population of electric utility rate managers, and 95% confidence limits on the preference weights were calculated.

The next chapter summarizes the information on preference weights for ratemaking objectives on both a regional and national basis as received and calculated from the responses. First, a single response is examined in order to illustrate fully the analysis procedure followed.

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10 A normal distribution curve is assumed.

5. RESULTS OF AHP ANALYSIS

5.1 Introduction

This chapter examines the results of the national survey from three perspectives. First, a single respondent's preferences are analyzed in detail for the purpose of more fully explaining the procedure followed for all the responses. Also, some possible ratemaking steps are hypothesized to meet this respondent's determined preferences. Second, the national results are reviewed, and differences found between regulators and utility rate managers are discussed. Third, the responses are divided into the nine Electric Reliability Council Areas[11] as shown in Figure 5.1 and results compared among areas in an attempt to examine effects of different utility operating characteristics.

5.2 Analysis of Single Respondent's Ratemaking Objectives

The respondent, arbitrarily selected for analysis, is a utility rate manager for a Midwest utility providing electric power in the MAIN Electric Reliability Council area. This respondent was first asked to make pairwise comparisons between each of the major ratemaking objectives of: (1) revenue requirements, (2) conservation, (3) fairness, (4) stability (in rates), and (5) simplicity. For example, this respondent considered the fairness ratemaking objective to be strongly more important than the conservation objective and indicated that by checking the appropriate block in the questionnaire. By placing his "X" closer to side B (designating the side on which "fairness" is listed) than to side A (designating the side or which "conservation is listed), he indicated that fairness was the predominant objective of the two in his opinion.

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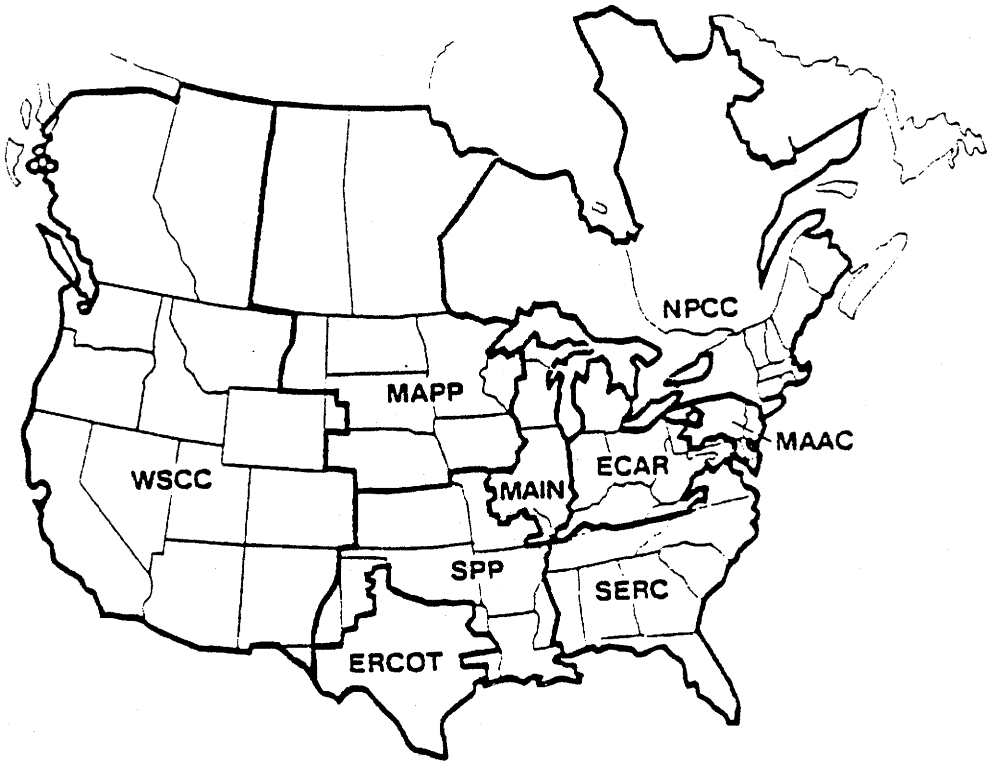
11 The North American Electric Reliability Council (NERC) was found by the electric utility industry in 1968 to promote reliability and adequacy of bulk power supply in the electric utility systems in North America. NERC is comprised of nine separate councils. While several of the regions extend into Canada, only the U.S. portions of those regions are considered in this paper [28].



ECAR
East Central Area Reliability Coordination Agreement

ERCOT
Electric Reliability Council of Texas

MAAC
Mid-Atlantic Area Council

MAIN
Mid-America Interpool Network

MAPP
Mid-continent Area Power Pool

NPCC
Northeast Power Coordinating Council

SERC
Southeastern Electric Reliability Council

SPP
Southwest Power Pool

WSCC
Western Systems Coordinating Council

Figure 5.1 National Electric Reliability Councils

SOURCE: Electric Power Supply and Demand 1983-1992. National Electric Reliability Council. Princeton, N.J., July 1983.

(The closer the "X" is placed to one of the objectives, the greater the weight it is given relative to the other). The portion of the questionnaire illustrating the procedure for indicating preference between two choices is shown below:

WITH RESPECT TO ELECTRIC UTILITY RATE DESIGN:

A	Absolute Importance	Very Strong	Strongly Important	Weakly Important	Equal Importance	Weakly Important	Strongly Important	Very Strong	Absolute Importance	B
Conservation							X			Fairness

His indicated preference between these two objectives, as well as his other preferences, was next translated into numbers using Saaty's ratio scale and put in matrix form. The results were as follows:

		B				
		Rev. Reqts.	Conser-vation	Fairness	Sta-bility	Sim-plicity
A	Rev. Reqts.	1	5	3	3	7
	Conservation	1/2	1	1/5	1/5	3
	Fairness	1/3	5	1	5	5
	Stability	1/3	5	1/5	1	5
	Simplicity	1/7	1/3	1/5	1/5	1

As a further explanation of its interpretation, the second column space of the third row contains a 5. This corresponds to the "X" under "Strongly Important" in the questionnaire form above and indicates his degree of preference for the fairness objective over the conservation objective. The other entries in the matrix were derived in the same way. The next step is the computation of a vector of priorities from the above matrix. This consists of calculating the principal eigenvector of the matrix. For illustration and comparison purposes to the calculations given by the computer, the weights of this respondent's major ratemaking objectives are approximated with a hand calculator similarly to that done for the car example in Appendix A. The first step in approximating the weights is to normalize each column in the matrix. The elements in each resulting row are then added with the sum being divided by the number of elements in the row. This results in the following normalized matrix:

$$\begin{vmatrix} 0.500 & 0.306 & 0.651 & 0.319 & 0.333 \\ 0.100 & 0.061 & 0.044 & 0.021 & 0.143 \\ 0.165 & 0.306 & 0.217 & 0.532 & 0.238 \\ 0.165 & 0.306 & 0.044 & 0.107 & 0.238 \\ 0.070 & 0.021 & 0.044 & 0.021 & 0.048 \end{vmatrix} \rightarrow \begin{matrix} 0.42 \\ 0.07 \\ 0.29 \\ 0.18 \\ 0.04 \end{matrix}$$

It is of interest to note that the above approximation results compare to those that were calculated by the computer as is shown below:

	Priority Weights	
	Approximation	Computer
Revenue Requirements	0.42	0.43
Conservation	0.07	0.06
Fairness	0.20	0.31
Stability	0.18	0.16
Simplicity	0.04	0.04

As can be seen, the approximation method produces results which are fairly close to the computer-derived results.[12] The consistency ratio for this matrix of preferences was calculated by the computer to be 0.13 or very close to the 0.10 C.R. deemed to be good by Saaty. (The C.R. could have been approximated by hand as shown in the car example, but the calculations are quite lengthy.) It can be seen that this rate manager gives highest priority (0.43) to designing rates that will enable the company to meet its revenue requirements. The lowest priority weights are assigned to designing rates to promote conservation and which are simple to understand. The second highest priority (0.31) is given to the matter of fairness of the rates to the different customers or customer classes.

12 The computer-derived results are used in the further calculations of this decision maker's priority weights.

After the weights for these five objectives have been explicitly determined, more information must be obtained before these priorities can be systematically applied to the design of rates. For example, how does one interpret fairness? Does fairness imply that cost-of-service studies should be followed exclusively? Does it mean favoring one customer class over another? Does it mean setting rates no higher than alternative competing energy sources?

Similarly in terms of the conservation objective, which kind of conservation efforts should be emphasized--ones that lead to energy conservation or reduction in peak demands? These are the types of questions that can best be answered by ascertaining the weights of certain subobjectives or subelements that relate to the major objectives. These subelements were previously discussed and identified hierarchically in Figure 4.1. Specifically, the respondent was asked to make judgments on the importance of the level three subelements relative to those objectives to which they are linked on level two.

The subelements of the fairness objective for this particular decision maker are next analyzed. The first step is similar to that followed for the major objectives; i.e., to place the preferences expressed on the questionnaire into numerical form in accordance with Saaty's ratio scale. The principal eigenvector of the matrix is then calculated. The matrix of preferences is as follows:

With Respect to Fairness	Rates that Track Costs	Reasonable Residential Rates	Attractive Industrial Rates	Price Comparability
Rates that Track Costs	1	4	4	4
Reasonable Residential Rates	1/4	1	1	3
Attractive Industrial Rates	1/4	1	1	1/3
Price Comparability	1/4	1/3	3	1

The computer arrived at the following weightings (rounded here to the nearest one-hundredth):

Rates that Track Costs	0.54
Reasonable Residential Rates	0.20
Attractive Industrial Rates	0.11
Price Comparability	0.15

The objective, revenue requirements, has three subelements--revenue adequacy, revenue stability, and energy conservation. As stated earlier, energy conservation was included as a subelement of revenue requirements as well as a subelement of conservation on the theory that energy conservation efforts could produce some short-term changes in revenues without corresponding changes in expenses. In other words, reductions in usages over the short run could cause net income to fall if costs do not fall by an equivalent amount of the revenue loss. By including reduction in energy usage as a subelement of revenue requirements, it can be determined how much concern this matter is to decision makers. For the individual response under study, the matrix of preferences of these elements is as follows:

With Respect to Revenue Requirements	Revenue Adequacy	Reduction in Energy Usage	Revenue Stability
Revenue Adequacy	1	5	3
Reduction in Energy Usage	1/5	1	1/5
Revenue Stability	1/3	5	1

The principal eigenvector of the matrix calculated by the computer gave the following results:

Revenue Adequacy	0.62
Reduction in Energy Usage	0.08
Revenue Stability	0.30

As was expected, the weight (concern in this case) assigned to an impact on revenues from any potential effort to reduce energy usage was relatively small.

In regard to the subelements of the conservation objective, which are reduction in energy usage and reduction in generating plant requirements, the decision maker under study expressed the following preferences:

With Respect to Conservation	Reduction in Generating Plant Requirements	Reduction in Energy Usage
Reduction in Generating Plant Requirements	1	7
Reduction in Energy Usage	1/7	1

This results in a relative weighting, in respect to conservation, of 0.88 for reduction in generating plant requirements and 0.12 for reduction in energy usage, indicating little interest in pursuing energy conservation.[13] The subelements of each related major objective are next multiplied by the priority weight attributed to that major objective to arrive at an appropriate weighting for each subelement. For the major objective of revenue requirements, the priority weighting was 0.43. This weighting is then multiplied by the relative weight of each subelement of revenue requirements to arrive at the following overall weights of the subelements:

	Relative Weight	X Relative Weight of Revenue Reqts.	= Composite Weight Associated with Revenue Reqts.
Revenue Adequacy	0.62	0.430	0.27
Revenue Stability	0.30	0.430	0.13
Energy Conservation	0.08	0.430	0.03

13 The consistency ratio for the total hierarchy was 0.13 which is higher than the desired 0.10 but only slightly.

This weighting is then multiplied by the relative weight of each subelement of fairness to arrive at the following weights of the subelements:

	Relative Weight	X Relative Weight of Fairness	= Composite Weight Associated with Fairness
Rates that Track Costs	0.54	0.31	0.17
Reasonable Residential Rates	0.20	0.31	0.06
Attractive Industrial Rates	0.11	0.31	0.03
Price Comparability	0.15	0.31	0.05

For the conservation objective, the priority weighting was 0.06. This weighting was then multiplied by the relative weight of each subelement of conservation to arrive at the following weights of the subelements:

	Relative Weight	X	Relative Weight of Conservation	=	Composite Weight Associated with Conservation
Reduction in Energy Usage	0.125		0.06		0.008
Reduction in Generating Plant Reqts.	0.875		0.06		0.053

However, reduction in energy usage is a subelement of revenue requirements also. Therefore, the total weight to be attributed to reduction in energy usage is 0.008 + 0.030 = 0.038 or approximately 0.04. The objectives of rate stability and simplicity have no subelements.

The priority weights of elements or objectives that this particular decision maker takes into account in his ratemaking responsibilities are now explicitly expressed as follows:

Pricing Objectives	Proportional Weights
Revenue Adequacy	0.27
Revenue Stability	0.13
Reduction in Energy Usage	0.04
Reduction in Generating Plant Reqts.	0.05
Rates that Track Costs	0.17
Reasonable Residential Rates	0.06
Attractive Industrial Rates	0.03
Price Comparability	0.05
Stability in Rates	0.16
Simplicity	0.04
	Σ = 1.00

As can be seen, revenue adequacy (.27), revenue stability (0.13), and stability in rates (0.16) are important pricing objectives to this decision maker. In fact, their combined total, for this decision maker, represents over 50% of the weights to be attributed to all of the ratemaking objectives stated. It may be helpful, because of their combined weight, to omit these objectives from consideration temporarily and examine the remaining objectives. Designing rates on the basis of costs also received substantial weight (0.17), but it is a subelement of the fairness objective, and it is left in the remaining group for comparison purposes.

The weights of the remaining objectives are shown below as their actual value and then as normalized to sum to 1.00 to reflect the omission of the three objectives.

		Normalized
Reduction in Energy Usage	0.01[14]	0.03
Reduction in General Plant Reqts.	0.05	0.12
Rates that Track Costs	0.17	0.41
Reasonable Residential Rates	0.06	0.15
Attractive Industrial Rates	0.03	0.07
Price Comparability	0.05	0.12
Simplicity	0.04	0.10
	Σ = 0.41	Σ = 1.00

If the remaining objectives are examined (under the assumption that the revenue requirements and rate stability objectives will be met), it can be seen that designing rates on the basis of costs receives the greatest weight (0.41) from this decision maker. It is generally acknowledged as stated earlier, however, that the development of costs is not an exact science and that the choice of costing method depends on one's pricing objectives. This matter is addressed in more depth in later chapters.

This decision maker (assuming other considerations are equal) might choose a costing method and/or rate design that slightly favors the residential customer class (assigned a 0.15 weight) and one which maintains some price comparability with alternative fuels (0.12 weight). In the design of the rate structure, he may give some favorable consideration to imposing higher demand charges or possibly TOU rates[15] in order to depress peak demand or its growth and, hence, delay construction of new generating plant requirements (0.12 weight). Reduction in energy usage or energy conservation is of little concern to this decision maker (0.03). His utility probably has little oil-fired or high-variable cost generation; therefore, there is no need to try to reduce energy consumption per se.

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14 It should be remembered that approximately 0.03 of the total 0.04 weight attributed to the energy conservation objective was derived from its relationship with revenue requirements. By assigning revenue requirements a zero weighting, it eliminated any weighting contribution from the revenue requirements objective as it relates to energy conservation.

15 Referred to as Time-of-Day (TOD) or Time-of-Use (TOU) rates.

When compared to the national results (which are discussed in more detail in the next section), this respondent's interest in implementing a means to reduce the need for new plant construction is observed to be less than that expressed by regulators and utility rate managers on the average. The corresponding measures of the weight of this objective as derived on a national basis were as follows (in percentages):

Respondent	12.0
Utilities (National)	19.7
Regulators (National)	23.4

For the Reliability Council Area of MAIN in which this respondent's utility serves, the average weights attributed to this objective were:

Respondent	12.0
Utilities (MAIN)	9.9

The substantially lower weight given to this objective by the decision maker and the other MAIN respondents could indicate the possibility of the utilities in the region either having or approaching an excessive reserve situation in generating plant facilities. If this is true, one would not expect as an aggressive effort to implement load management or similar plans in this region as compared to some other regions, particularly SERC.[16] A comparison of each of this decision maker's preferences with those of other utility rate managers in the nation and in MAIN provided the results shown below. Certain preference weights of the selected decision maker and the mean response of the utility rate managers in the MAIN area are highlighted by enclosed boxes. These enclosed weights indicate a difference in results, when compared to the national average of utility managers, of approximately 100%.

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16 In SERC (southeastern states), both regulators and utility rate managers put a very high priority on reduction in generating plant requirements. The comparative weights assigned this objective by SERC regulators and rate managers would be 32% and 36%, respectively.

	(Respondent) Selected Decision Maker	Utility Rate Mgrs. (U.S.)	MAIN Utilities
Revenue Adequacy	27.0%	33.4%	32.7%
Revenue Stability	13.0	11.1	11.2
Reduction in Energy Usage	4.0	5.0	0.5
Reduction in Generating Plant Reqts.	5.0	6.6	$\boxed{3.6}$
Rates that Track Costs	$\boxed{17.0}$	9.2	14.3
Reasonable Residential Rates	6.0	4.9	3.3
Attractive Industrial Rates	3.0	3.1	4.5
Price Comparability	5.0	2.5	4.0
Stability in Rates	$\boxed{16.0}$	17.4	12.0
Simplicity	4.0	6.8	8.9

Each of the highlighted objectives would appear to signal concern over the possibility of excessive capacity in the MAIN area. The relatively low priority assigned to reducing need for generating facilities, the higher priority assigned to rates tracking costs, and the higher priority assigned to price comparability to other fuels suggest that possibility.

We now summarize how this decision maker's weighted ratemaking preferences would likely affect the structuring of rates. His first priority would be to establish rates that would provide the overall revenues found to be reasonable by his regulatory agency (27% weight). Second, he puts significant emphasis on designing rates that track costs (17%). However, as stated earlier, costs can be determined several ways. It may be that this decision maker would opt for the use of marginal costing, but most likely he would be in the majority of decision makers who choose to continue to follow the traditional accounting costs in setting rates. Given that he attributes more weight to achieving reasonable residential rates (6%) than attractive industrial rates (3%), he might be slightly influenced to select a costing method which favors the residential class of customers. The responses from his region's regulators place relatively less importance on costs (7.2%, from Table 5.5) and more emphasis on reasonable residential rates (9.3%). If we assume that these responses are indicative of his own state's regulators, a conflict could develop because of these differences in objectives.

Designing rates to influence conservation appears to be of relatively little interest to this utility decision maker--particularly in trying to achieve energy conservation. However, he might have to argue strenuously against rate structures such as inverted rates because the regulators in his region strongly support energy conservation (14.5%). Hopefully, the economic value of implementing or not implementing energy conservation steps for this particular utility would be discussed prior to any final actions.

Similar to other utility managers in the United States, this decision maker assigned relative high priority to stability in rates (16%) which indicates a desire to make only gradual changes in rates. For example, he might oppose mandatory TOU rates if it meant severe price changes for any group of customers. (He might also oppose them if he has excess capacity.) He is in further agreement with the nation's utility managers in that he is concerned about revenue stability (13%), and hence, would likely include in his design of rates a means of collecting more of his fixed cost requirements on the lower monthly usages of customers. This might be done through higher customer charges, higher block charges for lower usages, or higher demand charges for those customers with demand billing meters. He is not particularly concerned about simplicity of the rate design (4%).

5.3 Survey Results on National Basis

Certain national and regional data were presented in the previous section for comparison with the selected respondent's weighted ratemaking objectives. This section focuses on a comparison between the national results obtained from regulators versus those from utility rate managers. Table 5.1 presents a summary of the findings on the five major ratemaking objectives.

Table 5.1 National weighted ratemaking objectives

Objectives	Weights: Regulators	Weights: Utilities
Revenue Requirements	35.3%	48.1%
Conservation	16.5%	8.0%
Stability in Rates	13.4%	17.4%
Fairness	25.7%	19.7%
Simplicity	9.1%	6.8%

Figure 5.2 shows these results in graphic form.

One interesting result from this survey is the degree of conformity found between regulators and utility rate managers in their weightings of several of the objectives.[17] As can be seen, both regulators and utility rate managers place the greatest weights on designing rates to meet revenue requirements with the second highest for each being the fairness objective. The utility respondents did, however, place relatively more weight on the revenue requirements objective. The most substantial difference between the two groups lies in their judgments of the weight to be attributed to the conservation objective. Regulators would assign about twice as much importance to this objective than would the utility representatives. This likely means that utility respondents are more skeptical about the positive impacts conservation can have on the utility system and its customers. The differences between regulators and utility rate managers can be better analyzed by examining the subelements of each of the objectives shown above. Table 5.2 provides the weights found for the various objectives and/or their subelements. Ninety-five percent (95) confidence limits around the means of each of these weights are shown also.

17 However, a Chi-squared statistical test does indicate that the two sets of responses are statistically different at the .05 level of significance. See Appendix C.

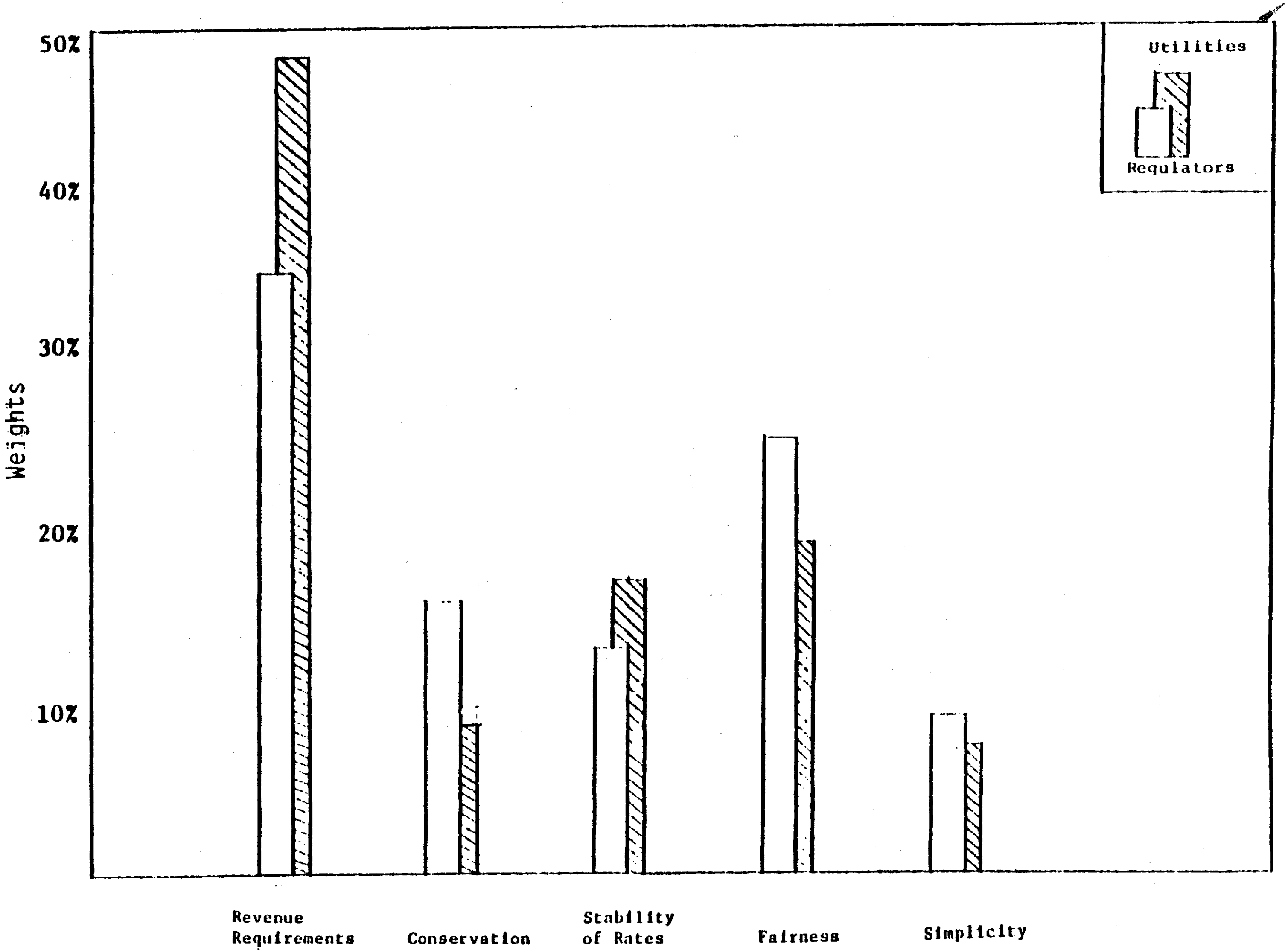


Figure 5.2 Weights of ratemaking objectives: utilities versus regulators

Table 5.2 Composite list of ratemaking objectives.

Objectives	Weights: Regulators	Weights: Utilities
Revenue Adequacy	20.4% ± 3.1%	33.4% ± 3.3%
Revenue Stability	8.1% ± 1.3%	11.2% ± 1.2%
Energy Conservation	11.0% ± 1.6%	5.0% ± 0.8%
Reduction in Generating Plant Reqts.	12.3% ± 2.6%	6.6% ± 1.4%
Cost of Service	10.1% ± 1.8%	9.2% ± 1.6%
Reasonable Residential Rates	8.3% ± 1.5%	3.1% ± 0.7%
Attractive Industrial Rates	4.2% ± 0.8%	4.9% ± 0.9%
Price Comparability	3.2% ± 0.6%	2.5% ± 0.6%
Stability of Rates	13.3% ± 2.1%	17.3% ± 2.2%
Simplicity	9.1% ± 1.9%	6.8% ± 0.9%

These mean weights are shown in graphical form on Figure 5.3. It can be seen that both groups give highest weight to the matter of designing rates that produce adequate revenues. However, the utility rate managers assign 33.4% of the total composite weight to this objective compared to 20.4% for regulators. This wide difference may be caused, in fact, by the failure in recent years of rates established by regulation to enable utilities to earn their allowed rates of return. Figure 5.4 displays this situation graphically.

Regulators and utility representatives agree that the second most important individual objective or component of an objective is rate stability. It is not unexpected to find significant weight attributed to this objective in that many of the complaints fielded by utilities and regulators in recent years have focused on the instability of rates. For example, the people who bought "Gold Medallion" homes in the late 1960s probably did not anticipate the sharp rises that would occur in their heating bills, and many have complained loudly as a result. The utility representative appear to be slightly more sensitive to this matter than regulators--probably because the utilities heavily promoted the use of electricity prior to the 1970s.

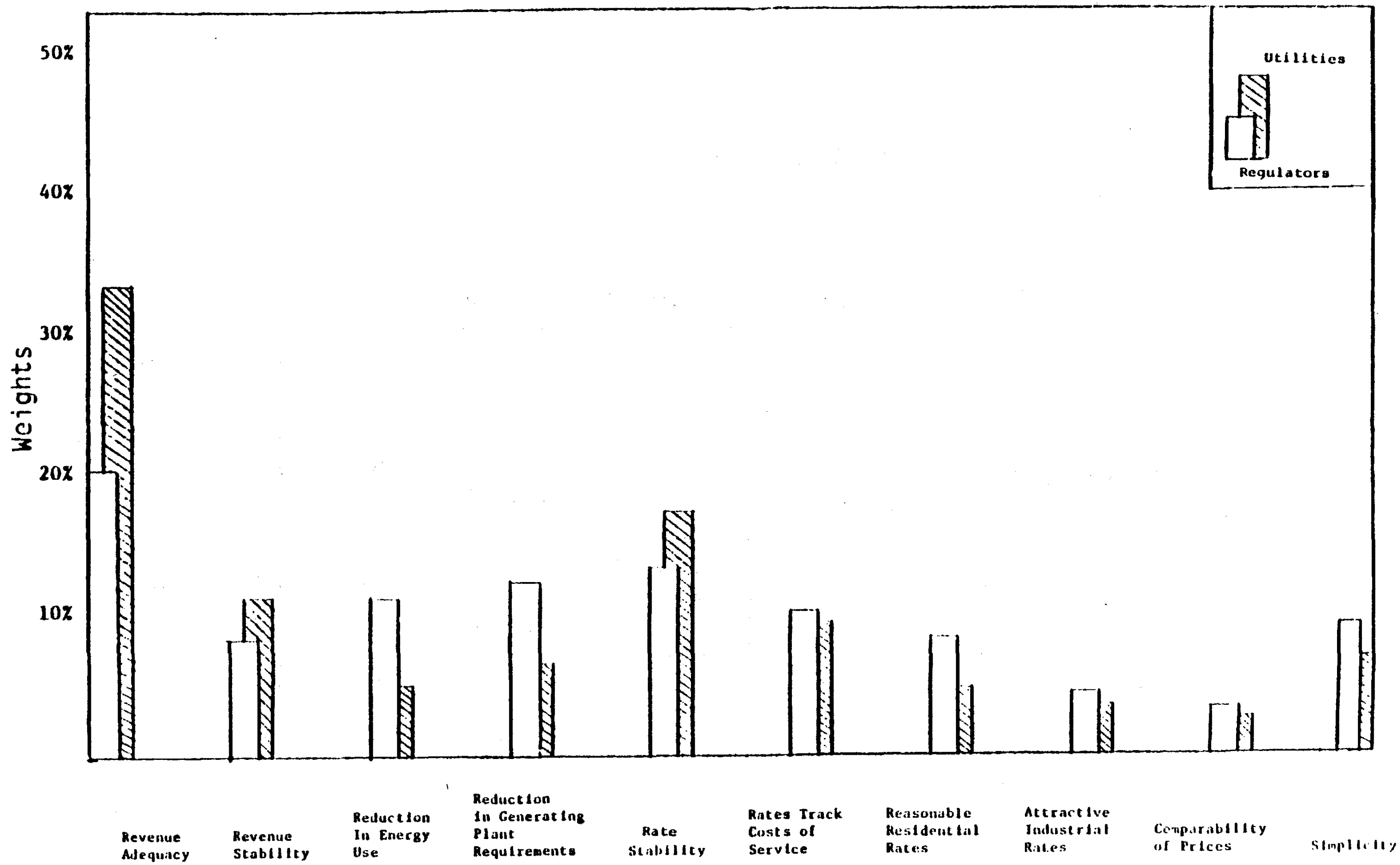


Figure 5.3 Bar graphs showing composite group of weights of ratemaking objectives: regulators vs. utilities

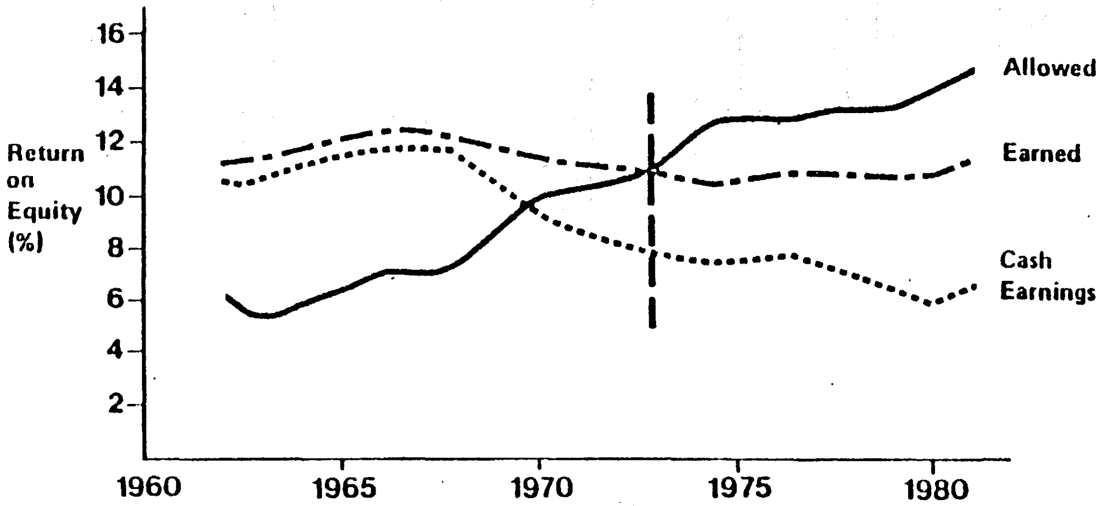


Figure 5.4 Utility equity returns

SOURCE: U.S. Department of Energy, The Future of Electric Power in America: Economic Supply for Economic Growth, June 1983, DOE/PE-0045.

In regard to the subelements of the fairness objective, both groups agreed that having rates track or be based on costs of providing service is the most important factor in determining fairness of the rates as they apply to different customer classes. Utilities attribute substantially less weight to the other three subelements of the fairness objective (reasonable residential rates, attractive industrial rates, and comparability of prices with other energy sources). Regulators, however, assign significant importance to the objective of reasonable residential rates. This kind of finding on the part of the regulators is not unexpected and probably underlines the importance of other customer classes intervening in general rate cases in order to protect their fair treatment in the division of cost responsibilities among classes.

Given that concern for revenue and rate stability received such substantial weight, it was decided (as stated in Chapter 4) to make a second set of comparisons by omitting revenue adequacy, revenue stability, and rate stability from the list of ratemaking objectives in the interest of highlighting differences in the remaining ratemaking objectives. However, a resurvey was not done. Instead, it was assumed that the objectives were independent; i.e., no interactions between the revenue requirements objective and the reduction in energy usage (or energy conservation) objective. A zero weight was assigned to these three objectives which effectively normalized the percentage weights assigned to the seven remaining objectives. It also served to modify the proportion of weight assigned to the energy conservation objective since its revenue effect no longer was a factor. Table 5.3 gives the results.

Table 5.3 Normalized weights of reduced number of objectives.

Objectives	Weights	
	Regulators	Utilities
Energy Conservation	7.2%	3.6%
Reduction in Generating Plant Reqts.	23.6	19.7
Rates that Track Costs	20.5	25.3
Reasonable Residential Rates	16.0	14.6
Attractive Industrial Rates	8.0	8.5
Price Comparability	6.2	7.2
Simplicity	18.5	21.1

As with the single decision maker selected for analysis, the interesting point here is that, with the revenue influence removed from the energy conservation objective, much more importance is attributed to reducing the need for new generating plant than to trying to encourage reductions in energy consumption. As can be seen, reducing plant requirements receives top priority by regulators. No doubt regulators are concerned about the strong upward pressure new construction has on rates. Utility managers are only slightly less concerned.

5.4 Regional Analyses

Electric Reliability Council Areas (designed herein as regions) were analyzed to determine if any major differences in responses could be observed across them, and if so, what particular costing and rate design procedures might be called for in those regions. The country was divided into the nine areas or regions, as discussed and shown previously in Figure 5.1, and responses were aggregated on that basis. The regional weighting results are shown in Table 5.4.[18]

18 The SERC and NPCC regions are chosen for detailed comparison beginning on page 69. A Chi-squared statistical test of significant difference is made on their responses and reported in Appendix C. A similar test should be conducted on other regions prior to comparison of the results between them.

Table 5.4 Regional Ratemaking Objectives

Regulators	Total U.S.	ERCOT	MAPP	MAIN	MAAC	NPCC	ECAR	SERC	WSCC	SPP
Number of Respondents	83	2	6	2	10	13	6	12	22	8
Objectives										
Revenue Adequacy	20.4	24.8	23.7	39.3	12.5	24.9	31.8	13.6	19.1	11.7
Revenue Stability	8.1	12.2	8.8	7.1	7.5	7.6	13.1	6.9	14.3	7.5
Reduction in Energy	11.0	3.3	10.5	14.5	10.6	7.8	13.2	10.4	6.8	11.5
Reduction in Plant Requirements	12.3	9.9	5.5	4.9	14.4	9.9	9.9	19.0	13.7	10.8
Rate Track Costs	10.1	16.6	8.9	7.2	9.1	12.9	7.7	10.1	9.8	11.0
Reasonable Residential Rates	8.3	5.2	5.4	9.3	9.0	6.7	4.5	7.6	8.9	12.5
Attractive Industrial Rates	4.1	5.2	2.3	3.7	5.9	4.4	2.7	4.8	2.7	7.1
Price Comparability	3.2	1.8	3.2	2.0	3.0	3.1	1.7	5.0	3.3	3.6
Stability in Rates	13.4	12.4	20.1	8.1	21.6	10.6	9.3	13.3	11.5	14.4
Simplicity	9.1	8.6	11.6	3.9	6.4	12.1	6.1	9.3	9.9	9.9

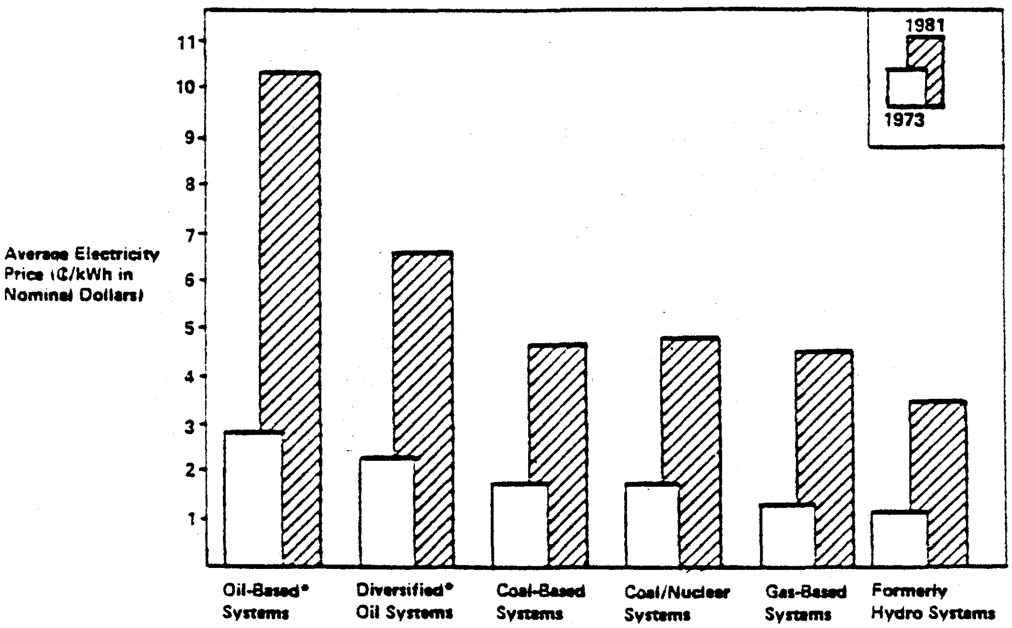
Utilities	Total U.S.	ERCOT	MAPP	MAIN	MAAC	NPCC	ECAR	SERC	WSCC	SPP
Number of Respondents	63	2	4	6	8	12	6	7	12	7
Objectives										
Revenue Adequacy	33.4	33.1	33.4	32.7	28.4	36.1	34.2	29.9	34.2	34.5
Revenue Stability	11.1	10.7	10.8	11.2	9.1	10.3	15.6	11.6	9.3	11.2
Reduction in Energy	5.0	4.8	4.6	5.5	3.4	6.1	5.2	4.3	5.2	3.4
Reduction in Plant Requirements	6.6	3.2	6.0	3.6	6.3	5.8	3.3	12.1	7.1	7.2
Rates Track Costs	9.2	10.4	11.3	14.3	9.5	8.3	8.0	7.4	7.1	10.2
Reasonable Residential Rates	4.9	2.3	4.6	3.3	7.1	5.6	4.2	3.1	5.8	3.2
Attractive Industrial Rates	3.1	2.4	3.6	4.5	5.6	1.8	3.4	3.0	3.1	2.3
Price Comparability	2.5	2.6	2.5	4.0	3.2	1.8	1.1	1.5	2.7	4.0
Stability in Rates	17.4	22.8	16.1	12.0	19.4	16.9	18.6	22.2	17.9	18.7
Simplicity	6.8	7.7	7.1	8.9	8.0	7.3	6.4	4.9	7.6	5.3

To highlight extremes across regions, the highest weight received from any region for each objective is shown in boxes. The number of respondents from each region is also shown. The numbers of respondents are somewhat misleading because the number of eligible respondents in each region varies significantly. For example, in the ERCOT (Texas) region, there are only three regulators and two responded. However, because of the fewness of the total respondents, reasonable confidence limits could not be established.

To better analyze the difference in expressed ratemaking weights across regions, one needs to know the circumstances affecting the utilities that serve in the regions. The influences that might significantly affect a utility's operations and, hence, choice of ratemaking objectives are the following: (1) fuel generation mix, (2) growth rate of demand, (3) system load factor, (4) location from fuel sources, and (5) demographics of the service area. It has been found, though, that fuel generation mix has the most influence on a utility's costs of producing power and the rates it must charge. [32] Figure 5.5 shows average electricity prices charges by utilities by type of primary generation fuel for the years 1973 and 1981.

Figure 5.6 provides a state-by-state comparison of the cost of electricity to an average residential customer using 1000 kWhs per month. The parallels between type of generating and high or low cost power can be observed. For exampls, in the Northwest the majority of generating in a state such as Idaho is from hydroelectric facilities and as a result rates are low. This can be contrasted with the New England states that have heavy amounts of oil generating and, consequently, high rates.

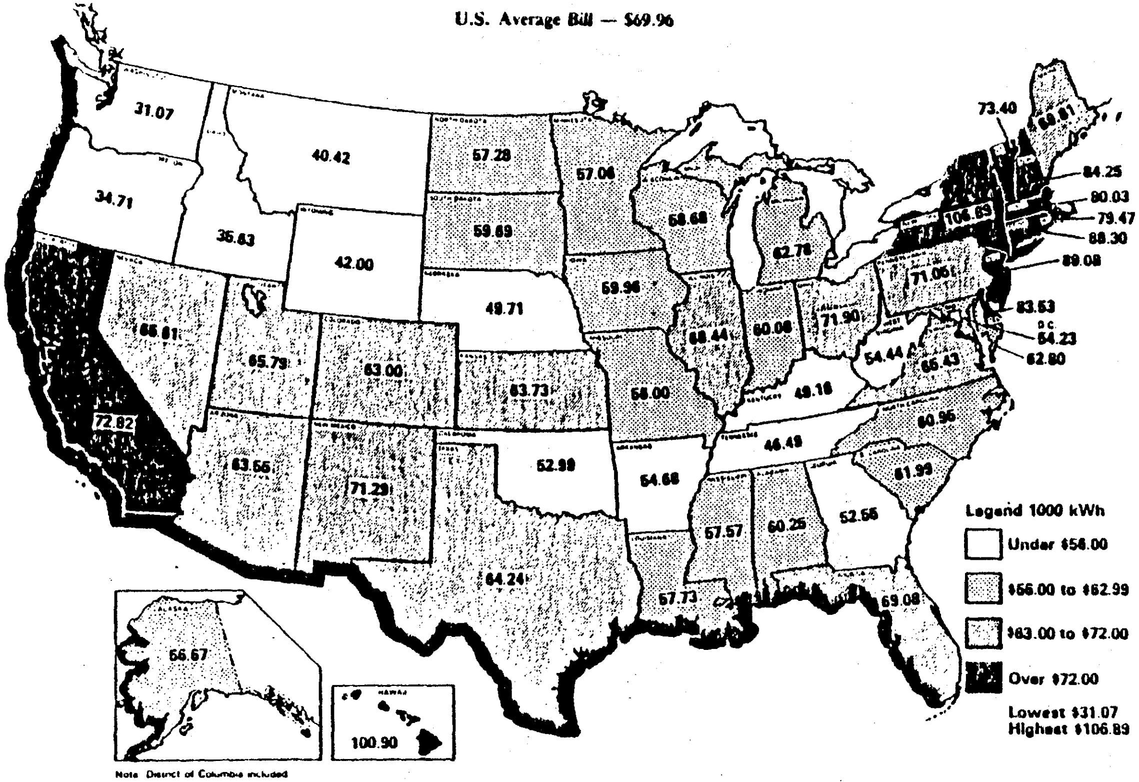
To illustrate these differences further, Figure 5.7 shows primary generation by fuel by regions for 1982 and as projected for 1992. Regional load factors are showin in Figure 5.8. These data should be helpful in analyzing the effects of system operating characteristics on weights attributed to ratemaking objectives. For this purpose, the utlity managers' responses are reviewed rather than the regulators' responses on the theory that the rate managers are more cognizant of the



Note: "Oil-based* systems" are systems which used oil as a primary generation fuel through the period. "Diversified Oil Systems" are systems which substituted a substantial amount of coal and nuclear generation for oil generation over the period.

Figure 5.5 Electricity prices sorted by primary generation fuel

SOURCE: The Future of Electric Power in America: Economic Supply for Economic Growth, U.S. DOE, June 1983.



State Average Monthly Bills, 1,000 kWh Residential, January 1, 1983

Figure 5.6 Average residential bill

SOURCE: Typical Electric Bills. Energy Information Administration, U.S. DOE, 1983.

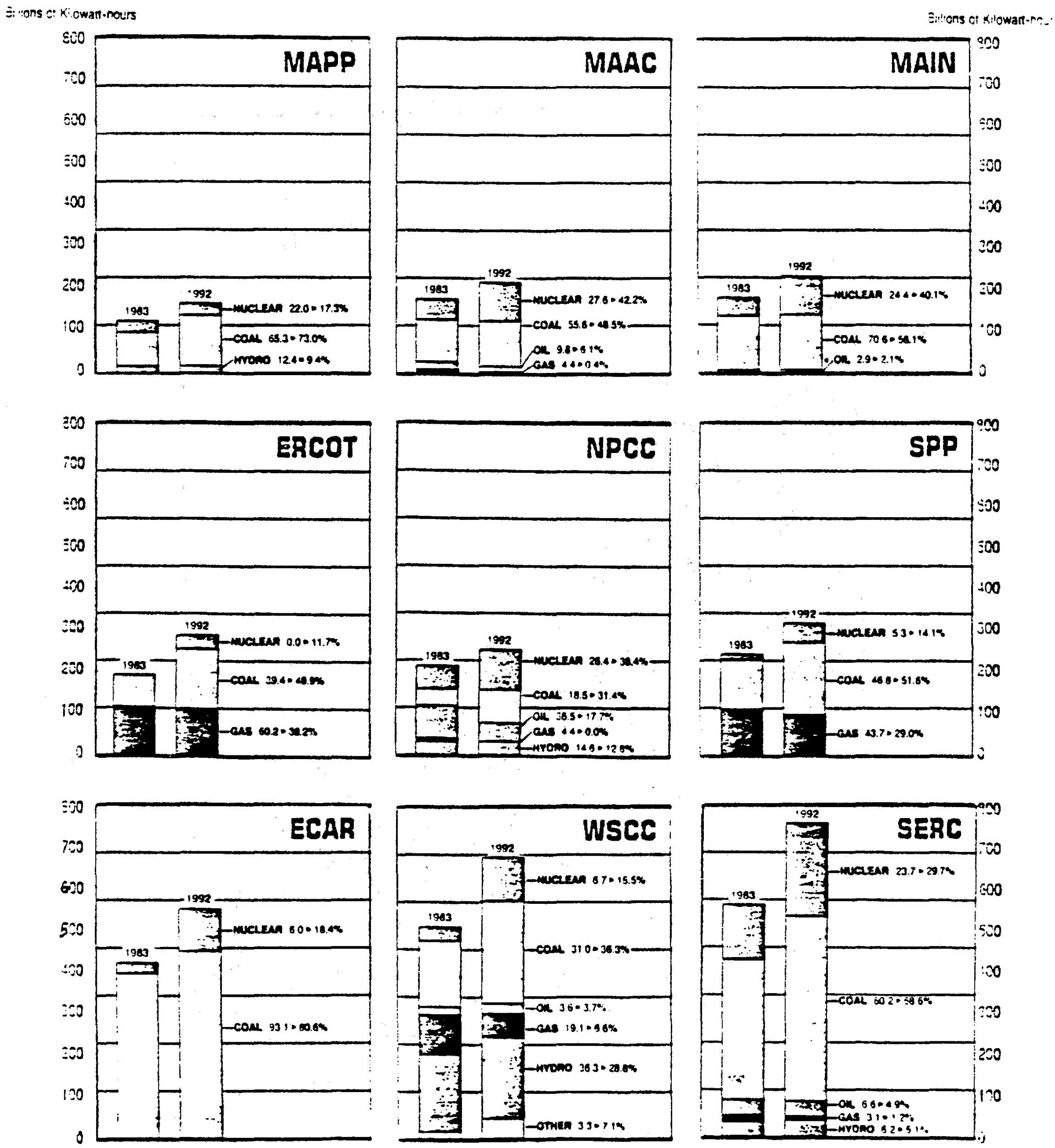


Figure 5.7 Primary generation by fuel by Electric Reliability Council Area for 1983 and 1992

SOURCE: Electric Power Supply and Demand 1983-1992. National Electric Reliability Council. Princeton, N.J., July 1983.

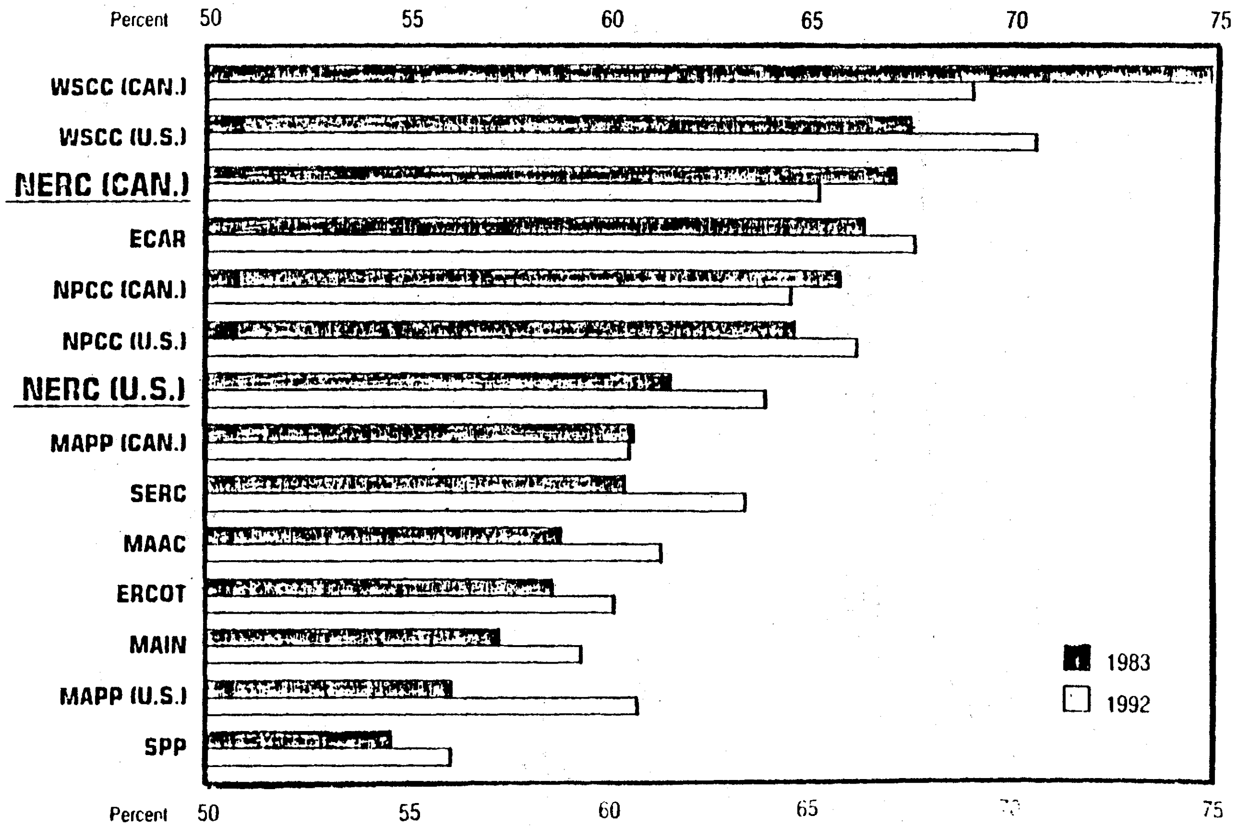


Figure 5.8 NERC annual load factors

SOURCE: Electric Power Supply and Demand 1983-1992. National Electric Reliability Council. Princeton, N.J., July 1983.

impact of utility operating characteristics on their utility costs and rates.

Two reliability regions are chosed here for specific study, SERC (comprised of the southeastern states) and NPCC (New England states). The SERC region is in the faster growing sunbelt of the nation and, with the exception of Florida, depends little on oil generation. The NPCC areas, in contrast, is experiencing slower growth and relies on oil for much of its generating fuel (see Figure 5.7). The ratemaking objectives of the utility managers in the two reigons were found to be as followed (sample sizes are given in Table 5.4):

	Weights[19]	
Pricing Objectives	SERC	NPCC
Revenue Adequacy	29.9%	36.1%
Revenue Stability	11.6	10.3
Reduction in Energy Usage	4.3	6.1
Reduction in Generating Plant Reqts.	12.1	5.8
Rates that Track Costs	7.4	8.3
Reasonable Residential Rates	3.1	5.6
Attractive Industrial Rates	3.0	1.8
Price Comparability	1.5	1.8
Stability in Rates	22.2	16.9
Simplicity	4.9	7.3
	Σ = 100.00	Σ = 100.00

If revenue adequacy, revenue stability, and rate stability are omitted under the assumption that they will be met and the remaining objectives normalized, the following weights are obtained:

19 A Chi-squared statistical test between the sets of weights for the pricing objectives for the two regions indicates that they are significantly different at the .05 level. See Appendix C.

Reduced Number of Pricing Objective	Weights SERC	NPCC
Reduction in Energy Usage	1.1%	4.9%
Reduction in Generating Plant. Reqts.	35.7	19.0
Rates that Track Costs	23.6	24.1
Reasonable Residential Rates	9.8	16.8
Attractive Industrial Rates	9.6	4.9
Price Comparability	4.4	5.4
Simplicity	15.8	24.9
	Σ = 100.00	Σ = 100.00

In both regions, energy conservation is rated relatively low in relation to encouraging conservation that would reduce the need for additional generating plants. However, the SERC respondents place substantially more emphasis on the latter. This, no doubt, reflects the faster growth in peak demand in the SERC regions.[20] The NPCC regions states, however, also have an interest in leveling their load so that they can reduce the amount of the time that they must depend on high cost oil-generating facilities. Based on these responses, neither appears to be in the possible over-capacity position of the MAIN region utilities. Both the SERC and NPCC regions attribute approximately equal weight to designing rates that track costs. The New England region, with its high rates, puts higher priority, in terms of fairness, in achieving reasonable residential rates. The SERC respondents place approximately equal weight on their concern for reasonable residential rates and attractive industrial rates. The Southeast, of course, has been engaged in trying to attract more high-paying industrial jobs for several years now, and this is likely a factor in their weightings of these objectives. Neither places much weight on the need for price comparability of electric rates with other fuels. Both are somewhat concerned about the simplicity or understandability of their rates, but the NPCC respondents are more concerned. This may reflect, in part, the higher rates in their region. Figure 5.8 shows that the load factors of both regions are expected to increase. The SERC region starts at a lower level but grows

20 The projected 10-year annual peak demand growth rate is 65% greater for SERC than for NPCC [28].

faster in terms of percentage growth. A movement to higher load factors would likely indicate the need for more baseload generation either from existing or new plants. The next chapters on costing will illustrate the influence of load factors on costing results.

The data for additional regional analyses are included in Table 5.4. These analyses are left for future research. Decision makers in a region should particularly be interested in any major discrepancy between priority weights assigned by regulators versus utility rate managers. It is possible that further clarification and discussion of a system's operating characteristics might enable a consensus to be reached on certain of the objectives. On other objectives (such as revenue requirements), it is likely that the regulators and utility managers will continue to differ on the degree of priority that should be assigned to them.

5.5 Importance of Costing

Discussions have been included in the previous sections on what rate structuring might be necessary to meet given ratemaking objectives under differing utility system operating characteristics. It is clear that a utility's circumstances should, and do, affect ratemaking objectives. Little, however, has been said about which costing methodology one should choose, based on one's ratemaking objectives. The importance of costs has been demonstrated by the fact that both regulators and utility rate managers attribute substantial weight to the fairness objective (second only to meeting the revenue requirements objective) and that both consider costs-to-serve to be the most important factor in determining fairness.

The problem arises, however, regarding which costing method to choose. At the first level of decisions, a decision maker can choose to base rates on either marginal costing or accounting costs or some blend of the two. As stated before, marginal costing supports the achievement of economic efficiency, but accounting costs have traditionally been preferred and followed by decision makers. However, it can be argued convincingly that the objective of economic efficiency, even though not measured independently in the survey, can be imputed substantial weight. This is because one could include portions of the objectives rate stability, conservation, and revenue requirements. The reason that economic efficiency can be inclusive of these three objectives is that, theoretically, rates designed on the basis of economic efficiency (hence, marginal costs) could do the following:

(1) Improve rate stability to customers by more accurately charging for use, therefore minimizing large rate shocks resulting from setting rates on the basis of lower imbedded costs.

(2) Induce efficient conservation practices by charging rates which reflect the incremental cost of power at times when power is more expensive to supply; and

(3) Enhance the utility's possibility of collecting revenues adequate to cover its costs by matching rates and costs more closely.

Some ratemaking experts, as previously indicated, would also argue that the economic efficiency objective would incorporate the fairness objective as well.

The final part of this paper briefly summarizes the development of a decision framework and a procedure for following traditional costing methodologies but, at the same time, attaining the approximately equivalent result of a marginal costing approach. The determination to use the latter approach depends, of course, on the relative weight a decision maker places on the economic efficiency objective.

6. DEVELOPMENT OF DECISION FRAMEWORK AND BRIEF DISCUSSION OF ADDITIONAL RESEARCH CONDUCTED

The results of the national survey of decision makers in the utility industry showed that there is substantial priority assigned to the objective of having rates track costs. As stated earlier, however, there is much dispute over how to define or compute those costs. Moreover, the RDS confirmed the likely continuation of that dispute by finding that there is no one correct procedure for determining costs, but that the method chosen depends on one's pricing objectives; i.e., which costing method meets a decision maker's perceived notions of equity and/or efficiency.

Based on surveys of current costing practices of utility regulatory commissions, the large majority of commissions (and hence, utilities under their jurisdictions) are using traditional accounting-derived costs as a basis for apportioning costs among customer classes. Several commissions did indicate that they take into account marginal costs in the design of rates after costs have been allocated to customer classes by accounting costs. Only a few commissions reported the use of marginal costs to apportion costs to customer classes [5,15].

The fact that several decision makers are reflecting marginal costs in the design of rates appears to indicate their concern about achieving the economic efficiency objective. Their actions could indicate a trend toward greater acceptance of marginal costing as a basis for designing rates.

The use of marginal costing assumes that economic efficiency would be assigned substantial weight by a decision maker in the setting of electric rates. A given decision maker, however, may have other ratemaking objectives which are of equal or higher priority. A general decision analysis framework was arrived at to facilitate making judgments in electric rate setting matters. The suggested procedure is given below.

Step 1

The first step in the procedure is to ascertain the weights a decision maker(s) would assign to the various ratemaking objectives and subobjectives. This report has discussed the mind's limitations, particularly in regard to making the complex tradeoffs that are involved in determining weights of multiple and conflicting objectives. The use of a structured decision analysis procedure such as the Analytic Hierarchy Process was demonstrated and suggested for weighting ratemaking objectives. There are other weighting methods, but the AHP appears superior in several ways including the opportunity to mathematically check one's consistency of choices.

After explicitly determining a weighted set of priorities, a decision maker may desire to reevaluate or modify them. For example, possible modifications, in desired priorities, could result from discussions, negotiations, and/or compromises with any other decision makers involved. Such interactions on these levels should help focus attention on exactly where disagreements lie and result in better "bottom line" decisions.

Finally, a tentative set of ratemaking objectives is established and put in ordered priorities.

Step 2

Parallel to ascertaining a weighted, tentative set of ratemaking priorities, system demand and supply characteristics (both present and future) need to be reviewed. Preferably, this should be done in the context of developing accounting and/or marginal cost-based rates. The possible impact of specific system characteristics should be considered in setting ratemaking objectives. For example, if system generation relies heavily on high-priced oil, then the objective of conservation of energy might need to be given a greater weight than an objective of reducing or conserving the system's peak demand.

If cost-of-service studies are to be made, then a decision maker must next decide if the economic efficiency objective is of sufficient weight to require marginal cost studies. If so and assuming marginal costs are not equal to accounting costs, then revenue reconciliation procedures must be implemented.

Step 3

After completing the determination of tentative weights for a set of ratemaking objectives and making an analysis of the costing studies, an attempt should be made to establish criteria for measuring the degree to which particular alternative costing methods and rate designs meet the set of ratemaking objectives. This, of course, would involve judgment since the cause and effect relationship of rate design changes versus demand changes in the electric utility industry tends to be long run.

Step 4

The final step in the general procedure would involve evaluating the final rates against the set of ratemaking objectives selected and determining whether additional studies or information is needed prior to final agreement on the class rate levels and design of the rates. This total process is in the context of the decision analysis framework described in Chapter 3.

The flow chart suggesting how decision analysis can be used in electric utility ratemaking matters is shown in Figure 6.1. This chart can be generally followed for any given set of weights for the ratemaking objectives. It also shows how the objective of economic efficiency (through marginal costing) can be incorporated into the overall determination of rates.

The second part of our research included the testing of this concept on synthetically created, but representative, utilities. One important finding was that specific utility circumstances dictated which accounting cost allocation method was "correct" in terms of meeting the economic efficiency objective. This finding would probably hold true for most other ratemaking objectives as well. This indicates that there is no reason to expect neighboring utilities to utilize the same cost allocation methods, even if agreement is reached on a given set of ratemaking objectives, unless their supply and demand characteristics are very similar.

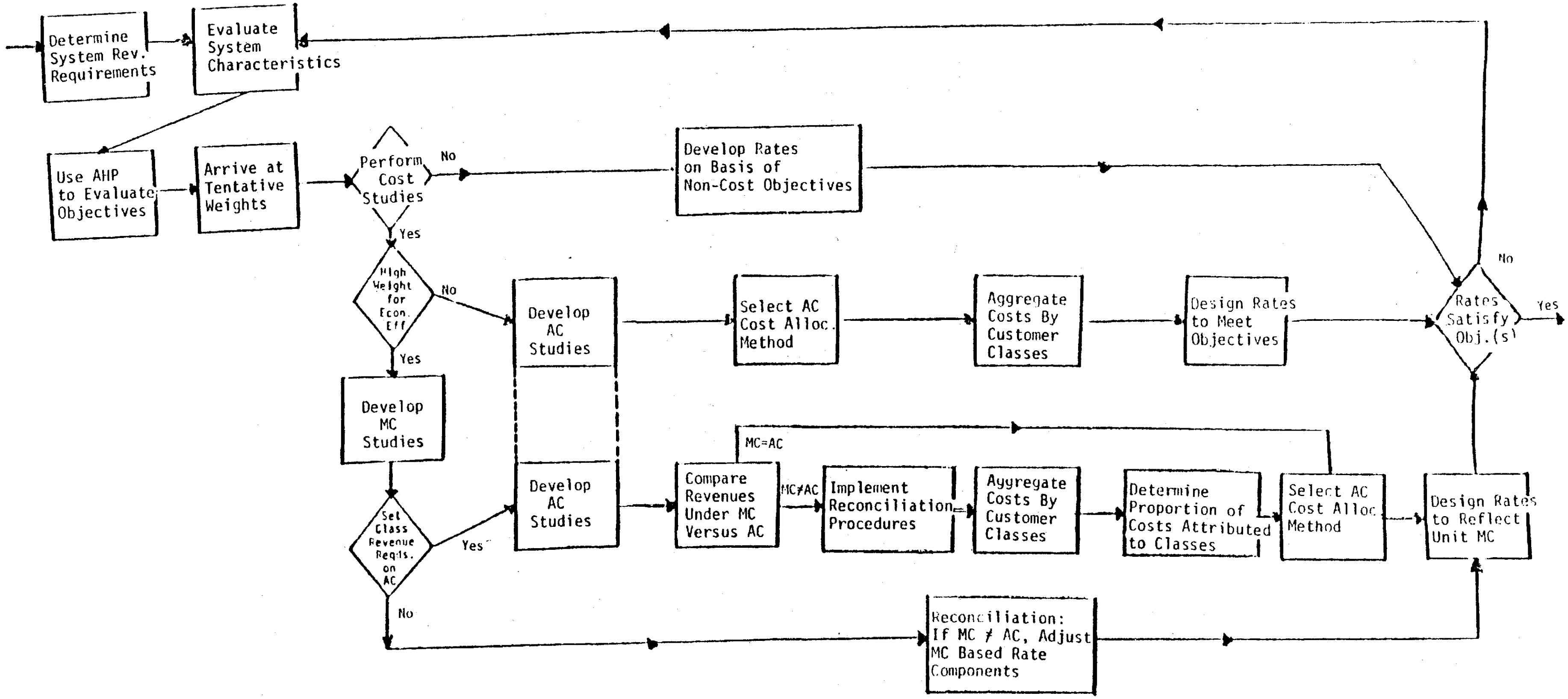


Figure 6.1 General decision analysis framework for electric ratemaking

APPENDICES

APPENDIX A

SIMPLE EXAMPLE OF AN APPLICATION OF AHP

Assume a person (the author of this paper in this case) has decided to buy a new car and he has eliminated all but three for various reasons. The three remaining possible cars are: (A) a $8500 Honda, (B) a $13,000 Buick, and (C) a $7500 Chevrolet Citation. Also assume the factors he is now considering in his purchase decision are as follows: cost, gas mileage, maintenance, appearance, and resale value. Following the AHP, a decision hierarchy could be constructed as shown in Figure A.1.

First, pairwise comparisons are made between the characteristics or attributes of a car with respect to their importance in the selection process. To facilitate these comparisons, Saaty's ratio scale, as discussed earlier, will be used for indicating one's measure or preference for one attribute versus another. In the car problem, Table A.1 is used to list the results of the pairwise comparisons of the characteristics considered with respect to selection of a car. (The author's judgments and preferences are used for this example.)

The first row compares the cost characteristics with the other characteristics. In the first column of the first row, a one is placed because cost is compared with itself. The second column space of the first row contains a three which indicates that the cost characteristic is weakly more important when compared to good mileage. In the last column of the first row, cost is considered very strong or of demonstrated importance when compared to resale value (indicating my

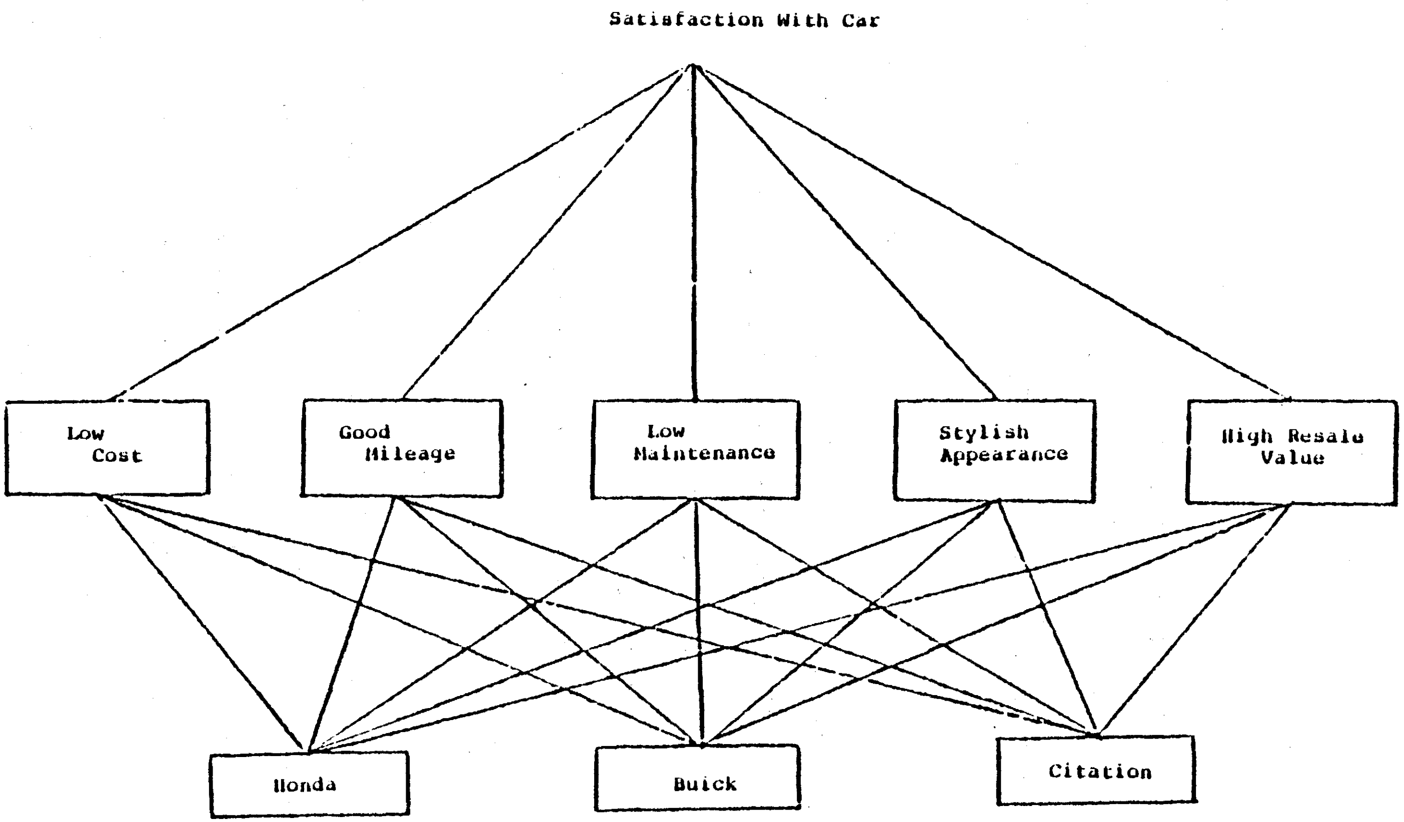


Figure A.1 Car purchase decision under AHP

Table A.1 Matrix of comparisons

In Respect to Satisfaction	Low Cost	Good Mileage	Low Maintenance	Stylish Appearance	High Resale Value
Low Cost	1	3	5	7	7
Good Mileage	1/3	1	5	7	5
Low Maintenance	1/5	1/5	1	3	5
Stylish Appearance	1/7	1/7	1/3	1	3
High Resale Value	1/7	1/5	1/5	1/3	1

preference to keep a car about six to ten years). The entries in the first column are the reciprocals of the first row indicating the inverse relation of relative strength of the other characteristics when compared with the cost characteristic. Similar statements could be made about the other rows and columns.

After obtaining the pairwise judgments, the next step is the computation of a vector of priorities from the above matrix. In terms of matrix algebra, this consists of calculating the principal eigenvector of the matrix. When normalized, the eigenvector becomes the vector of priorities [31]. Standard programs are available for computing the eigenvector of a matrix. Large-scale computers give the most accurate results but microcomputers closely approximate them. Saaty also lists some approximation methods that can be done by hand calculators. One of the allegedly better ones is as follows:

> Divide the elements of each column by the sum of that column (i.e., normalize the column) and then add the elements in each resulting row and divide this sum by the number of elements in the row. This is the process of averaging over the normalized columns. [31]

If this approximation method is followed for the car example, each column of the matrix of comparisons is normalized to obtain the matrix in Table A.2. Next, the elements in each row are added and divided by the number of columns.

Therefore, the column vector of priorities, expressed as a row vector, is (.47, .29, .13, .07, .04) which provides the priority rankings for the characteristics of cost, mileage, maintenance, appearance, and resale value, respectively. It can be seen that cost is significantly more important to the author than any other characteristic.

Table A.2 Normalized matrix

$$\begin{bmatrix} .55 & .66 & .43 & .38 & .33 \\ .18 & .22 & .43 & .38 & .24 \\ .11 & .045 & .09 & .16 & .24 \\ .08 & .03 & .03 & .06 & .14 \\ .08 & .045 & .02 & .02 & .05 \end{bmatrix} \quad \begin{matrix} .47 \\ .29 \\ .13 \\ .07 \\ .04 \end{matrix}$$

Table A.3 Weighting of the matrix

$$\begin{bmatrix} 1 & 3 & 5 & 7 & .7 \\ .33 & 1 & 5 & 7 & .5 \\ .20 & .20 & 1 & 3 & 5 \\ .143 & .143 & .333 & 1 & 3 \\ .143 & .20 & .20 & .333 & 1 \end{bmatrix} \begin{bmatrix} .47 \\ .29 \\ .13 \\ .07 \\ .04 \end{bmatrix} = \begin{bmatrix} 2.76 \\ 1.79 \\ .69 \\ .34 \\ .22 \end{bmatrix}$$

However, the manner in which these priorities can systematically be applied to influence the author's decision regarding which car to buy has not yet been shown. Prior to doing that, though, Saaty's method for checking for the degree of consistency in the judgment or weightings of these characteristics will be demonstrated. Again, for illustration purposes, a rough approximation method will be used. To be more accurate, a computer is required because the maximum eigenvalue of the matrix must be calculated. To find an approximation for the maximum eigenvalue of the matrix, multiply the matrix of comparisons on the right by the solution vector of priorities obtaining a new vector (see Table A.3).

If corresponding elements of this vector are divided by the solution vector, the following numbers are obtained: 5.87, 6.17, 5.31, 4.86, 5.5. By taking the average, an approximation of the maximum eigenvalue (λ_{max}) for the matrix is obtained [31]. This number is 5.54. (On a computer, 5.50 was found to be the equivalent and more accurate figure.) The closer the maximum eigenvalue is to n, the number of activities represented in the matrix, the more consistent the result is supposed to be. As stated in Chapter 3, Saaty has developed a consistency ratio (C.R.) for determining whether the deviation from consistency is large enough to require reconsideration of the weights assigned to the various characteristics or attributes by the decision maker in the pairwise comparisons. Prior to calculating the C.R., the consistency index (C.I.) must be determined since its value is needed in calculating C.R. The formula for C.I. is as follows:

$$C.I. = \frac{\lambda_{max} - N}{N - 1} \quad \text{or} \quad \frac{5.54 - 5}{5 - 1} = 0.135$$

Now C.R. = C.I./R.I., where R.I. is the random index and is defined by Saaty as being the consistency index of a randomly generated reciprocal matrix form with reciprocals forced. Based on a large number of trial runs, Saaty provides the following table of R.I.'s [31].

Table A.4 Random indexes

N	R.I.	N	R.I.
1	0.00	8	1.42
2	0.00	9	1.45
3	0.58	10	1.49
4	0.90	11	1.51
5	1.12	12	1.48
6	1.24	13	1.56
7	1.32		

A consistency ratio of 0.10 or less is considered good. Readers interested in further discussion and mathematical support for these calculations and contentions are referred to Saaty [31]. For the car example, the C.R. for the first matrix would be .135/1.12 or 0.12, which is very close to 0.10. The next step in the car choosing example is to evaluate each car in respect to each characteristic. This is done by making pairwise comparisons between the cars relative to each characteristic. The following table illustrates this step.

Table A.5 Pairwise comparisons of subelements

Relative to Cost	A	B	C
A	1	5	1/3
B	1/5	1	1/7
C	3	7	1

λ_{max} = 3.066
Eigenvector = 0.28, 0.07, 0.65
C.I. = 0.066/2 = .033
C.R. = 0.033/0.58 = .06

Relative to Mileage	A	B	C
A	1	9	5
B	1/9	1	1/6
C	1/5	6	1

λ_{max} = 3.163
Eigenvector = 0.73, 0.05, 0.22
C.I. = 0.81
C.R. = 0.81/0.58 = .14

Relative to Maintenance	A	B	C
A	1	3	5
B	1/3	1	3
C	1/5	1/3	1

λ_{max} = 3.04
Eigenvector = 0.64, 0.26, 0.10
C.I. = .02
C.R. = .03

Relative to Appearance	A	B	C
A	1	1/5	1/3
B	5	1	3
C	3	1/3	a

λ_{max} = 3.04
Eigenvector = 0.10, 0.64, 0.26
C.I. = .02
C.R. = .03

Relative to Resale Value	A	B	C
A	1	7	5
B	1/7	1	1/5
C	1/5	5	1

λ_{max} = 3.18
Eigenvector = 0.71, 0.07, 0.21
C.I. = .09; C.R. = .15

The eigenvectors of each 3*3 matrix comprise a larger 5*3 matrix shown below.

	Cost	Mileage	Mainten.	Appear.	Resale
A	.28	.73	.54	.10	.72
B	.07	.05	.26	.64	.07
C	.65	.22	.10	.26	.21

$$\begin{bmatrix} .47 \\ .29 \\ .13 \\ .07 \\ .04 \end{bmatrix}$$

To obtain the overall ranking of the cars, the above matrix is multiplied by the column version of the row vector of the weights of the characteristics (.47, .29, .13, .07, .04). This is equivalent to weighting each of the above five eigenvectors by the priority of the corresponding characteristics and then adding to obtain the following results:

A = .46

B = .13

C = .41

Therefore, by considering all the factors explicitly (costs, information, and personal preferences), the formal decision process indicates that the author should buy a Honda even though it is more expensive initially than a Citation and even though the author places significant weight on initial costs. The Buick came in last with a low preference weighting.

One advantage of placing any complex decision, particularly one that requires tradeoffs among objectives, into a formal decision making structure is that it permits the examination of reasons for the outcome.

For example, if more than one decision maker is involved, it may be possible to reach accord more easily on a given course of action. If there were disagreement, for instance, between the author and his wife regarding the car choice, she could question and disagree on the weights given the various characteristics or how the cars should be judged relative to them. In other words, if more than one decision maker is involved, the explicitness of a formal decision analysis approach such as AHP allows one to determine where disagreements are and concentrate on their resolution.

APPENDIX B

QUESTIONNAIRE AND COMMENTS OF SELECTED RESPONDENTS

INTRODUCTION

We are interested in determining the importance ratemakers and utilities place on certain factors involved in electric utility ratemaking. We would very much appreciate your help. It will only take about 10 minutes of your time, and we believe you will be very interested in the overall results to be compiled from across the country. Your individual response will be kept confidential, and, in fact, you need not indicate who you are if you so choose.

We have initially selected five major factors and eight underlying factors or subfactors which we believe encompass the major considerations of electric rate design. If you believe we have omitted a significant factor, please note it to us.

Following the method used by Professor Thomas Saaty in his The Analytic Hierarchy Process, we are asking you to compare the factors selected as being most significant in the consideration of designing electric rates as follows:

A. REVENUE REQUIREMENTS (effectiveness of rate design in ensuring recovery of all reasonably incurred costs)

B. SIMPLICITY (ability of rate design to be understandable to consumer)

C. STABILITY (effectiveness of rate design in minimizing large adverse price changes to customers)

D. CONSERVATION (ability of rate design to effect conservation of resources utilized in production of electric power)

E. FAIRNESS (effectiveness of rate design in providing rates which are considered "fair" between and among customers and customer classes)

PLEASE TURN TO THE NEXT PAGE NOW AND INDICATE THE WEIGHT OF YOUR PREFERENCES.

QUESTIONNAIRE

Please indicate your preference of how the factors listed under A and B rank in importance to one another by placing one and only one "x" closer to A if you think the factor under A is more important than the factor under B. If you think the factor under B is more important than the factor under A, place your "x" closer to B. For example, if you think the consideration of Revenue Requirements is more important than the Simplicity criterion in the design of rates, then you would place an "x" to the left of the Equal Importance column. The closer you place your "x" to column A, the more importance you are indicating for Revenue Requirements relative to Simplicity. If you consider Simplicity more important, then you would place your "x" to the right of the Equal Importance column. Also, you may place your "x" between designated columns for further refinement of your opinion. Please proceed.

WITH RESPECT TO ELECTRIC UTILITY RATE DESIGN:

A	Absolute Importance	Very Strong	Strongly Important	Weakly Important	Equal Importance	Weakly Important	Strongly Important	Very Strong	Absolute Importance	B
Revenue Requirements										Simplicity
Revenue Requirements										Conservation
Revenue Requirements										Fairness
Simplicity										Conservation
Simplicity										Fairness
Conservation										Fairness
Stability										Revenue Requirements
Stability										Conservation
Fairness										Stability
Stability										Simplicity

Now, some of the major factors or goals have underlying subfactors or subgoals. Will you please make similar one-to-one comparisons between the subgoals with respect to how each impacts one or more of the major factors, as indicated.

First, with respect to designing rates to meet the criterion of Revenue Requirements, please compare the relative importance of Revenue Recovery (adequacy), Revenue Stability (avoidance of large swings in revenue levels to the utility), and Reduction in Energy (Sales): i.e., the importance of each as it impacts the Revenue Requirements goal. We have labeled the subgoals under columns C and D as follows.

The instructions are the same.

WITH RESPECT TO REVENUE REQUIREMENTS:

C	Absolute Importance	Very Strong	Strongly Important	Weakly Important	Equal Importance	Weakly Important	Strongly Important	Very Strong	Absolute Importance	D
Revenue Recovery										Revenue Stability
Revenue Recovery										Reduction in Energy
Revenue Stability										Reduction in Energy

With respect to the goal of Conservation, please compare the relative importance of Reduction in Generation Plant Capacity Requirements to Reduction in Energy Usage.

WITH RESPECT TO CONSERVATION:

E	Absolute Importance	Very Strong	Strongly Important	Weakly Important	Equal Importance	Weakly Important	Strongly Important	Very Strong	Absolute Importance	F
Reduction in Generating Plant Requirements										Reduction in Energy Usage

With respect to achieving the goal of Fairness, please compare the relative importance of each of the following in designing overall rates: Rates which reflect "reasonable" residential rates; Rates which reflect "attractive" industrial rates; Rates that track costs of service, and Rates that reflect comparability to prices of other energy forms.

WITH RESPECT TO FAIRNESS:

G	Absolute Importance	Very Strong	Strongly Important	Weakly Important	Equal Importance	Weakly Important	Strongly Important	Very Strong	Absolute Importance	H
Reasonable Residential Rates										Attractive Industrial Rates
Reasonable Residential Rates										Rates that Track Costs
Reasonable Residential Rates										Price Comparability with Other Energy
Attractive Industrial Rates										Rates that Track Costs
Attractive Industrial Rates										Price Comparability with Other Energy
Rates that Track Cost										Price Comparability with Other Energy

The following is _requested_ but is _optional_ (in any event, individual responses will not be made public nor released in any form).

1. Area of country in which your company is located, i.e., N.E., etc.

   ____

2. State ______________________________

3. Name of Company

   ____

4. Your Name ______________________________

5. Please check here if you desire a summary of the results __________

6. Please return as early as possible the Questionnaire portion to:

   Robert K. Koger, Chairman
   North Carolina Utilities Commission
   P. O. Box 991
   Raleigh, North Carolina 27602

   Tel. No. (919) 733-4072

Comments

Comments of Regulator X

I did have some trouble with answering that portion of the questionanire relating to fairness. For example, those being polled are asked to differentiate between Reasonable Residential Rates and Attractive Industrial Rates. Although it is not articulated, I take the question to be--should the residential class be subsidizing the industrial class, or vice versa? Absent a number of caveats, neither view would seem proper and therefore answers on either side of equanimity are inapropos. Equipoise is impossible given my understanding of what I think the questionnaire is asking because you obviously can't be equally in favor of both.

In the same section are those questions dealing with the concept of Price Comparability with Other Energy. I was somewhat unsure as to what was being asked. Was the question, for example, should we price electricity for resistance heating at a cost comparable to alternate heating fuels (natural gas, propane, middle distillates)? Such a pricing strategy, however, would bear no relationship to cost and would be difficult if not impossible to justify on any reasonable basis. The only justification I can see for such a concept is setting interruptible and therefore discretionary natural gas purchases pegged at a parity with or below the alternate oil price so long as commodity costs are reasonably covered.

Comments of Regulator Y

Thanks for the opportunity to participate in your questionnaire. I don't believe you have omitted a significant factor. Definitionally they seem to parallel with those in PURPA:

PURPA		QUESTIONNAIRE
Conservation by end user. Efficiency of use of facilities and resources by electric utility	)	Conservation
Equity	(	Simplicity Stability Fairness
		Revenue Requirements

We have exerted considerable effort in trying to balance these factors as is indicated in my response to the attached questionnaire. I qualify conservation as the efficient use of energy rather than simply reduction in use and equate tracking costs with marginal supply costs and the related revenue requirement adjustments.

Comments of a Utility Rates Manager

I am returning a completed questionnaire forwarded with your letter of June 21, 1982. I must admit that completing the questionnaire was a very interesting exercise. My first reaction when reviewing the five items of importance to ratemakers and utilities that you are interested in can be put in the context of an answer to a multiple choice question as "all of the above." What made completing the questionnaire so interesting yet difficult was the matrix approach whereby one was required to discriminate between the perceived relative importance of each of these items.

I chose to use this survey as a means to probe the importance my own two managers of cost and rate design ascribe to each of these rate design criteria. I also independently completed the survey. After this was done, the three of us gathered to discuss the results. In doing this mini-survey, I discovered just how subjective the responses to this type survey will be. We represent three individuals in upper and middle management, who have worked very closely together on rate design during the past decade of regulatory complexities. In completing the survey, initially, there was significant diverse opinions expressed by each of us as to certain of the comparative items. We discussed each item to arrive at a consensus carefully reviewing the meaning your survey ascribes to the various criteria being evaluated. We reflected upon the experience in rate design we've had in the past including where our company rates were, where we now are, and where they are going. The judgments we have made to support those directions, etc., and finally settled upon are indicated on the enclosed, completed survey form.

We completed the survey, we enjoyed doing it, we learned something from doing it, but by no means was it an easy task. The questionnaire is very subjective. Any summary analysis of positions taken across the country by regulators and utilities will have to be viewed with that in mind.

APPENDIX C

CHI-SQUARED TESTS OF INDEPENDENCE

The chi-squared test can be used to determine whether there is a relationship between two or more classes or groups of data. First, a null hypothesis is made that the classes are independent of each other. If the computed value for chi-square is greater than a given level of significance, then the null hypothesis is rejected. In these tests, a .05 level of significance is used.

Test 1: For the two sets of national ratemaking weights shown on page 70 for regulator and utility managers, the null hypothesis would be that there is no relationship between the two sets of weights; that is, that the weights are independent of each other.

A contingency table is constructed from the data below.

Objectives	Regulator	Utilities	Totals
Revenue Requirements	35.3	48.1	83.4
Conservation	16.5	8.0	24.5
Stability in Rates	13.4	17.4	30.8
Fairness	25.7	19.7	45.4
Simplicity	9.1	6.8	15.9
Totals	100.0	100.0	200.00

	Expected Weights	
Objectives	Regulator	Utilities
Revenue Requirements	41.70	41.70
Conservation	12.25	12.25
Stability in Rates	15.40	15.40
Fairness	22.70	22.70
Simplicity	7.95	7.95

$$\chi^2 = \frac{(f_o - f_e)^2}{f_e}$$

$$\chi^2 = \frac{(35.3 - 41.7)^2}{41.7} \quad --- \quad \frac{(6.8 - 7.95)^2}{7.95} = 6.56$$

d.f. = (r-c)(c-1) = 4

α at .05 = 9.488

Therefore, do not reject null hypothesis. The weights of the regulators and utility rate managers are determined to be statistically independent of each other.

Test 2: Determine if there is a significant difference between the responses of the SERC and NPCC Regions.

H_o: There is a significant difference between the weights for the two regions.

The data and contingency table are shown below.

Objectives	SERC	NPCC	Totals
Revenue Adequacy	13.6	24.9	38.5
Revenue Stability	6.9	7.6	14.5
Energy Conservation	10.4	7.8	18.2
Reduction in Generating Plant Reqts.	19.0	9.9	28.9
Cost of Service	10.0	12.9	23.0
Reasonable Residential Rates	7.6	6.7	14.3
Attractive Industrial Rate	4.8	4.4	9.2
Price Comparability	5.0	3.1	8.1
Stability of Rates	13.3	10.6	23.9
Simplicity	9.3	12.1	21.4
Totals	100.0	100.0	100.0

Objectives	Expected Weights SERC	NPCC
Revenue Adequacy	19.75	19.75
Revenue Stability	7.25	7.25
Energy Conservation	9.10	9.10
Reduction in Generating Plant Reqts.	14.55	14.55
Cost of Service	11.50	11.50
Reasonable Residential Rates	7.15	7.15
Attractive Industrial Rates	4.60	4.60
Price Comparability	4.05	4.05
Stability of Rates	11.95	11.95
Simplicity	10.70	10.70

The number of cells with less than 6 is not over 20%; therefore, the chi-squared test is still considered valid.

d.f. = 9; $\chi^2 = 8.00$; at $\alpha = .05$; $\chi^2 = 16.919$

The hypothesis is not rejected. There is a significant difference between the weights for the two regions.

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