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Least-Cost Transportation Planning in ODOT: Feasability Report

Anthony M. Rufolo
Portland State University

Lois M. Bronfman
Portland State University

James G. Strathman
Portland State University

LEAST-COST TRANSPORTATION PLANNING IN ODOT

Feasibility Report

By

Anthony M. Rufolo
Lois Martin Bronfman
James G. Strathman

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Oregon Department of Transportation
Salem Oregon 97310

Center for Urban Studies
School of Urban and Public Affairs
Portland State University
Portland, OR 97207-0751
(503) 725-4020
(503) 725-5199 FAX
http://www.upa.pdx.edu/centers.html#CUS

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Abstract

Least Cost Planning or Integrated Resource Planning is used in the electric utility industry to broaden the scope of choices to meet service requirements. This typically includes methods to reduce the demand for electricity as well as the more traditional electric generation options. Techniques have been developed to compare the cost of electricity generation with the cost of meeting service requirements by reducing electricity usage. In addition to cost considerations, utilities typically take account of uncertainty associated with forecasts and a variety of other considerations in specifying their least cost plan.

The basic economic rationale, that users pay a price less than the cost of providing additional service, is the same between the utilities and transportation. However, there are also fundamental differences. Consumers are more concerned about the nature of the service for transportation, the use of the transportation system is affected by the quality of service provided, transportation modes have system or network relations that make it harder to treat sections in isolation, and transportation funding levels determine the amount of transportation service provided while forecasts determine the amount of electricity to be provided. Hence, although least cost principles hold promise to improve transportation planning, the techniques used in the utility industry can not be directly transferred to transportation.

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LEAST-COST TRANSPORTATION PLANNING IN ODOT

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EXECUTIVE SUMMARY

Least-cost planning (LCP) or integrated resource planning (IRP) is used in the electric utility industry to broaden the scope of choices to meet service requirements. Rather than focus exclusively on building additional generating capacity to meet expected demand, utilities also consider methods to reduce the demand for electricity. These are typically referred to as demand-side management (DSM) programs. The basic procedure is to identify supply options to meet expected requirements, identify DSM options, and then pick the least costly combination of supply side and demand side options. To make this comparison, many utilities calculate a standardized unit cost of electricity, called the levelized cost of each option. The levelized cost is the cost of generating electricity for supply options or the cost of reducing the amount of electricity needed for demand options. This calculation makes comparisons across widely different options more consistent. While choosing options with the lowest levelized cost is one aim of the utilities, other factors enter into the final mix of options chosen.

Evaluation of the literature on least-cost planning and interviews with utilities using LCP or IRP indicate that the process is far from a uniform or mechanical one. There are a variety of criteria that are used in defining cost and a large array of issues other than cost that enter into the final mix of options chosen. Further, the methodology has evolved gradually over a long time period and relies on a large number of studies that have been done to evaluate the effectiveness of various demand-side options.

The basic economic rationale for least-cost planning in the utilities is that customers were being charged a price for electricity that was below the cost of generating additional electricity. Because customers were not paying the full cost of adding to capacity, they had a tendency to use more electricity than would be efficient. Hence, some investments to convince customers to use less electricity would be less costly than generating the additional electricity. In this respect, there are clear parallels between the situation the utilities have faced and the current situation in transportation.

The least-cost planning framework has the potential to substantially improve transportation planning in terms of economic efficiency. However, it can not be adapted without first addressing fundamental differences between transportation planning and electric utility planning. Four differences between the systems have been identified as being particularly important. These are summarized in Table 1.

First, the level of consumer satisfaction with the method of service provided is more of an issue in transportation than in the provision of electricity. Most least-cost options in the utility industry, especially those relating to non-business consumers, do not change the level of service that the customer receives, they just change the amount of electricity used in achieving the customer's service goals. For example, customers typically do not care whether the comfort level in homes is achieved by generating more electricity, by improving home insulation, or by using more efficient heaters and air conditioners. Transportation, especially personal transportation, involves many characteristics that customers do value, such as flexibility, comfort, and time. Hence, evaluation techniques must be sensitive to customer satisfaction with the method of service provision.

Table 1

Key Differences Between Electric Utilities and Transportation

Issue	Electric Utilities	Transportation
Consumer Satisfaction	Maintained or improved. Service goals are usually achieved.	May change in either direction. Time, flexibility, and other characteristics of the service are affected by the policies chosen.
Service Quality	Amount of electricity used is seldom affected by service quality (e.g., "brown-outs") for residential users. Goal is for quality to be independent of usage.	Quality of service is an integral part of the planning process. Changes in quality affect usage.
Project v. Modal System	Most supply and demand options are largely independent of each other (e.g., an insulation program does not affect costs or benefits of most other options).	Each segment of the modal system affects other segments (e.g., eliminating a bottleneck at one point may create bottlenecks elsewhere in the system).
Level of Service	Expected to provide all electricity demanded at prevailing price in most circumstances.	Funding level determines the amount of service provided. Projects compete for budget. Some DSM options may raise revenue.

Second, use of the transportation system is affected by the quality of the service provided. Delays caused by congestion of roads or mass transit systems may cause changes in travel patterns. Reducing these delays then may increase the number of people using the system. These changes in the quality of service are less likely to occur because of choices made regarding provision of electricity. The evaluation techniques must be sensitive to potential users of the transportation system, or those diverted from using it because of service quality.

Third, each transportation mode has system or network characteristics that make it less feasible to treat parts of the system in isolation. These network components are not of great importance in evaluating electricity generation or consumption, but they are in evaluating transportation. In particular, some demand management options that might be considered at the mode level are largely precluded if the analysis is done at the project level. For example, Oregon is currently considering the effect of land use decisions on the transportation system and vice versa. However, certain options relating to land use, such as increased density, may not be effectively evaluated as alternatives to specific road improvements. Increased density in a particular area is likely to increase the demand for road capacity in that area even if it reduces the demand overall. Hence, evaluating the land use option relative to a specific road improvement option may generate different conclusions than comparing the options at a more aggregate level.

Fourth, electricity planning is done with the expectation that all of the electricity required will in fact be provided. In transportation planning, different levels of service associated with different funding levels are routinely analyzed. Also, because many transportation demand management options raise revenue, the impact of changes in revenue must be considered.

RECOMMENDATIONS FOR FURTHER ACTION

The differences between electric utility planning and transportation planning mean that while the process of least cost planning can be applied to transportation, the specific method used by the utilities has only limited direct usefulness. The basic process of calculating levelized cost and comparing projects on this basis is not directly applicable to transportation. In the electric utility industry, the cost of generating units of electricity can be compared readily to the cost of reducing demand for units of electricity. However, in transportation there are no similar units of analysis for comparison. Further, consumer satisfaction with the transportation system, network considerations, and evaluation of the level of service to be provided generate additional complications for the transportation planning process.

We have identified two alternative approaches for further development of the least-cost technique to transportation planning in Oregon. The first is a broad-based analysis of transportation modes and comprehensive strategies associated with improving transportation services and reducing the demand for transportation services. This level of analysis would focus on major policy options affecting the transportation system. It would be at this level that policies such as congestion pricing, land use changes, and related policies could be fairly evaluated. In addition to broad policy direction, this type of analysis could generate criteria to be used in evaluating specific transportation projects. For example, communities that implement certain policies may be given a higher priority for transportation investments. This approach is likely to require costly analysis and does not directly provide information regarding specific transportation investments.

The second basic approach is to adapt the utility levelized cost approach to analysis of specific transportation improvements. To implement this approach, a specific improvement would have to be identified as well as the level of service likely to result from that improvement. Other options to achieve this level of service could then be considered, both other supply options and demand side options. All options could then be evaluated on some comparable basis, possibly even using the levelized cost approach as it is used in the utilities. If an option could provide the same level of service at a lower cost, then it should be an improvement over the base case. This approach does not always find "the" best solution since there are likely to be limitations on the range of options considered. Also, consumer satisfaction must be considered so that changes in service are not accomplished at the expense of consumer time or other service characteristics.

Either of these approaches is open to a substantial range of options in actual implementation, and it may be that both must be developed to appropriately implement the least-cost planning approach. An important lesson from the utilities is that there does not appear to be one best way to do least-cost planning. Rather, it is important to broaden the range of options considered to achieve transportation objectives and to generate information on the cost and effectiveness of various alternatives.

Two specific issues will be important in the first phase of any attempt to implement the least-cost approach. The first is the identification of objectives. A benefit of the technique for utility planning is the clear objective to either generate electricity or reduce the demand for electricity. The objective for transportation planning is not so readily identified, and there are likely to be several objectives that must be considered. For example, mobility is a conceptually clear objective for transportation, but there are no obvious ways to measure this objective for planning purposes. Alternatively, reducing vehicle miles traveled (VMT) is a concrete objective, but it does not fully reflect the service provided to transportation users. Many policies that reduce VMT may make users of the transportation system worse off.

The second important issue will be to determine the procedure by which each option will be evaluated. The major benefit of the least-cost planning technique is to provide a mechanism for comparing disparate solutions to a problem that allows advocates for each to understand why their preferred solution was (or was not) adopted. If the process is not perceived as giving all options a full and fair consideration, it is likely to be a futile exercise.

Finally, the cost of the analysis must be considered. The complications in the evaluation caused by the differences between transportation and provision of electricity could substantially affect the cost of conducting the analysis. The high potential cost means that there must be a careful evaluation of the complexity of the analysis that will be done for each option. Budget constraints mean that the trade-off is likely be between a systematic application of low cost evaluation to a wide range of options versus selected application of more costly evaluation techniques.

1.0 INTRODUCTION

This report assesses the potential applicability of least-cost planning techniques used in the electric utility industry to transportation planning. We approach the problem from a number of perspectives. First, relying on economic theory, we compare the justification and appropriateness of least-cost planning in the utility market with the transportation sector. Then we clarify the economic definitions of cost-effectiveness, cost/benefit and least cost planning, and suggest how these can be applied in the transportation sector. Our second perspective, looks at the "state of the art" of least-cost planning in the electric utility industry. In addition to reviewing relevant literature and specific utility planning documents, we report on the results of structured interviews with utilities about their least-cost planning process. Finally we briefly review and discuss the current practice of least-cost planning in the transportation industry. Our objective is to clarify the conceptual and practical issues of implementing a least-cost planning framework, and to demystify the process of least-cost planning within the utility industry to better understand what practices and procedures can be transferred to the transportation sector.

Before proceeding, we should be clear that we think some form of least-cost analysis would be a major improvement in transportation planning. However, we are going to be critical of the technique in the belief that it is better to understand its potential shortcomings before devoting substantial resources to its development. We hope that by identifying the potential problems a form of least-cost planning well-suited to transportation can be developed.

2.0 LITERATURE REVIEW

Least-Cost Planning/IRP is a framework for planning developed specifically to change the decision-making in the electric utility industry in a manner which permits rethinking how and why energy is used; and to expand the range of energy options to include both demand-side technologies and strategies (Berry, 1992; Hirst, 1993; Hanson et al; 1991). While a fundamental component of LCP/IRP is the development of conservation supply curves and the use of some form of least-cost analysis for comparison, least-cost planning addresses additional considerations as well. As Hanson et al (1991: 36) observe:

> "A central goal of least-cost planning is to provide energy services at minimum cost using demand and supply options. Minimizing the cost of energy services....extends beyond achieving the lowest cost for power supply; meeting energy requirements efficiently requires attention to economic, environmental, and social effects. Thus, the intent of least-cost planning is to consider all relevant factors explicitly, and to balance competing interests to determine the method for meeting energy requirements."

The literature on Least Cost Planning/IRP in the electric utility industry spans over two decades. It is inclusive of studies and documents under a number of subject headings including demand-side management (DSM), demand-side planning, load management, conservation, and integrative resource planning (IRP). For this report we relied on a literature search at the Bonneville Power Administration Library. We accessed *Proquest* and reviewed documents published since 1987. In addition, we sought recommendations from a number of experts in the field, including Martin Schweitzer, Eric Hirst, Edward Hillsman and Benson Bronfman, all either currently or formerly associated with Oak Ridge National Laboratory, which is widely recognized as a pioneer on the subject. Finally, we obtained materials from the libraries of several private utilities, research firms, the Northwest Power Planning Council, and the Electric Power Research Institute.

2.1 OVERVIEW OF LITERATURE ON LCP/IRP

The literature on LCP/IRP covers a variety of perspectives and issues. The early discussions are marked by a philosophical/theoretical discourse on the conceptualization of Least Cost Planning (e.g., Lovins, 1977, Sant et al, 1979, Gellings et al, 1988). As individual utilities, PUC's and states attempted to develop least cost planning frameworks, discussions turned to exploring or disputing specific methods and techniques. Attention was focused on financial and economic assumptions, screening techniques, appropriate cost tests, and measurement techniques (e.g., Northwest Power Planning Council, 1989; Train, 1993; Kahn, 1991; Hirst, 1992; Borlich, 1994; Hanson et al, 1991).

Implementation of demand side management strategies led to the development of a substantial body of the literature devoted to documenting and evaluating their performance (e.g., Bronfman, 1986; Hirst, 1990; Hirst and Reed, 1991; Weisbrod et al, 1994); and the spread of LCP/IRP was facilitated by literature on the costs and performance of supply and demand technologies (EPRI, 1991,1993, 1993) and market information on packaged modeling aids (EPRI, 1989). Another part of the literature documents and evaluates different strategies (e.g., mandates or incentives) for getting utilities and customers to adopt demand-side measures (e.g., Nadel and Jorder, 1992; National Association of Regulatory Utility Commissioners, 1992).

Finally, as LCP/IRP has been adopted by more utilities a number of researchers turned to the problem of evaluating the process and performance of Integrated Resource planning in meeting the goal of increased use of demand-side resources in planning (Schweitzer et al, 1990; Hirst et al, 1991; Yourstone, et al, 1991; Hirst, 1992). Other studies looked at the operation and effectiveness of different strategies for involving groups and individuals outside the utility in the planning process (Cohen and Chaison, 1990; Raab and Schweitzer, 1992; Schweitzer and Raab, 1992; Schweitzer et al, 1993; English et al, 1994).

2.2 CONCEPTUAL ORIGINS

Most firms will argue that they try to produce their output for the lowest cost possible, and the utilities certainly try to make that case to their regulators. However, producing a given amount of output for the lowest cost is not necessarily the most efficient way to proceed. It is also necessary to consider the value of the output created and to weigh the cost of production against the value of the output. In addition, a private producer will only take account of the private cost of production, and there may be other effects that are not taken into account. If market conditions do not provide incentives for efficient behavior, it is termed a market failure (Bator, 1958).

A variety of methods have been derived to evaluate policies intended to correct inefficient use of resources in the presence of market failure. The most common is cost-benefit analysis (e.g., see Mishan, 1988; Anderson and Settle, 1977; or Schofield, 1987). The economic literature on cost-benefit analysis defines a specific set of procedures to conduct the evaluation, but the term is often used by others to denote any comparison of cost and benefits. When a specific goal is to be achieved, it is not necessary to evaluate benefits. Policies that all achieve the same outcome can be evaluated on the basis of least cost, and this type of analysis is referred to in the economic literature as cost-effectiveness analysis (e.g., Anderson and Settle, 1977: 16; Mishan, 1988: 110-114; Schofield, 1987: 64-66, 108-110).

The concept of least-cost analysis evolved from cost-benefit and cost-effectiveness analysis. This is fairly clearly seen in the widely used manual Economic Analysis of Demand-Side Management Programs, published by the California Energy Commission and the California Public Utilities Commission in 1987. This manual does not use the term "least-cost planning," but it specifies many of the methods and tests used by utilities in least cost planning. The terminology in the manual relates to cost-benefit and cost-effectiveness.

The concept of Least Cost Planning/IRP has its origin in the energy debates in the 70s which focused on the basic questions of how much energy would be required for who, and how best, from a strategic perspective, to organize energy use in the nation (Gellings et al, 1987). In these debates Amory Lovins championed "soft energy paths." Focusing initially on energy forecasts, Lovins challenged existing energy projections and proposed that the nation pursue a broad range of "soft" technologies (as opposed to "hard" alternatives like large scale electric generating plants) which, if adopted, would promote greater efficiency, reduce demand and restructure how energy services are provided (Lovins, 1977).

Central to Lovins' argument were the notions that the consumer was not interested in consuming energy *per se* but in its end uses, and that flexibility, reliability through diversity, and environmental concerns were dimensions that needed to be built into energy planning. These ideas were teamed with the idea that regulators and other decision-makers should consider all costs (i.e., total social costs) over the long term in making decisions.

The actual term "Least-Cost Planning" was coined by Roger Sant (Sant et al, 1979),who proposed estimating the energy savings of cost competitive, end use efficiency strategies and comparing these costs with conventional energy forms. Both Sant's and Lovins' visions included seeking least-cost solutions from a total societal perspective for all energy consuming sectors, including transportation.(Lovins, 1977).

While these debates were played out in public forums, the actual context in which utilities made their decisions was changing dramatically, and in a way as to make consideration of demand-side resource strategies more appealing (Hirst, 1992; Hanson; 1991; Gellings et al, 1987; Clinton et al, 1986). The oil embargo and subsequent inflation contributed to the increase in the costs of large generating plants while at the same time, energy forecasts were proving unreliable as price increases and the adoption of energy efficient technologies were reducing demand for electricity. Utilities in turn were proposing rate increases which brought the historically private decision-making processes under more critical public scrutiny.

By the mid 70s the public policy climate had also changed. Federal legislation was passed which promoted the "proper and efficient" use of energy through consideration of more competitive supply and demands-side resources (1975 Energy Policy and Conservation Act; 1978 National Energy Conservation and Policy Act; 1978 Public Utilities Regulatory and Policy Act), and a new regulatory framework was being constructed in the states (Clinton, et al, 1986). These changes, combined with the ideas and activism of conservation proponents, shifted utility planners thinking away from traditional planning to the development of a new form of least cost planning.

2.3 EVOLUTION OF LEAST-COST PLANNING TO INTEGRATIVE RESOURCE PLANNING

Since the mid seventies the concept of Least-Cost Planning and the methods behind it have gone through many changes, emerging in the latter part of the 80s as Integrated Resource Planning. The Electric Power Research Institute (Gellings et al, 1987) documented this evolution in its study Moving Toward Integrated Resource Planning: Understanding the Theory and Practice of Least-Cost Planning and Demand-Side Management. Hanson et al (1991), Mitchell (1992) and Hirst (1992) provide further documentation of the evolution of the planning methodology through 1994.

While today demand-side management within the utilities is a subset of activities which contributes to the Integrated Resource Plan, Gellings et al (1987) document an early conceptual distinction between least-cost planning and demand-side management which underscores the different perspectives of planners within and outside utilities which persisted over two decades. In the early years, utilities developed methodologies for "demand-side management." They shied away from the term least-cost planning in order not to be associated with the breadth of the ideas linked to Lovins and others, and so as not to undermine the notion that they had always made "optimal" business choices. While both perspectives shifted the focus from supply options to the demand-side, they differed in many ways.

LCP had more of a societal perspective; DSM more of a utility perspective.

LCP usually considered all forms of energy; DSM usually concentrated on electricity.

LCP usually stressed the maximum technical potential of demand-side alternatives; DSM stressed likely market acceptance and use.

LCP generally stressed the long term; DSM focused on both the short and long term.

LCP included environmental and national security considerations; DSM focused on the value of energy services rendered and received.

LCP concentrated on the gross, aggregate impact of forecasting programs; DSM also included details like specific end-use and time-of-day energy consumption.

LCP's scope was more likely to involve a state or the nation; DSM's scope was one utility. (Gellings et al, 1987).

In practice the two concepts were often confused and over time the specific methodologies for selecting least-cost strategies converged into what is now known as "Integrated Resource Planning". These differences between the LCP and DSM perspectives, however, have been played out in conflicts over what cost tests to apply (Burkhart, 1990), what economic assumptions to make (Ruff, 1988;), and when and how to include environmental costs and benefits in the analysis (Burkhart, 1989).

As with the conceptual underpinnings, the development of the practice of LCP/IRP has been iterative and unique to the perspectives of different planning bodies. The archives of many utilities contain numerous studies and papers which document the conceptual and process evolution within the organization (e.g., Bull, 1992; Corum and Gibson, 1991).

Still there are models for LCP/IRP which are generally accepted by the industry. For example, in the early years of development some utilities attempted to emulate the methods developed by of the Northwest Power Planning Council. Others looked to the Bonneville Power Administration to define a least-cost planning process more directly applicable to an organization whose function it is to sell electricity. By the late 80s and early 90s, research was being conducted which attempted to describe the process as it was being implemented by those utilities with the best reputation in the industry for IRP (Donovan and Germer, 1989; Schweitzer et al, 1990; Hill et al, 1992; Hirst et al, 1991), and numerous states were putting in place specific requirements for Integrated Resource Planning.

Drawing on these studies, his own experience, the regulations and laws guiding IRP, Eric Hirst identified the components of a "good" integrated resource plan (Hirst, 1992). Ironically, the convergence of views as to what constitutes IRP came at a time in which the rule changes with regard to the buying and selling of electricity were moving many utility planners to rethink the planning process. The process of IRP as described by Hirst is now being redefined (Toon and Schaffhauser, 1994).

2.4 COMPARISON OF LCP/IRP WITH TRADITIONAL UTILITY PLANNING

Students of LCP/IRP are in general agreement as to its basic characteristics (Hirst, 1992, 1994; Hanson et al, 1991; Gellings, 1987). These include

- explicit consideration of objectives;

- explicit consideration and fair treatment of a wide variety of options including demand, supply, transmission and distribution, and pricing alternatives;

- consideration of environmental and other social costs of providing energy services;

- public participation in the development of the resource plan;

- analysis of uncertainties associated with different external factors and resource options.

LCP/IRP differs from traditional utility planning both in process and in the application of procedures. Hanson et al (1991) observe that a significant feature of least-cost planning is "its function as a planning process rather than only as a planning technique". The process, as they define it, "encompasses a broader range of participants, a larger set of objectives, and a more diverse set of options than does traditional electric planning" (See Table 2). Donovan and Germer (1989) and Hirst (1993) cite more specific changes in planning which came with the adoption of LCP/IRP.

Table 2
Features of Traditional and Least-Cost Planning

Feature	Traditional Planning	Least-Cost Planning
Options	Supply options	Demand & supply options
Focus of economic cost analysis	Rate-payers	Multiple groups (society, program participants, rate-payers, individuals, etc.)
Objectives	Single	Multiple
Environmental quality	Meet minimum requirements	Improve quality beyond minimum levels
Judgment	Implicit	Explicit
Preferences	Implicit	Explicit
Reliability	Meet traditional standards	Choose appropriate reliability level
Role of public groups	Intervention	Participation

Source: Hanson et al (1991)

2.5 FORECASTING

Traditional utility planning forecasted future demand largely by extrapolating past consumption trends into the future with very little alteration; growth was considered stable and predictable. The events of the 70s exposed the weaknesses of this approach. Increasingly, utilities adopted the techniques and tools of econometric forecasting and in some cases end-use forecasting (Donovan and Germer, 1989). In addition, utilities recognized that forecasting was an imperfect science. The development strategies and procedures for dealing with uncertainty also distinguishes LCP/IRP from traditional utility planning (Donovan and Germer, 1989; Sheets and Watson, 1994).

2.6 DEMAND-SIDE MANAGEMENT

LCP/IRP differs from most traditional planning in that it places demand-side options on "an equal playing field" with supply alternatives. Part of the process of screening options involves the development of conservation supply curves (Donovan and Germer, 1989). Typically, utilities establish the "levelized costs" or "net present value" of different resource development options. Options are ranked using a number of cost-effectiveness tests (e.g., participant test; the rate-payer impact test; total resource cost test or utility test). Each of these tests represents a different perspective on the costs and benefits of a resource option. For example, the RIM test (rate payer impact) looks at the costs and benefits from the perspective of the impact on the bill of the customer. For a review of standard practice see the California Energy Commission and Public Utilities Commission (1987). Results of these tests allow options to be selected based on the "avoided cost" of construction of a large electric generating facility.

Making explicit these different perspectives as well as incorporating them into the planning process is a significant change from the traditional utility planning process. Debates over which tests to apply define much of conflict between the public utility commission and the utilities. However, recommended practice argues that the tests are not to be used individually or in isolation; they must be compared with each other. As stated by the California Energy Commission, "this multi-perspective approach will require utilities and Commission to consider tradeoffs between the various tests." This approach is in fact taken by many utilities in their plans (for example, see the testimony of San Diego Gas and Electric Company to State of California Energy Resources Conservation and Development Commission, October, 1994).

Quantifying savings of conservation measures and identifying costs was a new area of inquiry for most utilities. Donovan and Germer (1989) observe, "the DSM component of the LCP process is filled with theoretical as well as practical difficulties." How much do the programs cost? How much energy is saved by specific programs? Who is paying for the saved energy? Who should pay for conservation? As they note, in the last decade considerable resources have been devoted to these questions in evaluating the performance and impact of DSM programs (American Council for Energy-Efficient Economy, 1992; Hirst and Reed, 1991; Cambridge Systematics, 1994; Northwest Power Planning Council, 1994).

2.7 SUPPLY RESOURCES

What has happened with the supply options? While utilities continue to analyze supply side alternatives, the process differs from traditional planning in a couple of ways. As the utility market has been deregulated, utilities have given increased attention to purchased power. In addition, both staff and the tools used for analysis have become more sophisticated (Donovan and Germer, 1987).

2.8 INTEGRATION

Having selected a set of resource development options utilities attempt to find an "optimal" or acceptable resource portfolio. This activity is also not new to utility planning. What is new is including consideration of demand-side options in the selection process. In addition, as with supply-side planning, the process and procedures for selection of the appropriate mix of options has become increasingly sophisticated. Hirst (1992) describes two basic integrative methods. One is a dynamic programming model which selects the mix of options that optimizes the stated objective. The other uses a simulation model in which alternative resource mixes are tested. In both cases the process has become more quantitative and explicit than with the traditional planning process.

2.9 UNCERTAINTY TESTING

Another characteristic of LCP/IRP which distinguishes it from traditional planning is a greater emphasis on sensitivity or uncertainty analysis in the process. These strategies grew out of the utilities' recognition of the limits to their forecasting abilities. Hirst (1992) lists five different analytical techniques used by utilities for uncertainty analysis: scenario; sensitivity; portfolio; probabilistic; and worst-case. Each of these techniques requires assumptions about what is given and what is uncertain. Again, making explicit these considerations has become an important part of the process that distinguishes LCP/IRP from traditional planning.

2.10 PUBLIC PARTICIPATION

Prior to the 70s, utility planning was, for the most part, an activity which came under routine review by relatively passive public utility commissions. Rising fuel costs and concerns over future development of nuclear power changed the situation. In LCP/IRP the concerns of the public utility commissions and the energy and interests of potential intervenors became channeled into the planning process through a variety of mechanisms. Considerable academic attention has been given to the effectiveness of these different option in terms of increasing the amount of demand-side management included in utility plans (Schweitzer et al, 1992, 1994; Raab, 1992; English, 1994).

2.11 RELEVANCE OF UTILITY EXPERIENCE AS DOCUMENTED IN THE LITERATURE

For the last two decades the least-cost planning process was worked and reworked within the electric utility sector. Is the experience of the utility industry and the specific methodology of LCP\IRP relevant to the transportation planning? On the surface, this experience should be relevant. Transportation demand management had its origins in the same energy debates as the utility DSM (Hillsman, 1993; Birk and Zegras, 1993). Moreover, as the economic and political pressures of the 70s and 80s led to an interest in utility demand-side management, so too one finds in the 1990s similar pressure in the transportation sector. Planners point to the increasing cost of highway construction within a constrained budgetary context. Others focus on the external costs of highway construction (e.g., land use and air quality). Lastly, interest groups and the public are increasingly challenging the transportation decision-making process. For example, in 1991 Maine citizens, in response to a proposed highway project, passed a citizen-initiated referendum, the Sensible Transportation Act (23 M.R.S.A./73).

Aided by Federal legislation which requires consideration of multimodal options; legislative endorsement of "efficient" or " least cost" strategies (e.g. State of Washington, SHR 1928), state and local budgetary constraints, and the interest of a number of individuals and groups active in the transportation policy area (e.g., McCoy et al, 1994; the California Energy Commission, 1994; DeCorla-Souza, 1994; Replogle, 1994; Johnston, 1994; Steiner, 1992), some planners have turned their attention to the experience of the utility industry for guidance. As Sheets and Watson (1994) observe, the value of LCP/IRP in the electric utility industry is that it provides a model of "... a consistent framework in which alternative resource strategies can be evaluated...."

The argument that LCP/IRP provides a consistent framework to compare demand-side and supply-side alternatives is indeed appealing. Our review of the literature suggests, however, that much of the experience of the utilities is unique to that industry. One important variable is the difference in the institutional framework in which planning is done. Then too, the nature of the demand for electricity is not directly comparable to the demand for transportation. We conclude that just as the development of Least Cost Planning /IRP was shaped by the economic, social, institutional, and political forces unique to the electric utility industry, so to, the application of least cost planning to transportation will be structured by the defining characteristics of the transportation sector. Thus, while the body of literature on least-cost planning is extensive, it's usefulness is primarily to suggest a conceptual framework for analysis, and to offer a body of experience for comparison, rather than to provide a "cookbook" for analysis. As Hillsman (1993) and Sheets and Watson (1993) suggest, the task of identifying the similarities and differences between the utility sector and the transportation sector can be an important exercise in shifting the planning focus in transportation and in restructuring planning analysis. This is the perspective recently taken by a number of analysts of transportation least-cost planning, who draw upon the conceptual underpinnings of LCP/IRP and modify them to fit their understanding of the transportation sector.

2.12 LITERATURE ON LEAST-COST PLANNING IN TRANSPORTATION

Literature on transportation least-cost planning supplements a growing number of studies which address transportation demand management and/or multi-modal planning (Ferguson, 1990; Downs, 1992; Wachs, 1991; Kuzmyak and Schreffler, 1990; Orski, 1990; Ulberg, 1994). Analysts have looked to the utility experience with LCP/IRP to provide a framework in which to compare a broad range of supply and demand options to achieve maximum social efficiency (Sheets and Watson, 1992; McCoy, 1994; Dobbs). Each acknowledges that there are important differences between the demand for electricity and for transportation, and that the institutional frameworks in which decisions are made are not comparable. While in agreement that the framework is not "a formal model", each analyst uses the utility experience to raise different issues and to propose different approaches. The diverse perspectives are not mutually exclusive but complementary; they suggest many avenues for change, for rethinking current planning practices, and for research. We review here this small but rapidly evolving literature.

Sheets and Watson review key elements of the Northwest Power Planning Council's experience with LCP/IRP (e.g., setting goals, forecasting, evaluating measures, considering total costs, identification of least-cost mix forecasting, supply and demand screening), and suggest how application of the least-cost principals could lead to improvements in transportation planning. Specifically, they use the Council's experience to raise questions about the goal(s) of transportation planning (access), to suggest the importance of planning for "uncertainty", to discuss ways in which to classify a broad range of transportation options, and to identify "total social costs." Steiner (1992) uses the utility experience to categorize demand management measures and to suggest differences in the regulatory and decision-making environment which affect the implementation of DSM. Finally, she uses the utility experience to argue for congestion pricing and to promote long term planning goals.

Hillsman (1993) also identifies major differences between utility and transportation demand-side management as currently practiced. He summarizes these as differences in the services demanded, the nature and role of infrastructure and equipment, in regulation, and in how services are delivered. Noting that the concepts and procedures for LCP/IRP developed incrementally, Hillsman calls for research which will explore the implications of these differences.

McCoy et al (1994) discusses the utility approach and focuses on the specific elements of least-cost planning which they think are transferable to transportation. These concepts include "the avoided plant concept, supply curves, and use of levelized cost to compare projects with different on-line dates and variable service lives" (McCoy, 1994: 8). For these authors the closest analogy in the utility industry is peak load management applied to distribution system feeder upgrades. This planning is site-specific and extremely data intensive, and "investments in infrastructure upgrades can only be accomplished through understanding the needs of customers/users and then targeting end users and marketing a portfolio of lower cost alternatives" (McCoy, et al, 1994: 14). For them the best way to apply transportation least-cost principals is at the project level.

While the above authors have focused on the general procedures and principals of least-cost planning, others have tackled specific problems in an effort to fill in the information gaps. Eco Northwest is currently leading a team preparing a handbook for least-cost planning for the Federal Highway Administration. Robert Johnston of University of California at Davis, with the support of the California Energy Commission, is exploring the utility of different integrative transportation models while at the same time commenting on the information and organization demands of a new planning approach which applies least-cost principals (Johnston, 1994). Nelson and Shakow (1994) have focused on the development of a planning approach and prototype computer model which incorporates the principles of least cost planning and full cost accounting. In contrast to the recommendation of McCoy et al, their computer model simulates transportation at a systemic level (i.e., the Puget Sound metropolitan region).

Finally, a number of authors have focused on defining and quantifying transportation costs. Todd Litman's (1994) study is one example. Litman's study tackles the problem of "transportation cost analysis." Arguing that significant costs are often ignored in transportation decision making, he explores the implications of current theory and practice for measuring transportation costs on efficiency and social equity. Then, using 11 different modes, he attempts to define all road transport costs, including user, social and environmental and to assign a "best guess" dollar value.

3.0 THE ECONOMIC CONTEXT OF LEAST-COST PLANNING

One of the central theorems of economics is that a market system will lead to an efficient allocation of resources under a certain set of conditions. One of these conditions is that each price in the market be equal to the cost of producing one more unit of the good or service (known as the marginal cost of production). This price must reflect all costs associated with production of the good or service, including the costs referred to as externalities, such as air pollution costs. When price is equal to the cost of producing one more unit, consumers will consume up to the point where their benefit from one more unit is exactly equal to the resource cost of producing that unit. No informed consumer would use more nor less than this amount.

When the price paid diverges from the marginal cost of production there is a tendency for the consumer to use either too much or too little of the good or service. For example, if steel production creates air and water pollution but the cost of the pollution is not reflected in the price of steel, there will be a tendency to use too much steel. Alternatively, if the price is set above the cost of producing one more unit, say because the producer holds a patent, then there will be too little consumption.

When prices send the wrong signals, attempts to intervene in the market are often evaluated using cost-benefit analysis. Cost-benefit analysis is an attempt to identify all of the costs and benefits of a particular action. The general rule is that an activity is desirable if its benefits exceed its costs. Benefits and costs that occur at various future times are adjusted to a present equivalent value through a process called discounting. What economists call cost-benefit analysis is often referred to as social cost-benefit analysis because the procedure considers all costs and benefits for society as a whole. Many applications that are called cost-benefit analyses limit the range of costs or benefits that are considered, so their use does not necessarily promote greater efficiency. For example, a steel company looking at the costs and benefits of producing steel would not consider the air pollution costs in determining how much to produce, but a social cost-benefit analysis would include these costs.

For most goods and services, the benefit is measured in terms of people's direct consumption of the good or service. However, both electricity and transportation are generally valued for their use in achieving other objectives rather than for their intrinsic value to the consumer. Hence, reductions in use may occur without necessarily making consumers worse off. Whether treated as direct consumption items or as items used to achieve other objectives, there will be a tendency to use too much of a good or service that is priced below the cost of producing one more unit.

For electricity, consider the decision to wash dishes. The consumer has a number of choices, but focus attention on the use of a dishwasher. In making the capital expenditure on a dishwasher, the consumer will typically face a range of options regarding energy usage and capital cost. Some dishwashers are more energy efficient than others, but they achieve this by using more capital inputs, such as better insulation or more efficient motors. Economic theory says that consumers should choose more efficient dishwashers by appropriately comparing the value of future energy savings with the higher purchase cost of the more efficient machine. Hence, someone who washes many dishes would be more likely to choose the energy-efficient machine than someone who washes few dishes, and this is an economically efficient outcome in both cases. It is important to note that inducing the person who washes few dishes to purchase an energy efficient machine is a waste of resources if the energy savings do not compensate for the higher capital costs.

In addition to affecting capital purchases, the price of the electricity will determine how often the dishwasher is used. If the cost is very high, the consumer is more likely to wait until the dishwasher is full, and even wash some dishes manually. This may seem like a trivial example, but the implications are important for attempting to identify efficiency enhancing policies. If the price of electricity is below the cost of producing additional electricity, the consumer will take into account the price in determining which type of dishwasher to buy, not the social resource cost of the additional electricity. Hence, the consumer will overuse electricity. Note that there are at least two sources of overuse in this example. The first is that the consumer chooses a less energy efficient machine than would be optimal. The second is that the consumer uses the machine too much once it is purchased.

The ideal efficiency response to this situation would be to raise price equal to the marginal cost of electricity generation. But if the price can not be raised, there is a potential to improve the allocation of resources by convincing some consumers to purchase the more energy efficient machine and by convincing consumers to use dishwashers less frequently. A subsidy to purchase the more efficient machine would overcome one of the problems. The subsidy should be based on the difference between the price paid for electricity by the consumer and the cost of generating the additional electricity used by the less efficient machine (Kahn, 1991). If the subsidy is too large, some people will purchase the efficient machine even though they do not save enough electricity to offset the higher initial cost.

Note that the subsidy would only solve the problem of machine purchase; the price of electricity would still encourage overuse of the machine. In fact, overuse could increase after the subsidy since the cost per load of running the efficient dishwasher would be less than that for the inefficient one. Hence, the subsidy in this case has the potential to increase efficiency, but it would not be as effective as a price increase. In trying to develop demand side management options, it is important to consider the various ways that price distortions could alter behavior.

3.1 LEAST-COST PLANNING PROCESS IN THE UTILITIES

The least-cost planning/integrated resource planning process in the utilities can be interpreted as an attempt to offset the impact of prices that are below the cost of generating additional electricity. The basics of the process are fairly straightforward although the details become quite complex (A more detailed description is presented in Appendix B). Also, the specific nature of the process differs substantially among the utilities that use it (Hirst, 1992; Schweitzer et al, 1990).

The typical first step in the process is to estimate the demand for electricity that would have to be met if the utility does nothing to reduce future demand. This projection becomes the baseline for comparison of various alternatives. Methods to meet this projected electricity requirement through generation of electricity are then analyzed. The various types of supply sources are evaluated with respect to their cost and the amount of electricity that would be generated. To make the projects comparable, the levelized cost of electricity (see Appendix B) is calculated for each option. This is essentially a method that allows for consistent comparison of costs.

The utility then examines actions that might reduce the demand for electricity. This is the demand side management part of least cost planning. Each option is evaluated in terms of its cost and the amount of electricity that would not have to be generated if it were implemented. Electricity that would not have to be generated is then treated as being comparable to electricity generated in meeting the future requirements. To make it comparable on a cost basis, the levelized cost of "producing" electricity through each demand management program is calculated.

The integration process looks at the levelized cost of both supply and demand options to meet the expected electricity requirements, and tries to find the least costly combination. Conceptually, the least costly of the supply or demand options is first selected, then the next least costly and so on until enough resources have been identified to meet the projected requirements. In practice, the integration process is more complicated than this. At the integration stage, other factors, such as flexibility and reliability of the system, are entered into the analysis (Hirst, 1992).

The process is further complicated by the incentives that the utilities have relative to the objectives of their regulators. For example, utilities are commonly reluctant to consider air and water pollution costs as part of the cost of generating electricity because these costs are not paid by the utility nor its customers. Hence, least-cost from the perspective of the utility may be different from least cost from the perspective of a regulatory agency. There are several different types of cost tests that the utilities use, and they can lead to different options being chosen (California Energy Commission and California PUC, 1987).

Some regulatory agencies also do not use the economic rationale as the basis for their least-cost directives. Rather, they seem to consider any demand management option as being part of the least cost package without consideration of its cost relative to the cost of generating electricity. From an efficiency perspective, this can lead to inefficient levels of demand management; and from a utility perspective, it can lead to additional conflict between the utility's least-cost plan and the desires of the regulatory agency (see interview section).

In least-cost planning for utilities, economic efficiency can be improved by reducing electricity consumption. A subsidy to consumers to adopt energy conservation makes economic sense so long as the subsidy is less than the difference between the cost of energy to the consumer and the cost of energy production, where the cost of energy production is the full social cost and not just the cost to the utility. The benefits of such efforts must be carefully evaluated to determine the actual amount of energy saved due to the program. Careful evaluation of the electricity savings from various demand reduction programs is a key part of the least-cost planning process. Concern has been raised that many demand-side management options have been over-used because of inflated estimates of the benefits (Train, 1993).

3.2 RELATION BETWEEN COST-EFFECTIVENESS, COST-BENEFIT, AND LEAST-COST PLANNING

In social cost-benefit analysis all costs and all benefits to all parties are evaluated. The timing of the costs and benefits is accounted for by discounting all future costs and benefits to a present value. This can be a very time-consuming and costly procedure, and it is open to disagreement regarding the monetary value of various costs and benefits, as well as the appropriate discount rate. Cost effectiveness analysis removes some of the most ambiguous parts of most cost-benefit studies by assuming that a specific level of benefits is to be provided and then trying to determine the least costly way to achieve this level of benefits. Not having to evaluate the monetary value of benefits eliminates many of the most controversial parts of a cost-benefit study since benefits are typically much harder to evaluate than costs. Especially in public infrastructure investment, it is easier to determine the cost of a project than it is to determine the value of the benefits that will be generated. Moreover, costs tend to occur near the beginning of the project while benefits are typically spread over a long time period. Hence, the choice of discount rate is less important in evaluating the cost of the projects than it is in evaluating the benefits.

The term "cost effectiveness" is sometimes used to represent the unit cost of achieving some stated objective. For example, to compare two projects with different amounts of electricity saved, the comparison could be in terms of cost effectiveness per unit of electricity saved. This procedure also eliminates the direct requirement to evaluate benefits, but it makes the implicit assumption that all units of the output are interchangeable, and that enough units will be provided by various means to achieve a specific objective. In the case of electricity, the objective is to "provide" a given amount of power either through generation or through conservation. Hence, picking the least costly methods among a variety of options would generate the desired outcome at least cost among the options considered. However, this approach does not evaluate the overall benefits relative to the overall cost of production to determine if the "right" amount is provided. Using our dishwasher example, the procedure determines the least costly combination of efficient dishwashers and electricity to achieve the consumer's desired level of dish washing, but it does not affect the over-use of electricity from using the dishwasher too much.

To the extent that least-cost planning can be compared to these other techniques, it is closely related to cost-effectiveness analysis. While it is an oversimplification to state that the major thrust of least-cost planning is to generate a cost-effective plan to provide a given set of services, the technical part of the analysis is commonly framed in this manner. It is in the latter part of the process, when flexibility, uncertainty, and other factors enter into consideration, that least-cost planning deviates from simple cost effectiveness analysis. The comparison is summarized in Table 3.

The major difference between transportation and electricity generation is the need to evaluate benefits, or at least to consider changes in peoples' perceptions of their well-being. Because transportation is not a homogeneous commodity, different types of transportation services can not be treated interchangeably. There are two ways to approach this issue. The first is to try to evaluate changes in benefits directly. This would include evaluation of changes in travel time, people's willingness-to-pay for comfort, convenience and flexibility and so on. Alternatively, the cost of a subsidy required to get people to change their behavior could be compared to the difference between marginal cost and price in the two situations.

For example, suppose that a person drives to work at a full social cost of $10 per trip, but that the out-of-pocket cost is only $5. The bus for the same trip charges $1 and has a full social cost of $3. It might appear that the savings from convincing the person to use the bus is $7 per trip, but this does not take into account the difference in the trips as perceived by the commuter. By choosing the auto when the cost is already $4 higher than the bus, the person is showing that they value the auto at least $4 more than the bus for that trip. This may be due to time savings, flexibility, or other factors. A careful evaluation of costs and benefits would include estimations of the value the person places on other characteristics of the trip by the two modes. Suppose that the person values the auto trip at $6.50 more than the bus trip. In this case, the person would choose the auto even though the bus would be the more efficient choice.

Table 3

Cost-Benefit, Cost-Effectiveness and Least-Cost Analysis

Method	Description	Advantages	Disadvantages
Cost-Benefit	An accounting of all costs and benefits of a project to determine if there are net benefits to society.	Well-specified methodology. Accounts for all costs and benefits.	Can be very data-intensive, time-consuming, and costly. There may be disagreement about key values, especially non-market values like the cost of pollution.
Cost-Effectiveness	Compares the cost of achieving a specific outcome by different means.	Less costly and time-consuming, and avoids the problems of estimating the value of benefits.	Requires that the level of service be specified in advance.
Least-Cost	Least cost method to achieve a given level of service. Very similar in concept to cost-effectiveness, but includes issues other than economic cost in the analysis.	Well-defined methodology. Also avoids estimation of the value of benefits.	Parts of the process are specific to the utility industry and do not readily transfer to transportation.

Rather than try to estimate all of the benefits to the commuter of each mode, we could proceed as follows. The person does not take into account the extra $3 per trip in cost to others associated with the car rather than the bus since this is the difference in the external costs. If the person would take the bus for any subsidy of less than $3 per trip, there is a net gain for society. Note that the net gain may not be very large. For example, if other characteristics make the auto trip worthwhile for an additional monetary cost difference of up to $2.50, then the shift to transit would generate a net social gain of only $.50 (i.e., the difference in total cost minus the consumer's loss in satisfaction). If offered a subsidy of $3, the consumer would then switch to the bus but, as noted, the net savings to society from this switch would be only $.50 because much of the savings in cost is off-set by the reduced consumption value. Nevertheless, any traveler that accepts the subsidy generates a net improvement in efficiency, and it is not necessary in this case to evaluate the benefits to each individual.

Changes in consumer satisfaction are more problematic if the consumer is not given a choice. For example, if regulations force a person to switch from a car to a bus, say because autos are banned from the downtown, then it is absolutely imperative to measure the change in consumption and the value the consumer places on this change. For example, someone might be willing to pay up to $15 additional to be able to use an auto rather than mass transit. If this person is forced by regulation to use mass transit, there is a net loss of $12 from the switch (the person's loss minus the social cost savings).

While these points are acknowledged in the least-cost utility planning literature, few programs substantially alter a person's perception of the benefits they receive, so the issue does not really come up. Changes in travel behavior are likely to have much greater impact on a person's satisfaction than changes in the source or use of their electricity. When personal satisfaction with the transportation system is affected by demand side management or other programs, evaluation of changes in benefits may substantially increase the complexity and cost of the analysis.

4.0 THE RELATIONSHIP BETWEEN UTILITY AND TRANSPORTATION LEAST-COST PLANNING

In essence, the fundamental problem that led to the use of least-cost planning in the utilities is the same as that in the transportation arena: people do not pay the full marginal cost of transportation just as they were not paying the full marginal cost of electricity. When people pay less than the marginal cost of providing a resource, they use too much of it from a social efficiency perspective. Hence, taking actions to induce them to use less of this resource may lower overall social cost.

Other issues also contributed to the adoption of least-cost planning by utilities. For example, the cost and difficulty of siting new power plants were increasing, and concern over environmental impacts of electricity generation were increasing. Most of these issues can be viewed as relating to the cost of generating additional electricity. Much of the impetus toward least-cost planning in transportation appears to be related to similar concerns. The cost of adding capacity to the road system is increasing as are concerns about environmental impacts. From a cost perspective, these represent an increase in the cost of adding users relative to the cost for existing users. In economic terms, the marginal cost of developing facilities to accommodate new trip making is growing faster than the average cost, leading to greater efficiency distortions.

Many people will correctly argue at this point that planning, whether in the utilities or in transportation, encompasses more than what an economist defines as "social efficiency." While this is clearly true, there are two points to consider. The first is that least-cost planning as practiced in the electric utility industry does indeed take into account many factors other than social efficiency. The second is that the underlying rationale to consider least cost planning is to improve efficiency. Hence, while other considerations will be subsequently addressed in this report, the major emphasis will be on the use of least cost planning to improve the efficiency with which Oregon meets its transportation requirements.

The first lesson to be learned is that the traditional approach to planning in both the utilities and in transportation is too narrowly focused. In the utilities, the standard approach to planning was to make a projection of the need for electricity at some point in the future and then to determine how to make sure that sufficient generating capacity would be available.

From an economic perspective, there was an implicit assumption that the demand for electricity was very inelastic (i.e., that people would continue to consume the same amount of electricity no matter what its price). In these circumstances, a planning procedure oriented toward providing that amount of electricity would make sense. While the energy crisis of the 1970's demonstrated unequivocally that people's energy consumption is sensitive to price, regulatory constraints also meant that allowing prices to rise to the level of marginal generating costs was not a viable option for directly affecting energy consumption.

Faced with rising cost for new generating capacity and evidence that energy conservation was a viable alternative, the utilities and their regulators began to look at the possibility of reducing the demand for electricity as an alternative to increasing generating capacity. The least-cost planning technique was identified as having the potential to create a "win-win" situation for utilities and rate-payers. In an appropriate regulatory environment, the utilities could convince their customers to use less electricity while slowing the rate of increase in their average cost of generating electricity. This was also attractive to many of the critics of the utility industry because it created an opportunity for the utilities to consider environmental costs and other factors in their decision-making.

The early attempts at least-cost planning were simply efforts to introduce demand reduction techniques (Hillsman, 1993; Sheets and Watson, 1994). These could be as simple as subsidizing insulation for people who heated their homes with electricity, or as far-reaching as working to change building codes to require more insulation in new homes. A key element in the development of least-cost planning was the building up of a body of knowledge about the effectiveness of various demand-side options. The development of this body of knowledge, its transferability across utilities, and the focus on effectiveness of policies, have all been important in the acceptability of the technique among the utilities.

Transportation planning has been undertaken in much the same way as electric utility planning. Planners tend to forecast travel demand and then consider improvements that will meet desired level-of-service objectives. A major change in emphasis occurred with the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). At the very least this act requires comparison across modes in making transportation investment decisions. Other transportation and planning considerations have entered to make even broader considerations important in transportation planning. In response, a number of people have suggested that the utility least-cost planning approach could be adapted to transportation planning.

While there are many similarities between utility and transportation planning, there are also important differences. The first is that the least-cost plan in electricity is almost exclusively focused on the generation of electricity or its consumption. There is very little emphasis on changes that lead consumers to get less satisfaction from their use of electricity. Where the change in activity does affect the consumer, there is more emphasis on mitigation than on evaluation of the cost or benefits of that change. For example, use of an energy efficient appliance does not substantially affect consumer satisfaction. Where consumer satisfaction is affected, for example by changes in lighting, the emphasis has been on finding situations where this impact is not of great importance or on mitigating the impact. Hence, the utilities have not placed much emphasis on evaluating the benefits or costs to consumers of changes in satisfaction. This is less true for commercial and industrial users, where some consideration of changes in the quality of service (e.g., interruptable service) have been evaluated; but the general approach puts little emphasis on evaluating changes in consumer satisfaction.

Transportation services can not be treated this way, especially personal transportation services. Any change in mode, trip length, trip scheduling, or other aspect of travel is likely to affect well-being. People are concerned with many aspects of the transportation system, such as safety, convenience, and flexibility, so that each trip can not be treated in isolation. Addressing changes in the value of service to commercial and industrial users is likely to be more readily accomplished than the evaluation of changes in service for individuals.

Second, the quality of transportation services is affected by the rate of use while the quality of electricity services are not for most customers. In effect, quality deterioration is used as a method to identify needed transportation improvements. Hence, changes in usage change the quality of service and cause changes in behavior. This is most clear with respect to congestion. Delays caused by congestion deter some trip-makers from using a transportation mode. Hence, reducing congestion will shorten delays and cause some increase in use by those who were deterred by the congestion. In electricity consumption there is no similar quality-induced change in usage.

The third difference is that the value of any one segment of a transportation mode is dependent on the availability and quality of other segments of the mode. For example, an important issue for mass transit is the collection of riders before the trip and their distribution after the trip. Without convenient collection and distribution, the mass transit system does not function well. The more options that exist, the more valuable any one segment of the network becomes. Roads that dead-end or run into serious congestion are much less valuable to the user than roads that offer easy access to many places. Hence, the network aspect is much more important in transportation than it is in electricity.

Another aspect of the network element is that changes in one part of the transportation network have effects over other parts of the network. Thus, eliminating a bottleneck may cause traffic to divert from other roads, thereby increasing the service level on the alternate routes. Again, this is much less of an issue in utility planning. A related issue is that there must be some understanding of the inter-relationships among modes. People often change modes when traveling (e.g., driving to a park-and-ride lot and taking mass transit, or taking a taxi to an airport). These intermodal relationships are of little relevance in utility planning.

The fourth difference is that the utilities generally plan to provide all of the service that they forecast as being demanded while transportation planners routinely specify different possible levels of service for different levels of funding. Hence, the transportation planning system must also take account of the availability of funding and the cost of achieving certain outcomes. This can affect the usefulness of standard techniques in evaluating options. For example, cost-benefit analysis is sometimes used in Oregon transportation planning analysis. Usually, if benefits exceed costs then a project is justified on economic grounds, but this rule does not apply for analyzing a single project when it is in competition with other projects for a limited budget. A complete analysis might find that after prioritizing all projects, only those whose benefits are at least twice their costs should be funded. If this type of prioritization is not done, a project whose benefits exceed its costs might be funded while other projects whose benefits exceed costs by a much greater amount are not. Again, this issue does not typically arise in the utility industry since enough projects to meet projected demand are typically adopted.

Some demand side options for transportation raise revenue, such as congestion pricing or development impact fees. This revenue may replace other sources of funds or allow completion of other projects whose benefits exceed their costs. These issues should also be addressed in applying the least-cost framework to transportation planning.

The revenue generating potential raises another important consideration. Many demand side options in transportation would impose higher costs on some users. These changes raise distributional concerns that must be addressed. Sudden increases in the cost of transportation can affect not only current expenditures but also wealth. For example, housing prices in outlying locations can be expected to decline if commuting costs are raised substantially.

None of these considerations argue that the least-cost planning framework should not be used for transportation planning, but they do indicate that the adaptation must be done carefully. There are a range of issues that could be addressed with respect to least-cost planning and transportation.

The simplest step in applying least-cost principles to transportation planning would be to increase the range of options considered for meeting transportation requirements. This would include demand side management, land use, and a variety of other options in addition to road construction and rehabilitation. Increasing the range of options considered is the first fundamental step in applying the least-cost planning principles, and this step should be adopted if there is to be any consideration of using the least cost approach.

The second step in the application of the least-cost methodology would be to expand the range of costs evaluated for each transportation option, and to compare these costs on a consistent basis. In addition to expanding the range of costs considered, the timing of the costs would have to be made comparable through some form of discounting. A focus on cost alone would be very similar to the procedure used in the utility industry. It could be applied to very narrowly defined transportation objectives, such as getting a certain amount of wheat from eastern Oregon to a port, or getting a given number of people from a certain area to work at another location during specified times. This approach assumes that the quality and quantity of transportation services is fixed and that the major concern is finding the least costly method to provide that level of service.

The next issue to address is the change in well-being of the consumer. Typically, the change in transportation cost will be the most important item for freight transportation, but other factors must be introduced for personal transportation. The most basic approach to this issue is to consider the time and safety of passengers in evaluating alternative modes. This approach tends to ignore many other important issues, such as flexibility, privacy, and convenience. The identification and evaluation of benefits associated with transportation options is typically much more difficult than evaluation of the costs.

Once the costs and benefits to users have been identified, network impacts must be considered. Does a specific project have network implications, and, if so, are they likely to be large relative to the costs and benefits directly attributable to the project? For example, would removing a bottleneck at one point simply cause a tie-up somewhere else in the network? Additional environmental considerations or equity considerations associated with mobility could enter at this stage.

Finally, a decision regarding the treatment of revenue must be made. Demand side options that generate revenue create opportunities for either reducing other revenue sources or increasing expenditures. Deciding how to treat these revenues could be a further substantial complication to the process.

4.1 RELATION BETWEEN LEAST-COST PROCESS AND THE OREGON TRANSPORTATION PLAN

Since the specific process to be used for a least-cost planning approach has not been identified, it is not possible to directly relate the process to the Oregon Transportation Plan (OTP). However, the general principles of least-cost planning seem to be consistent with the OTP. The OTP encompasses a variety of goals and policies that are consistent with the least-cost approach to planning. A good example is the policy goal of "Efficiency" (policy 1B, p. 38). Since it has been argued that efficiency is a primary goal of the entire least-cost process, it is clearly consistent with the efficiency objective of the OTP. Policy 1D, "Environmental Responsibility," is addressed within the least-cost framework at its broadest level, since all economic costs, including environmental costs, are considered in carrying out the analysis. Policy 2B.3 relates to increasing the availability of non-automobile options and promoting the design of infrastructure and land use which encourages their use; the least-cost process is likely to identify projects and approaches consistent with this goal.

OTP implementation goals 4B "Efficient and Effective Improvements," 4C "Cost and Benefit Relationships," and 4D "Flexibility" are all consistent with the least-cost framework. The least-cost process is also likely to be consistent with 4M.2 in establishing incentives for participation rather than directives or regulation, and 4N in encouraging public participation. While the specific focus on least-cost may not be consistent with some other parts of the plan, it is anticipated that these issues can be addressed as the methodology is developed.

4.2 APPLYING LEAST-COST METHODOLOGY

The least-cost methodology as used in the utilities is relatively straightforward. For each option, the amount of electricity generated or the amount that will not be needed because of a demand-side action is estimated. This estimate holds over a substantial future time frame, typically at least twenty years. The cost of achieving this option is determined. The timing of costs is adjusted for by calculating a "levelized cost" (this is explained more fully in Appendix B),which is essentially an expected cost per unit over the life of the activity. By putting a comparable cost on all options, the "least cost" ones can be readily identified.

This procedure can be readily applied to options that are alternative means of achieving a specific outcome. For example, the application for reducing congestion along a specific road segment can be generated in a conceptually straightforward manner, as follows. The amount of traffic is estimated along with the expected level of service if nothing is done to accommodate traffic growth. Then the cost of increasing capacity to achieve some specific level of service is estimated. The cost of achieving this outcome by means of capacity improvement becomes the base against which alternatives are compared.

Other possible methods of achieving the same level of service through demand side management or other approaches are then considered. For each, the cost to achieve the specified level of service is calculated. Standardized cost comparisons (levelized cost) are made for the various alternatives to determine the least cost way to achieve this level of service. This procedure would determine the least cost way to achieve a specific level of service, but it does not provide a method to make comparisons with other possible transportation improvements. Hence, the direct application of the levelized cost procedure as used in the utilities provides only limited guidance in a very specific situation.

Another problem with this approach is determining the appropriate baseline for comparison. Is the expansion of capacity the most likely outcome in the existing set of priorities? If not, how did the choice of level of service affect the choice among options? For example, if no additional service is provided, the resulting slowdown in traffic and increase in externalities may make some options look better than they would in the absence of the worsening congestion.

4.3 MODE APPROACHES VERSUS SEGMENT APPROACHES

Certain demand side options in the transportation arena must be viewed as mode changes, while others can be applied to individual segments of the system. For example, a choice of congestion pricing as a demand side management procedure could be made at the mode level, but it is less likely to be an option for some subset of the network. If only part of the network is subject to congestion pricing, then traffic will be diverted to other parts of the network and other complications are likely to arise.

Because some choices must be made at a more aggregate level, applying least cost methodology to individual segments of the network would likely lead to a different set of options chosen than if the decisions are made at the mode level. To appropriately apply the least cost methodology to transportation networks, it is necessary to separate the options that must be applied at the mode level from the options that can be applied to parts of the network. Until this is done, any application of least cost methodology to the corridor or road will not be able to appropriately evaluate the full range of options.

Options that might make sense to consider at the route or corridor level include various methods to increase capacity other than by adding lanes as well as alternative means of commuting. These options can be addressed using the least cost methodology after policies that must be set for the entire mode have been settled. Clearly, some modal policies could be changed in the future, and this should also be incorporated into the methodology if possible. For example, if congestion pricing is not currently feasible but might be incorporated within ten years, the choices at the program level may be different than if there is no prospect for this change.

4.4 COST OF ANALYSIS

Least cost planning in the utility industry is a costly process. Costs are controlled by using results from other utilities in evaluating the impact of a specific option. Since the options tend to be non-overlapping and additive, there is no major loss by starting from an incomplete set of alternatives and gradually considering more over time. If the costs or benefits of an option are unclear, then one utility can try the project and do a careful evaluation. If the project proves to be successful, then others can adopt the technique in the future. The time lost while evaluation is done is seldom critical to the success of a program.

Transportation planners are likely to find that the cost of generating a least cost plan is greater for transportation than it is for utilities. One reason is the possibility that benefits may have to be estimated as well as costs. Also, transportation planning is more likely to encompass choices between competing options than is found in electric utility planning. Few options for the utilities are mutually exclusive. For example, more housing insulation does not change the value of additional generating capacity but a road expansion would change the value of additional carpooling. Hence, inter-relationships among options may have to receive more attention than they do in utility planning.

Once a complete set of options for transportation has been identified, each option must be evaluated using a consistent set of criteria. Specification of the criteria and the scope of analysis will have an important impact on the cost. At one extreme, a full social cost-benefit analysis could be done for each option. Aside from the cost, the time required to conduct the analysis would likely be excessive. However, if a less costly analysis is to be done, then it is necessary to have agreement about the procedure to be used and the level of analysis required.

5.0 UTILITY INTERVIEWS

5.1 SCOPE AND COVERAGE

Interviews were conducted with utilities across the country in order to explore the realities of LCP/IRP from the perspective of the utility (the interview protocol is included as Appendix A). A majority of the utilities interviewed were selected from a list of those identified as doing "state of the art" LCP/IRP by researchers at Oak Ridge National Laboratory (ORNL) (Hirst, 1992; Schweitzer et al, 1990). Of the 34 utilities identified by ORNL, 25 were contacted and 14 interviews were recorded. In addition, interviews were conducted with two large power administrations (Bonneville and TVA), the Northwest Power Planning Council, as well as two smaller utilities and one large utility conglomerate not identified by ORNL. Interviews were structured to obtain information on the utility's understanding as to why it is doing LCP/IRP; its understanding of what LCP/IRP is; its description of the key elements of an IRP process; the impact of the plan on resource allocation decisions; impact on the organization; specific procedures in the IRP process (e.g., screening options and cost criteria); and overall assessment of the strengths and weaknesses of the LCP/IRP process.

We chose to interview any person designated by the utility as being knowledgeable about the LCP/IRP process. In most instances this person was a manager of planning. However, several "modelers" were also interviewed and, in one instance, the interview was with a director of marketing. Most of the interviews were conducted by phone.

The information which we obtained from the interviews reflects those aspects of the process which are most likely to come to mind and the perspective of the position of the person whom we selected to interview. We noted, for example, that in one instance we got a somewhat different assessment from the marketing director in a utility than from the director of IRP planning. Such variation is expected and provides a opportunity to "test" some of our observations and conclusions.

5.2 UNDERLYING CONCEPTS

As early as 1976, critics of traditional utility planning advocated a new approach which was designed to include demand side options as well as supply resources in planning for future resource acquisition decisions. These demand options were perceived as less costly than many of the supply options, which at that time were proving to be very costly to the utility and the public. This early prodding evolved into what is now known in the industry as Least-Cost Planning or Integrated Resource Planning (Hanson, et al, 1991). While the most common designation currently is Integrated Resource Planning, the two terms are often used synonymously and, for many in the industry, mean the same activity. However, because the two designations exist, we probed in our interviews for any differences which might have some significance for our understanding of what is "state of the art."

Most interviewees indicated that the central idea in the LCP/IRP process was the "integration of supply and demand side options on 'the same playing field.'" Some indicated that IRP also meant the inclusion of other factors such as environmental and social issues, and several mentioned the "public involvement component."

Some interviewees, however, defined a distinction between the two concepts. As one planner stated: "We never consider least cost *per se*.... Integrative planning is when low cost is just one of the criteria." Another observed: "The plan we adopt may not be the absolute LC ...for one, there are many definitions of least cost." Still another explained, "IRP came about when it became clear that just looking at minimizing costs wasn't good enough ... that there were multiple objectives." And still another observed that the designation was changed to IRP for "political reasons." It was in recognition that there "isn't a perfect solution" and that "choices have to be made." These comments reflect the extent to which LCP/IRP is not just a "least cost" methodology; it is a planning process involving both analytical and evaluative dimensions, of which cost-effectiveness is but one factor.

5.3 ADOPTION OF LCP/IRP PROCEDURES

The adoption of LCP/IRP has taken over two decades and has been facilitated by a number of factors. Those mentioned by our interviewees include:

* the development of appropriate computer hardware and software tools;

* the implementation of legal mandates and incentives;

* the dissemination of information and standards throughout the industry by professional associations and research organizations (e.g., Electric Power Research Institute and Oak Ridge National Laboratory);

* the development of new planning and modeling tools by highly visible and reputable organizations (e.g., the Northwest Power Planning Council and the Bonneville Power Administration);

* the political pressure of intervenors and the perceived benefits to the utility of redirecting this pressure into the planning process;

* the perception that the planning process was "just good business." (Note: this perception is changing with increased competition; however, <u>it is the public dimension of the process which is of most concern</u>.

Among those utilities that we interviewed, the majority completed their first Integrated Resource Plan between 1988 and 1992. Three have been doing some form of LCP or IRP since the early 1980s, and one, a smaller municipal utility, was in the process of setting up an Integrative Resource Planning procedure. Other studies have more systematically documented the adoption of IRP among utilities. Mitchell (1992) has recorded the spread of the IRP regulatory framework: in 1989 only seven states had full-featured IRP frameworks. However, by 1991 there were 14 states with such frameworks. Hirst (1992) suggests that by 1992 the electric utilities doing LCP/IRP were selling electricity in over half of the states.

When asked why they initiated IRP, the answers suggest the importance of mandates and incentives as well as the practicality of employing more rigorous planning strategies. Among the utilities we interviewed, a majority were either mandated by State or Federal law to employ IRP, or IRP was required in order to have utility rates approved.

One of the utilities to first employ IRP described some important motivations for its adoption of the procedure: "The old planning strategies were clearly inadequate ... the risk of making big mistakes with nuclear power plants forced us to look at other things ... to develop tools to better understand the process." Noting that the process "evolved over time," another suggested that there was "pressure from the intervenors" to consider demand side options. It was "in the best interest" of the utility to reduce cost; and there were "monetary incentives from the commission" (the commission allowed utilities to put the cost of new conservation measures into the rate base).

The combined pressure of mandates, evolving industry standards and community expectations were perhaps best summed up by another interviewee in the Northwest, who bluntly explained that "not wanting to spit in the wind" was their main motivation for doing IRP. Several interviewees suggested the importance of the development of computer hardware and software which facilitated the implementation of a quantified, least cost/integrated planning methodology.

Finally, a number of utilities indicated that if the pressure from a public utility commission (PUC) were not there or if there was no requirement, they would still be doing the process, but it would not look quite the same. In particular, they might not make the process so public and they would probably not develop the detailed documentation which is now characteristic of many of the plans. Most of the interviewees did indicate that the changing competitive environment for the utility industry was calling into question the usefulness of some of the activities required in the IRP, most specifically the documentation of the various assumptions and parameters employed in the models. Such information, they think, will be detrimental to their competitive position in the market. However, most agreed that the tools and methods developed were not going to be cast away. They would just be modified to reflect a new competitive environment.

5.4 THE LCP/IRP METHODS AND PROCESS

A number of studies have reviewed the LCP/IRP activities of utilities, documenting them in considerable detail and providing guidelines for the preparation of "good" integrated resource plans (Schweitzer, et al; 1990, 1991; Hill et al, 1991; Hirst, 1992). One of these authors, Eric Hirst, has worked directly with a number of the utilities we interviewed, and was considered by them to be an expert in the field. For this reason we draw upon his work to provide a basic overview of the LCP/IRP as found in the electric utility industry.

According to Hirst (1992), a "good" integrative resource planning approach has the following characteristics:

* explicit consideration and fair treatment of a wide variety of demand and supply options;
* consideration of environmental and other social costs of providing energy services;
* public participation in the development of the resource plan;
* and analysis of uncertainties associated with different external factors and resource options.

The planning process is broken into the following major components:

* identification of goals and key issues that need to be addressed in the plan;
* forecasting the annual electricity use and peak demand;
* assessment and screening of supply-side options;
* assessment and screening of demand-side options;
* resource integration to determine how well different combinations of supply and demand resources meet future electricity needs and how expensive they are;
* uncertainty analysis which tests different resource portfolios to identify a mix of options that meet the goals of the utility and the PUC;
* public participation.

5.5 HOW IS THE PLANNING PROCESS DESCRIBED?

The descriptions mirrored the key characteristics and components of the planning process outlined by Hirst and others. There is a clear understanding of the strong analytical base to the process in which supply side options and demand side option are, at least at one stage, costed and compared. Note was made of forecast models, integrative models and procedures for doing sensitivity analysis, as well as mechanisms for public involvement. (There was only one exception to this perspective and that was the utility which had yet to do an IRP). In reviewing these components utilities varied as to what each emphasized. Several of the utilities choose to emphasize the organizational process, while others focus on the step-by-step modeling activities, and several emphasize the public involvement process. Utilities also varied in the commitment to quantitative analysis.

5.6 GOALS

Aside from meeting legal requirements, what are the specific goals of an LCP/IRP process as seen by the utilities? Because of the emphasis placed on least cost in the literature, we assumed that the responses would, for the most part, mirror these economic factors. Rather, many respondents indicated other goals for the process, which suggests the extent to which LCP/IRP is as much an organizational process as it is an analytical methodology for comparing supply and demand side options. Consider the following responses to the question addressing the goals of LCP/IRP.

> "don't know economic goal...trying to plan for next year ... next 5 years."

> "efficiency is not a goal...(try to) come up with best plan for company and customer; i.e., lowest rate providing a given level of reliability."

> "Internally, IRP is a mechanism by which company identifies strategic intent for future...externally, (the goal is to) document this intent for the regulator."

"Fair representation for the way utility is thinking, useful information to managers and meets regulatory requirements."

"from regulation perspective, (goal is to) make sure we're doing as much DSM as possible ... (for utility) make sure we're not doing anything imprudent ... doing something that keeps us in competition."

"develop a plan to be used as a guide ... define what are the least cost options available to meet a given level of demand."

"trying to come up with optimal plan and pursue everything that is within that plan."

"a plan that provides reliable, cost effective energy, that evaluates supply and demand on equal plain, with consideration of different futures."

5.7 IMPLEMENTATION OF LCP/IRP

While the basic characteristics of the IRP process described by interviewees are similar to those outlined above, Hirst documents considerable variation in implementation. Our interviews support his findings and indicate that the variation is due to a number of factors. First, individual states and PUC's have different requirements for what should be included in an IRP. Such requirements can structure the form of analysis, prescribe options to be considered, define the involvement of the public and specify the content of the plan submitted for review. For example, one utility stated that for its most recent plan the commission mandated that they consider 110 demand side options. In addition, nearly all of the utilities discussed the evolutionary nature of the process and observed that each planning process was somewhat different from the other.

Many factors have contributed to this dynamic. Planners had to learn to shift the focus from analysis of the cost of individual projects to one in which they looked at a variety of supply and demand activities for a variety of customers over time. In addition, planners learned with each iteration of the process. The Northwest Power Planning Council observed that after its first plan the staff concluded that "you're always going to make mistakes both in forecasting and decision-making". For them, this information called for the development of a more rigorous model (ISSAC) which allowed them to place a value on different options and to model mistakes. It also led to the greater emphasis on procedures to test for uncertainty. Other factors which were mentioned by other utilities and which contributed to variation were corporate values, the level of planning expertise, computer and software capability, and the time constraints placed on the analysis.

These factors also contribute to the relative emphasis that different utilities give to quantitative and qualitative analysis. While there are obvious methodological constraints to analysis and short cuts are made in the models, other factors such as size, time, resources and commitment are also important.

5.8 DATA REQUIREMENTS AND THE SIZE OF THE PLANNING DOCUMENTS

IRP data requirements are often quite extensive, and the documents which describe and report on the process are detailed and very large. The more quantitative the planning methods employed by the utility, the more extensive are the data requirements. These requirements sometimes limit the effort undertaken by the utility and structure the mix of quantitative and qualitative analysis. In addition, the documents, which describe in considerable detail the planning process, the assumptions, and calculations in the analysis, contain thousands of pages and are published in multiple volumes. Fortunately, they are often quite readable and as a consequence, provide a detailed record of the methods, assumptions and criteria for evaluation used by the utility in the development of the plan. (See Appendix C).

5.9 PLANNING HORIZONS

Requirements for issuing a plan or for filing with the PUC vary as does the time span for which the analysis is done. Of the 24 utilities reviewed by Schweitzer et al (1990), nearly half prepare new plans or update existing ones annually. Moreover, the IRP period does not always coincide with the PUC filing period. As Schweitzer and his associates conclude, "resource planning is nearly a continuous activity."

The time span covered by these plans ranges from 10 years to 30 years with the majority covering 20-24. (Schweitzer, 1990, p. 21). Hirst discusses the need for a short-term action plan which calls for implementation of the intermediate steps for reaching long term objectives. While some utilities develop these short term plans, not all do. Schweitzer found 11 out of his sample and he noted that in some cases these plans did not reflect the objectives found in the long term plan. Our sample, the majority of which was drawn from Schweitzer's list, confirmed these earlier findings.

5.10 STAFFING

Responding to the requirements of the IRP process has resulted in an increase in staff and reorganization of the planning effort. Increase in staff size is usually the result of the addition of several individuals who work exclusively on coordinating the process, the expansion or addition of staff for demand side programs, and the contracting of consultants. Some staffs are relatively small (2-4 people) while others, like at Bonneville, can be very large (in excess of 50 people). The most frequent impact noted, however, was the inclusion within the planning process of individuals from a variety of different groups (e.g., transmission planning, forecasting, financial planning, and legal departments) within the company who contribute part of their time to the IRP process (see also Schweitzer, et al, 1990). Before IRP, these individuals often worked in relative isolation. Now they are frequently represented on interdepartmental teams or committees that review, coordinate and report to superiors on the development of the plan.

The extent of involvement of senior officers and boards is also variable. In most of the interview cases there was some oversight from the beginning of the planning process. The extent of this oversight varied from one utility to the next. For the Northwest Power Planning Council and several of the independently owned utilities (IOU's), involvement with staff activities was periodic but intensive. Requests could be and were made for documented explanations of assumptions made and paths chosen. In most other instances, however, the oversight was more a matter of keeping track of the process to insure work was being done.

5.11 EXPENSE

Most interviewees did not view the LCP/IRP process as excessively expensive. As one noted "within the framework of the larger utility budget, the cost was minor." There were, however, two interviewees who felt that the mandated requirements which their utilities had to meet were very burdensome and expensive ... in one case in excess of "$2 million." It should also be highlighted that utilities do not each have the burden of evaluating costs and effectiveness for each of the various options. Rather, they can draw on an extensive list of options with evaluations of cost and effectiveness drawn from other utilities' experience.

5.12 PUBLIC INVOLVEMENT

Public involvement is an important part of LCP/IRP. All of the utilities interviewed, with the exception of the one which had yet to develop an IRP process, had some sort of public involvement program. This involvement was in the form of interaction with the PUC staff, state energy officers, other interested utilities, environmental groups, customers, academics and other experts. Involvement occurred through mechanisms such as advisory groups, binding and non-binding collaboratives, focus groups, workshops and customer surveys (see Schweitzer et al, 1991 and Schweitzer, 1992 for more discussion of these mechanisms).

Several of the utilities we interviewed had used a number of different mechanisms for public involvement. Most were very positive in evaluating this dimension of the LCP/IRP planning process. While the literature suggests that the importance of public involvement is to increase the amount of DSM resources utilized (e.g., Schweitzer et al, 1993), our interviews suggest other consequences as well. Involving the public in the planning process channels intervenor energy into a more manageable, less confrontational and ultimately less expensive (for the utility) forums. Moreover, it forces critics of utility planning and the advocates of new resource alternatives to make their case within the context of IRP. In addition, the utilities have newly discovered the value of increased information about customers' needs and values. Such information, a number of interviewees noted, is an important by-product of public involvement and of the IRP process. Finally, public involvement is seen as another factor that has restructured traditional utility planning and opened it up to new ideas and new methods, if not always more demand side resources.

5.13 ANALYTICAL PROCEDURES

As with other dimensions of the planning process, there is considerable variation among utilities in the application of analytical procedures, in the selection of models, and in the mix of quantitative and qualitative information. This variation has been documented extensively by others (Hirst, 1992; Schweitzer, et al, 1990, Schweitzer et al, 1991) and is not necessarily related to size. Our interviews focused on a number of aspects of the analytical process which are of direct interest to transportation planners. In particular, we explored the process by which demand and supply options are identified and screened, the financial criteria selected to compare options, the integration of environmental costs into the analysis, consideration of distributional impacts, uncertainty and reliability.

Identification of options to be screened is primarily a process of planners reviewing the growing body of literature in the industry. For example the Electric Power Research Institute has a number of documents which are designed to provide estimated costs for a variety of supply and demand options (EPRI, 1991, 1993, 1993). In several situations, the PUC mandated that certain options be considered, sometimes despite what the utility considered in its "best interest." For example, one electric company was mandated by the PUC to look at fuel switching. They did, but the interviewee noted, "the company never considered the option seriously even though it was discussed in its plan." As Hirst argues, however, in an ideal situation a broad range of supply and demand-side options "should be considered."

The initial screening of options involves a process of qualitative and quantitative assessment. Interviewees indicated that many options are "looked at" on the supply and demand side. Some options are judged at this stage to be unacceptable without new analysis. For example, photovoltaics may be eliminated as an option because the technology is presently too costly and the utility doesn't think it will be developed sufficiently to reduce costs in the time frame of the plan. Those options which make this first cut are then subjected to a more rigorous screening process where the costs are compared (e.g., levelized costs or net present value). To gather information on cost, utilities often rely on "generic" estimates provided by EPRI, for example, or on the experience of other utilities.

Typically the levelized cost of supply options are calculated and the least cost options identified, although the list of possible options will sometimes include options which are not absolutely least cost. As Hirst (1992) argues, some more expensive options may in subsequent analysis (e.g., the integration and uncertainty analysis phases) turn out to be attractive. Supply options are also compared on the basis of other factors such a "commercial status, technical status, licensing and lead time risks, cost risk" and rated.

Demand side resources are similarly screened by comparing levelized costs. However, consideration is also given to the benefits to be derived. As a consequence a number of different tests of cost effectiveness have been developed for screening options. As defined by Hirst (1992), these test include the following:

Participant Test - compares the direct costs and value received by customers participating in the program;

Rate payer Impact Test - compares impact on electricity rates;

Total Resource Cost Test - total costs and benefits independent of allocation to utilities, participants or non-participants;

Societal Test - similar to total resource test, but considers externalities;

Utility Cost Test - difference between utility avoided costs and the cost involved in program implementation.

The tests vary according to whose costs and whose benefits are to be compared. Which test "should" be applied, however, is sometimes a source of disagreement between the utilities and the PUC's.

The application of different cost tests is a vivid example of the difficulty which the industry has had in developing a methodology that is uniformly applied, and which in all cases will result in an agreed-upon solution. As documented in our interviews, which test is used, when and how, varies from one utility to the next. For example, the PUC's may require the screening of all options which pass the societal test. The utility, however, in its short term decisions will not use this test, but rather the rate payer impact test. Other utilities employ different, utility-unique tests as a method of further prioritizing options.

Whatever the choice, the final screening involves not only consideration of costs, but also other characteristics such as "technical feasibility, customer acceptance, environmental impact and effect on load factor" (Schweitzer, 1990). Our interviews suggest that these factors are integrated into the process qualitatively and more or less informally. Efforts to formalize the process are being made both in the modeling area and in the development of other procedures. For example, one utility described a focus group exercise in which a range of values (including cost) were identified, and another where projects were ranked by the utility's advisory group (see also Hirst, 1992).

5.14 MODELING

In the evolution of LCP/IRP, a number of models for forecasting, screening and integration have been developed by different organizations. Each model is different from the other in its approach and capabilities and each represents a different approach to analyzing systems. In a few instances, utilities have developed their own models; however, the most common practice is to purchase these models or, in the case of the smaller utilities, to hire consultants to do the more rigorous analytical work. Examples of these models include *REEPS, COMMEND*, and *INDEPTH* (for forecasting), *PROSCREEN*, *ELFIN* and *ISAAC* for screening and integration.

5.15 ENVIRONMENTAL AND OTHER SOCIAL COSTS

Most environmental and social costs, if they are considered at all, are done so qualitatively. While innovative quantitative work is being done by planning and research agencies, most utilities interviewed limit consideration of environmental costs to the expected cost to the utility of a change in regulations, or do not include them at all. However, a wide range of potential environmental issues are discussed and valued qualitatively.

5.16 UNCERTAINTY AND RISK

As the LCP/IRP process has evolved, uncertainty and risk considerations have become more important. Typically, the final stage of the process includes some form of uncertainty analysis. The strategies and tools used to deal with uncertainty and risk vary from one utility to the next. As described by Hirst and Schweitzer (1990) there are five types of uncertainty analysis.

Scenario — Alternative, internally consistent futures are constructed, and then resource options are identified to meet each future. Best options can then be combined into a unified plan.

Sensitivity — The preferred combination of options is identified. Key factors are then varied to see how the plan responds to these variations.

Portfolio — Multiple plans are developed, each of which meets different corporate goals. Often these plans are then subjected to sensitivity analysis.

Probabilistic Probabilities are assigned to different values of key uncertain variables, and outcomes are identified that are associated with the different values in combination. Results include the expected value and cumulative probability distribution for key outcomes, such as electricity prices and revenue requirements.

Worst-Case The utility creates a plan to meet an extreme set of conditions and later learns that it faces an entirely different set of conditions. The utility then adjusts its resource acquisition to meet the newly perceived conditions.

Our interviews suggested that utilities are constrained in the application of these techniques by time and resources.

5.17 ROLE OF PLANNING PROCESS/PLAN IN DECISION-MAKING

The existence of a planning process does not automatically translate into value for the decision maker. We asked a number of questions to explore the importance of the plan in decision-making and then we asked whether the plan affected the decisions of those who have the final say - the CEO or the Board of Directors. Most utilities considered the IRP plan as a "guide" to the decision-making process. Its importance, however, varied considerably. Consider the following comments about IRP in making resource allocation decisions:

> "model ... guide to resource allocation decisions. We identify types of resources need in the future ... real integration comes in having a bench mark for costs."
>
> "Plan is long term. Each decision is made on a project-by-project evaluation ... plan gives no guarantees."
>
> "guide to resource decisions ... important because it gives the staff analytical insight ... serves as a communication tool to the staff, the board and to customers."
>
> "before changes in the industry the plan was very important ... we wanted to do things consistent with the plan."
>
> "plan is very important. When senior officers accept the plan they're basically determining the course for the corporation ... continually questioning the plan. They go back regularly to consider parts of it ... ask for sub studies.
>
> "right now ... the way its currently set out, (it's) sort of a regulatory exercise. Company doesn't take it seriously."
>
> "avoided costs with commission. We worked very hard but found that there was not one prescription for the long term. (Plan) helped identify options, need for flexibility ... but in the short term we do what needs to be done."
>
> "it's the product of a costly, burdensome process which is dominated by lawyers and which contributes little to the decision-making process."

Acknowledging the limits of the plan's influence, many of the interviewees concluded that for the officers of the company, the plan is just one of the factors which contributes to their decisions. Equally interesting were the several occasions when interviewees noted that the public utility commission sometimes ignored the contents of an adopted plan when it reviewed rate applications from the utility.

5.18 STRENGTHS OF THE LCP/IRP PROCESS

If the IRP is not perceived as determining the actions of a corporation, does it have any other value? Surprisingly, we found almost unanimous agreement on a number of strengths of the planning process. From an analytical perspective, respondents observed that while everyone learned that IRP could not come up with one optimal solution ... "a right answer," it was still useful.

Respondents agreed that IRP has opened up the planning process by broadening the participation of diverse parties. Often noting the old days of " engineers sitting with their rulers," they view the participation of diverse people in the planning process as a step forward. The involvement of people was not just in reference to the general public and other outside interests. A majority of the respondents also indicated that a strength of their planning process was the extent to which it brought together diverse interests (marketing, transmission planners, company officers, engineering, forecasters) in the utility. Many did not want to lose this new level of organizational integration. The involvement of the public was also viewed as having benefits for marketing, as the utility gained better information about their customers' preferences.

Most respondents agreed that the use of IRP procedures has widened the range of options considered as resources. Sometimes citing specific examples, demand side management, fuel purchasing, and co-generation, respondents pointed to the increased involvement of the public, the mandates and regulatory oversight of the commissions as factors in the process which facilitated the widening. One interviewee noted that she felt the number of options would have broadened anyway because of the activities of intervenors. The IRP process brought the intervenors inside, reduced the level of conflict for the utility and forced protesters to present their case within the IRP framework. As one interviewee observed, while not perfect, the process does "consider a full range of resources" and "compares on some kind of equal basis."

There was agreement that LCP/IRP introduced multiple planning objectives including economic, social, and environmental into the planning process. Most observed that non-economic considerations were not part of the analytical process as they had not or could not be quantified. They were discussed in the regulatory process or incorporated into planning as qualitative screens for options.

There was agreement that the LCP/IRP process facilitated internal communication. It "created a common language" for people to speak with each other. The coordination of the planning effort among the various groups which had in previous times functioned quite independent of each other, had an impact on communication in the organization and led to the belief that the corporation was healthier and made better decisions because of it.

Several mentioned that the process resulted in the utility being more responsive to the market place or the community, and as a consequence enhanced the utility's credibility. Utility responsiveness grew out of the process by which the public (or at least some interested members) were integrated into the planning process, and out of the effort which the utilities have made to communicate their perspectives in public and in a manner which could be analyzed and understood. A by-product of this process, in addition, was greater information about their customers' needs and values. As the utilities move into a more competitive era, this information has great value.

IRP is a planning strategy which explicitly addresses uncertainty. Efforts to plan for uncertainty have been incorporated into the process using the variety of strategies mentioned above. These procedures have expanded the way people have looked at the future and have, through analysis and discussion, given consideration to the "values" which people place on these futures.

5.19 WEAKNESSES OF THE LCP/IRP PROCESS

Utility planners acknowledge that there are limits, both conceptual and practical, to their ability to analyze. These limits structure the outcome and its ultimate usefulness.

> "Truth is, forecasts are always all wrong ... we know this and try to accommodate for the uncertainty. Limited by computer power. Assumptions are made, short cuts are taken ... we define the problem so it is solvable."
>
> (Process) "takes a lot of analytical short cuts; outcomes are as good as our assumptions..."
>
> "idea of rate of return is naive ... are we really reflecting where we're going?"

Others mentioned that the process is time consuming and is limited by the time, resources and staff available.

The process sometimes allow for parties with special interests to get what they want under the guise of rigorous analysis. As noted earlier, one utility was mandated to include a number of DSM measures in its plan. In addition utilities respond to the pressure to consider options in order to avoid litigation or to satisfy customers. Although these options are included in the plan, they are not seriously considered by the final decision-makers. All of these strategies dilute the process designed to place supply and demand options on "an equal playing field."

All too often, the process and the product of the process are not considered legitimate tools for decision-making. Problems of legitimacy are not unique to staff or officers within the utility. Several examples were provided in which the commission (either the staff or commissioners) chose to ignore the process. In one case, after agreeing in the plan to undertake competitive bidding for selecting a least cost option, the PUC disagreed with the option which won the bid and challenged its rate application. This points to a fundamental disagreement with regulators as to how the process should be used. Interviewers noted also that a plan often did not determine what officers would do, but was one factor affecting their decisions.

Public involvement does not mean that there won't be litigation. Public involvement has been beneficial, according to the interviewees, because it has opened up the decision-making process, provided more information on consumer values and needs, and in many instances channeled conflict. IRP, however, operates in an environment in which there are many ways to protest actions of the utilities. IRP does not guarantee these other strategies won't be pursued.

6.0 INTERVIEWS WITH TRANSPORTATION SECTOR

6.1 SAMPLE SELECTION

Following the direction provided by the Technical Advisory Committee for this project, our interviews explored the concepts "least cost", LC planning, cost-effective and cost/benefit as they are currently being considered/applied at the Federal level. A limited number of interviews were conducted with state departments of transportation, with municipal transportation planners, and with researchers who are exploring or applying these concepts (see Appendix C for the list of interviewees).

6.2 LEAST COST PLANNING -- WHAT DOES IT MEAN?

At the Federal level, among transportation agencies which we interviewed, there is no clear mandate for least cost planning, and no agreed upon, conceptual understanding of the activity. The Transportation Research Board was primarily interested in using cost/benefit analysis to address its mandate from the President in the reorganization of government executive orders. Patrick DeCorla-Souza, of the Policy And Analysis Division of the Federal Highway Administration, who has been most public in his call for integrated transportation planning, considers the primary task at this time is to prod the states and municipalities into multi-objective, multi-modal planning. This includes some tests of cost-effectiveness or cost/benefit analysis. The community planner in the Metro Planning Division of the FHA, who has written the regulations outlining planning requirements, notes that the regulations "encourage" agencies to apply cost/benefit analysis.

At the state level, with a few exceptions (e.g., Washington, Maine, and California), the concept is virtually unheard of among transportation planners. This is certainly the case when the specifics of LCP/IRP as it has evolved in the electric utility industry are mentioned. Even among those researchers and interest groups who draw on the utility experience for comparison there is confusion about how the process operates, the conceptual issues underlying the process, as well as the function of the plan.

Much of the discussion about LCP is concerned with basic issues of methodology and process which can be addressed without applying the specific methods of the utility industry. As DeCorla Souza noted at the recent SeaTac Least Cost Transportation Symposium, the basic objectives of LCP/IRP in the utility industry are to move beyond mode or project-level analysis to system-level analysis, to broaden the search for solutions to include demand side as well as supply side, to move beyond consideration of agency cost to consideration of total social costs, to move from a linear to an interactive model of planning. We suggest that transportation agencies can develop their own planning systems to accomplish these goals without necessarily copying the utility process.

The interviews suggest that transportation planning is in much the same situation as utility planning in the 1970's. We found considerable concern about the merits of large scale projects, whether highway or transit, with huge capital costs and uncertain benefits. We observed the emerging, but sometimes not well understood regulations (e.g., the Washington State mandate to apply "a cost-effective methodology" in transportation planning) which push planners into new areas. We spoke with researchers exploring a variety of innovations and models in transportation. We heard the growing concern with issues of congestion and land use. And we noted the comment by more than one interviewee, that the process for making decisions is "pretty closed" and needs to be opened up.

Our interviews did not cover multi-modal planning activities. However, we did review a recently-published report which provides a synthesis of highway multi-modal planning at this time (Rutherford, 1994). The report concludes that multi-modal evaluation is hindered by the absence of an accepted measure of mobility, that the range of options compared is often limited to one mode, and that implementation is hindered by a number of institutional and financial barriers. Our view is that multi-modal planning as currently practiced should not be equated with least-cost planning as implemented in the electric utility industry.

6.3 LESSONS LEARNED FROM THE UTILITY AND TRANSPORTATION INTERVIEWS

Least Cost Planning/Integrated Resource Planning is a planning strategy which includes both quantitative and qualitative components, of which least cost analysis is just one dimension. As a concept which has evolved over several decades, there exists general agreement as to its basic components. There is, however, no single methodology that can be transferred directly from the utility to the transportation planning context.

Having identified this fundamental limitation, however, additional lessons can to be learned from the utility experience in developing a planning methodology which explicitly sets out to expand the number of demand side options considered and which focuses attention on expanding both the utility's and the public's understanding of the context in which policy decisions are being made. These lessons are briefly discussed below.

LCP/IRP, as employed in the utility context, expanded the range of supply and demand options considered in the planning process. Incentives, mandates and economic self-interest were factors contributing to the consideration of a broader range of supply and demand options in the utility experience; and the range of options analyzed for their plans is not boundless. An electric utility seldom seriously considers promoting an option which will shift customers from buying electricity to buying fuel for heating. Self-interest is a factor which limits analysis. Self-interest also affects the transportation planning process, and implementing a least cost methodology will not automatically open the process to consideration of a broad range of transportation supply and demand options.

The interviews suggest that LCP/IRP clarifies the issues related to policy and has established a body of experience that permits a more comprehensive assessment of the costs and benefits of different planning options. For example, the process

- clarifies different cost criteria;
- focuses planning on risk and uncertainty;
- expands decision-makers' thinking beyond specific projects and the immediate future.

Finding methods and strategies which clarify cost and benefits, which address uncertainty and risk and which expands thinking beyond individual projects is the challenge linked to the call for least cost planning in the transportation. Reviewing and analyzing the ways in which these tasks were accomplished in the utility experience is beneficial and suggests new approaches to be taken.

LCP/IRP involves a high level of quantitative analysis, combined with substantial doses of qualitative judgment. Distinguishing the different types of analysis, defining and formalizing the integration of the different types of analysis is beneficial to the utility and the public.

IRP broadens participation of diverse parties/interests in the planning process:

> Within the utility it often functions to integrate the different planning groups (e.g., regulatory, rates, transmission, marketing) in the planning process with apparent benefits to the decision-maker.
>
> It has made the planning process within the utilities more open, and identifies the key assumptions the utilities make in determining future courses of action.

To the extent that the process is considered legitimate by participants and by those observing the development of plans, the process probably reduces conflict or redirects it into less confrontational arenas. These achievements are appealing to a growing number of transportation analysts. Careful review of the experiences of the utility industry may reveal some strategies which could be transferred to the transportation sector.

IRP produces a long range planning document which may or may not guide decisions. In this respect it is similar to other planning documents. In most instances, however, the plan provides background material for strategic decisions. Because of the substantial analytical component, IRP is an expensive, skill-intensive activity. Many parties can contribute to the process, but the development and implementation of the analysis requires individuals with strong analytical skills and computer sophistication. While the expense can be handled easily by the larger utilities, it is a factor constraining the activities of smaller utilities. The expense associated with this process will be a consideration for transportation planning agencies.

7.0 CONCLUSIONS

Least-cost planning (LCP) or integrated resource planning (IRP) is used in the electric utility industry to broaden the scope of choices to meet service requirements. Rather than focus exclusively on building additional generating capacity to meet expected demand, utilities also consider methods to reduce the demand for electricity. These are typically referred to as demand-side management (DSM) programs. The basic procedure is to identify supply options to meet expected requirements, identify DSM options, and then pick the least costly combination of supply side and demand side options. To make this comparison, many utilities calculate a standardized unit cost of electricity, called the levelized cost of each option. The levelized cost is the cost of generating electricity for supply options or the cost of reducing the amount of electricity needed for demand options. This calculation makes comparisons across widely different options more consistent. While choosing options with the lowest levelized cost is one aim of the utilities, other factors enter into the final mix of options chosen.

Evaluation of the literature on least cost planning and interviews with utilities using LCP or IRP indicate that the process is far from a uniform or mechanical one. There are a variety of criteria that are used in defining cost and a large array of issues other than cost that enter into the final mix of options chosen. Further, the methodology has evolved gradually over a long time period and relies on a large number of studies that have been done to evaluate the effectiveness of various demand-side options.

The basic economic rationale for least cost planning in the utilities is that customers were being charged a price for electricity that was below the cost of generating additional electricity. Because customers were not paying the full cost of adding to capacity, they had a tendency to use more electricity than would be efficient. Hence, some investments to convince customers to use less electricity would be less costly than generating the additional electricity. There are many parallels between the situation the utilities faced and the situation currently faced in transportation.

The least-cost planning framework has the potential to substantially improve transportation planning in terms of economic efficiency. However, it can not be adapted without first addressing fundamental differences between transportation planning and electric utility planning. Four differences between the systems have been identified as being particularly important.

First, the level of consumer satisfaction with service attributes is more of an issue in transportation than in electricity. Most least-cost options in the utility industry, especially those relating to non-business consumers, do not change the level of service that the customer receives, they just change the amount of electricity used in achieving the customer's service goals. For example, customers typically do not care whether the comfort level in homes is achieved by generating more electricity, by improving home insulation, or by using more efficient heaters and air conditioners. Transportation, especially personal transportation, involves many characteristics that customers do value, such as flexibility, comfort, and time. Hence, evaluation techniques must be sensitive to customer satisfaction with the method of service provision.

Second, use of the transportation system is affected by the quality of the service provided. Delays caused by congestion of roads or mass transit systems may cause changes in travel patterns. Reducing these delays then may affect the number of people using the system. These changes in the quality of service are less likely to occur because of choices made regarding the generation or consumption of electricity. The evaluation techniques must be sensitive to potential users of the transportation system, or those diverted from using it because of changes in service quality.

Third, each transportation mode has system or network characteristics that make it less feasible to treat parts of the system in isolation. These network components are not of great importance in evaluating electricity, but they are in evaluating transportation. In particular, some demand management options that might be considered at the mode level are largely precluded if the analysis is done at the project level. For example, Oregon is currently considering the effect of land use decisions on the transportation system and vice versa. However, certain options relating to land use, such as increased density, may not be effectively evaluated as alternatives to specific road improvements. Increased density in a particular area is likely to increase the demand for road capacity in that area even if it reduces the demand overall. Hence, evaluating the land use option relative to a specific road improvement option may generate different conclusions than comparing the options at a more aggregate level.

Fourth, electricity planning is done with the expectation that all of the electricity required will in fact be provided. In transportation planning, different levels of service associated with different funding levels are routinely analyzed. Also, because many transportation demand management options raise revenue, the impact of changes in revenue must be considered.

While recognizing these limitations, we want to draw attention to the dimensions of the utility industry planning process which are appealing to transportation planners grappling with issues of congestion, land use and growth. As it has evolved over 30 years, Least-Cost Planning/Integrated Resource planning appears to have expanded the number of supply and demand options considered by the utilities in their planning efforts. As implemented, LCP/IRP has meant consideration and adoption of a variety of supply and demand side options for reasons other than cost minimization which, within the framework of integrated resource planning, were in the interest of the utility or the community. In addition, LCP/IRP has promoted public discussion of the assumptions, approaches and analytical tools used in the development of a plan and the selection of resources options. This has, we think, expanded not only the types of options considered, it has focused attention on other important dimensions of planning. Careful attention to forecasting, uncertainty and risk analysis are characteristics of the "best" plans. These areas need careful attention in transportation planning as well. Studying the experience of the utility industry in addressing these issues can be useful.

7.1 RECOMMENDATIONS FOR FURTHER ACTION

The differences between electric utility planning and transportation planning mean that while the process of least-cost planning can be applied to transportation, the specific method used by the utilities has only limited usefulness. The basic process of calculating levelized cost and comparing projects on this basis is not directly applicable to transportation. In the electric utility, the cost of generating units of electricity can be compared readily to the cost of reducing demand for units of electricity; however, in transportation there are no similar units of analysis for comparison. Further, consumer satisfaction with the transportation system, network considerations, and evaluation of the level of service to be provided generate additional complications for the transportation planning process.

We have identified two basic approaches for further development of the least-cost technique to transportation planning in Oregon. The first is a broad-based analysis of transportation modes and comprehensive strategies associated with providing transportation services and affecting the demand for transportation services. This level of analysis would identify major policy options affecting the transportation system. It would be at this level that policies such as congestion pricing, land use changes, and related policies could be evaluated. In addition to broad policy direction, this type of analysis could generate criteria to be used in evaluating specific transportation projects. For example, communities that implement certain policies may be given a higher priority for transportation investments. This approach is likely to require costly analysis and does not directly provide information regarding specific transportation investments.

The second basic approach is to adapt the utility levelized cost approach to analysis of specific transportation improvements. To implement this approach, a specific improvement would have to be identified as well as the level of service likely to result from that improvement. Other options to achieve this level of service could then be considered, both other supply options and demand side options. All options could then be compared on some comparable basis, possibly even using the levelized cost approach as it is used in the utilities. If an option could provide the same level of service at a lower cost, then it should be an improvement over the base case. This approach does not always find "the" best solution since there are likely to be limitations on the range of options considered. Also, consumer satisfaction must be considered so that changes in service are not accomplished at the expense of consumer time or other service characteristics.

Either of these basic approaches is open to a substantial range of options in actual implementation, and it may be that both must be developed to some extent to appropriately implement the least cost planning approach. An important lesson from the utilities is that there does not appear to be one best way to do least cost planning. Rather, it is important to broaden the range of options considered to achieve transportation objectives and to generate information on the cost and effectiveness of various alternatives.

Two specific issues will be important in the first phase of any attempt to implement the least cost approach. The first is the identification of objectives. A benefit of the technique for utility planning is the clear objective to either generate electricity or reduce the demand for electricity. The objective for transportation planning is not so readily identified, and there are likely to be several objectives that must be considered. For example, mobility is a conceptually clear objective for transportation, but there are no obvious ways to measure this objective for planning purposes. Alternatively, reducing vehicle miles traveled (VMT) is a concrete objective, but it does not relate to the service provided to transportation users. Many policies that reduce VMT may make users of the transportation system worse off.

The second important issue will be to determine the procedure by which each option will be evaluated. The major benefit of the least cost planning technique is to provide a mechanism for comparing disparate solutions to a problem that allows advocates for each solution to understand why their preferred solution was (or was not) adopted. If the process is not perceived as giving all options a full and fair evaluation, it is likely to be a futile exercise.

Finally, the cost of the analysis must be considered. The complications in the evaluation caused by the differences between transportation and provision of electricity could substantially affect the cost of conducting the analysis. The high potential cost means that there must be a careful evaluation of the complexity of the analysis that will be done for each option. Budget constraints mean that the trade-off is likely be between a systematic application of low cost evaluation to a wide range of options versus selected application of more costly evaluation techniques.

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APPENDIX A

ELECTRIC UTILITY INTERVIEW PROTOCOL

The study is funded by the Oregon Department of Transportation and is designed to assess the feasibility of applying Least Cost Planning/IRP to transportation planning. Your cooperation is requested in providing us with a clear picture of the "state of the art" regarding its use by utilities. We want to know how you would characterize the "best" way to do LCP. In addition, we want you to provide us with a realistic picture of how and why this planning tool is used in your organization, and to discuss its strengths and weaknesses as a tool for guiding investment decisions in the utility industry. It is our understanding that the utility currently employs LCP\IRP in making resource allocation decisions. Is this correct?

WHY UTILITY EMPLOYS LCP\IRP

1. Do you call your planning process LCP or IRP? If the latter ask why name was changed.

2. When did your utility first start using LCP/IRP?

3. What kind of planning did you do before LCP/IRP?

4. Why did your utility start using LCP/IRP? Please list all the reasons you can think of.

   Probe: If utility is required to do IRP, ask if there are other reasons for doing it or if it might have done IRP anyway, even if not required.

5. Have your reasons for doing IRP changed over time?

6. In addition to IRP, what other planning tools are used to make resource allocation decisions and why?

7. How important is the plan generated by the IRP process in making resource allocation decisions?

8. Has the importance of the plan changed over time? Explain your answer.

9. If you were no longer required to do IRP would you continue to do it? Explain answer.

   a. If no, what other strategy would you use for making resource allocation decisions?

DESCRIPTION OF LCP/IRP PROCESS

1. Describe the mechanics of your company's approach to LCP/IRP--what are the major steps in the process?

2. Who or what determine the major elements that make up the IRP process?

3. Who inside the utility is involved in determining the content of the plan (e.g., planners, managers, officers)?

   a. How do they influence the content of the plan (i.e., what are the procedures for giving input)?

4. By what procedures can the plan be reviewed, modified or changed?

IMPACT OF PLAN ON RESOURCE ALLOCATION DECISIONS

1. Who in the utility has the final say in making resource allocation decisions and how would you characterize their roles in the planning process?

2. Does the plan affect their decisions? How?

3. What other influences besides the plan affect their decisions?

IMPACT OF IRP ON ORGANIZATION

1. How large is your planning staff and how many are involved in the IRP process?

2. What is the expertise of your planning staff?

3. What time horizons guide your planning process?

4. Did you have to change (alter, increase the number of planners etc.) your organization in order to do IRP? If yes, how?

5. Are there costs to your organization because you do IRP? If yes, what are they?

6. Do resource costs, e.g., computer hardware, time, limit how much analysis you can do? If yes, explain.

7. What are the strengths of your process?

8. What are the weaknesses of your process?

NOW LET US BE MORE SPECIFIC ABOUT THE LCP/IRP PLANNING

1. What are you trying to achieve ..or what are your goals in LCP? (Probe for specific planning goals as well as non-economic goals)

   a. By what process did you arrive at these goals?

   b. Have your goals changed over time? If yes, why?

2. How in your planning process do you address uncertainty in demand?

3. How do you address the issue of reliability of system operations?

4. How do you address the issue of peak versus off-peak demand in the planning process?

5. In general, do you make distinctions between capital expenditures and operating expenditures in formulating the least cost plan?

FOCUS ON DEMAND SIDE OPTIONS

1. How do you develop the list of DSM options to be considered?

   a. Describe the process by which they are selected for analysis.

   b. Describe the criteria used in selecting options.

   c. How broad is your initial list, i.e., do you really consider all of the options out there? For example, do you consider fuel switching?

2. How do you develop estimates of the cost of DSM options and of their impact on energy demand?

   a. If company is involved in evaluating DSM programs, ask how much effort is given to the activity, by whom, and how the information is used.

   b. Do you have detailed information on customer equipment, preferences and use habits?

3. Does the state or the PUC provide an incentive for you to include DSM in your plan (other than requiring you to do IRP). If yes, what is the incentive.

   a. Specifically, how is your company compensated for including DSM options?

4. Do the pressures to include DSM option sometime lead you to "inflate" your demand estimates to make DSM look more attractive?

5. What financial criteria (e.g. participants test, rate payer impact, total resource cost, utility cost) do you use to compare costs?

6. Do you consider externalities, e.g., environmental costs, in making cost estimations? Where do they come in your analysis?

7. Have you considered DSM programs which require people to change their behavior (e.g., change the thermostat)? What lessons did you learn from these programs?

8. Do you consider the distributional impacts on different classes of customers of alternatives? How?

9. Are you concerned with building flexibility into your system. How do you include this dimension in your plan?

OVERALL EVALUATION OF THE STRENGTHS AND WEAKNESSES OF IRP AS A PLANNING TOOL

1. Has the experience of your utility with the use of IRP procedures widened the range of options considered as resources for your facility? If yes, how? If no, explain answer.

2. Has IRP broadened the participation of diverse parties/interests in the planning process? Is this the case in your utility's experience? If yes, how has this been accomplished? If no, explain answer.

3. It is argued that this integrative process in IRP opens consideration of multiple planning objectives such as social, environmental as well as economic. Has this been the case in the experience of your utility? If yes, how has this been accomplished? If no, explain answer.

4. In general, what are the strengths of IRP?

5. What are the weaknesses?

6. How useful is IRP in the current market situation (and regulatory environment)?

   a. What is different now?

   b. What kind of planning is useful?

   c. What is the future of IRP?

7. Does your plan affect the decisions of other utilities? If yes how? (Probe: expert advice, a standard on which to judge estimates etc.) If no, why not?

8. In what other ways besides the plan does the utility affect use of electricity in the region?

9. This is a study of the feasibility of using LCP/IRP in transportation planning. Drawing on your own experience with its use in utility planning, are there some observations, insights, lessons to be learned which could be applied to understanding the usefulness of LCP to transportation planning?

APPENDIX B

THE ANALYTICAL PROCESS OF LEAST COST PLANNING IN ELECTRIC UTILITIES

Least cost planning in the electric utilities seeks to evaluate a broad range of demand and supply resources to meet future customer energy-service needs, and to select the most cost-effective combination of alternative resources. The process starts with forecasts of future load demand for electricity, and compares it with the existing resource inventory. A broad range of supply and demand resource options are identified and integrated on the basis of levelized costs and other criteria. Finally, uncertainty about future load growth, energy prices, economic conditions and capital cost changes is analyzed for those resource alternatives. A mix of alternative resources is then selected as a least cost plan.

FUTURE DEMAND FORECASTS

To plan energy service to meet future customer needs, the first step in least cost planning is the forecast of how much energy is needed in the foreseeable future, such as 40 years from now. The electric utilities have used a sophisticated array of models to forecast future demand. However, no forecast is perfect, so many utilities now rely on a range of forecasts when either specifying their plans or when making choices under the least cost integration process.

INVENTORY OF EXISTING RESOURCES

The major objective in this step is to make an inventory of existing resources: the capacity, uses and the potential of existing resource supplies. This could include options for entering into long-term contracts with other producers. Some consideration is given to the reliability of each source over time.

IDENTIFICATION OF FUTURE ELECTRICITY NEEDS THAT WILL NOT BE MET BY EXISTING RESOURCES

Comparing future electricity demand and existing resources, it is not difficult to identify the future electricity needs that have to be met by sources other than existing resource supplies. The comparison also gives some indication of the timing that will be necessary to address the gaps. Lead times for both supply and demand options can be quite long, so planning must start well before a gap is expected to materialize.

IDENTIFICATION OF POTENTIAL RESOURCE OPTIONS

Potential resources include supply and demand resources. Supply resources refer to increasing electricity generation capacity. The generic supply categories include: existing utility-owned power plants and contracts; utility construction of new power plants; purchases from other organizations such as other utilities, qualifying facilities, and independent power producers; transmission and distribution improvements; and those that use new technologies (e.g., clean-coal and renewables, such as photovoltaics and wind).

Demand resources refer to reducing electricity consumption, which include energy-efficiency and load-management technologies and marketing strategies.

INTEGRATING DEMAND AND SUPPLY-SIDE RESOURCES

This is the most important part of the least cost planning. Resource integration includes specification of the criteria and methods to use in assessing resource portfolios, development of alternative resource portfolios designed to address different objectives, analytical integration of resources, assurance that the results of the analysis are internally consistent, identification of avoided energy and capacity costs, consideration of reliability and reserve margins, and treatment of the environmental costs of electricity production.

In order to compare the supply and demand resources, the levelized cost of each resource option has to be calculated. The resource costs must consider fuel, operating and maintenance expenses, depreciation, taxes, interest, net income and environmental externalities. These costs must be projected over the useful life of an investment and converted on the present value basis to a series of varying quantities to a financially equivalent constant quantity over a specified time interval. The choice of discount rate and the valuation of environmental externalities are especially important in calculating the levelized costs.

DISCOUNT RATE

The discount rate is the time value or opportunity cost of capital. Both before-tax discount rates and after-tax discount rates may be used (Electric Power Research Institute, 1991). The before-tax discount rate is equal to the sum of return on debt plus return on equity. The after-tax discount rate is equal to the before-tax discount rate minus the tax times the return on debt.

Neither discount rate may be completely appropriate for all electric utilities under all circumstances. However, use of an after-tax discount rate allows all costs to be properly recovered, because the after-tax discount rate reflects the effect of the deductibility of debt return on the federal income tax calculation for the utility. It tends to reduce the cost of money. Most utilities use an after-tax discount rate (Electric Power Research Institute, 1991).

The use of different discount rates has an important impact of the calculation of the levelized costs. A larger discount rate means that future benefits and costs are weighted lower, while a smaller discount rate means the future benefits and costs are valued more highly. Therefore, with a higher discount rate the revenues in the early years of a project are much more important than revenue in later years, when the compounding effect of a high discount rate has greatly reduced their present value.

ENVIRONMENTAL EXTERNALITIES

The environmental effects of using different resources are very important in electric utility planning, and the value and the weight of environmental externalities affects the selection of resources. More demand-side management resources may be selected if more emphasis is given to environmental effects.

Different planning methods treat environmental effects differently. There are three basic approaches. The first is the credit approach. A credit is given to resources that do not use fossil fuels. For example, the Wisconsin Electric Power Company (WEPCO) applied a fossil fuel emission credit of 15 percent to the cost of any resource that does not use fossil fuels (Hill, Hirst, and Schweitzer, 1992). The second approach is to use a weighting system. That is, the cost of each resource option is weighted by a factor from 0 to 1.0. For example, the New England Electric System (NEES) assigned an "environmental score" to each supply and demand resource. The "environmental score" varies from 0 to 0.15, which is determined by an environmental externality matrix that is developed on the basis of both qualitative and quantitative features of environmental externalities. The third approach is to use a ranking system. For example, Seattle City Light classified all demand and supply resources as those with low, moderate, high-moderate, and high levels of environmental impacts.

RESOURCE INTEGRATION METHODS

Utilities typically use one of two general approaches to assess alternative resource portfolios: the sequential approach and the simultaneous integration approach (Hill, Hirst, and Schweitzer, 1992). The sequential approach can be accomplished in one of two ways: demand first sequential methods or supply first sequential methods. In the demand first sequential approach, cost-effective demand-side management programs are selected first; their energy and/or demand effects are then subtracted from a gross demand forecast, resulting in a net demand forecast. Any further resource requirements are satisfied by supply resources. In the second sequential approach, traditional supply-side analysis is conducted first. An optimal capacity expansion plan is developed to meet a projected load forecast. Then, demand-side resources displace a portion of those on the supply side if the demand-side resources are more cost-effective.

Under the simultaneous approach, demand and supply resources are selected jointly. That is, dividing demand and supply resources into two distinct groups, an inter-group ranking of resources is accomplished using financial and other criteria, rather than strictly an intra-group ranking. The mix of resource options are then selected for inclusion in the plan on the basis of this ranking.

The criteria used in the ranking of resource options include minimizing revenue requirements, capital costs, or average electricity prices; ensuring adequate reserve margins and the ability to meet high load growth; maintaining certain financial ratios; and/or reducing environmental externalities (Hirst, 1992).

CALCULATION OF LEVELIZED COSTS

An equivalent annual payment forms the basis of one method of comparing resource options. If a series of payments is uniform over time except for a constant apparent escalation, the levelized value of the series can be computed by multiplying the initial monetary amount by the levelization factor, L_n.

$$Ln = \frac{k(1-k_n)}{a_n(1-k)}$$

Where

$$k = (1+e_a)/(1+i)$$

$$a_n = [(1+i)^{n-1}/i(1+i)^n]$$

$$e_a = [(1+e_r)\ (1+e_i)]^{-1}$$

and

e_r = the real annual escalation rate, or the annual rate of increase of an expenditure that is due to factors such as resource depletion, increased demand, and improvements in design or manufacturing (negative rate);

e_i = the annual inflation rate, or the rise in price levels caused by an increase in available currency and credit without a proportional increase in available goods and services of equal quality;

e_a = the apparent annual escalation rate, or the total annual rate of increase in cost, including the effects of both real escalation and inflation;

i = the annual discount rate;

n = the number of years.

UNCERTAINTY ANALYSIS

The last step in least cost planning is the uncertainty analysis. Major factors in uncertainty analysis include load growth, fuel prices, economic growth, capital costs of generating electricity, regulations, and customer responses to demand side programs. There are five basic methods to treat uncertainty: sensitivity analysis, scenario analysis, portfolio analysis, probabilistic analysis, and worst-case analysis (Hirst and Schweitzer, 1990).

With sensitivity analysis, a preferred plan (combination of resource options) is first identified. Key factors are then varied to see how the plan responds.

With scenario analysis, alternative, internally consistent, futures are constructed, and then resource options are identified to meet each future. Best options can then be combined into a unified plan.

With portfolio analysis, multiple plans are developed, each of which meets different corporate goals. Often, these plans are then subjected to sensitivity analysis.

With probabilistic analysis, probabilities are assigned to different values of key uncertain variables, and outcomes are identified that are associated with the different values of the key factors in combination. Results include the expected value and cumulative probability distribution for key outcomes, such as electricity price and revenue requirements.

With worst-case analysis, the utility creates a plan to meet an extreme set of conditions (e.g., high load growth and high fuel prices) and adjusts it as if it later learns that it faces an entirely different set of conditions (e.g., low load growth and low fuel prices). The utility then adjusts its resource acquisitions to meet the newly perceived conditions and evaluates the impact of this "worst case" if it selects the package under consideration.

APPENDIX C

ORGANIZATIONS INTERVIEWED

Electric Utilities/Agencies	Investor-owned(I) or Public (P)
Bonneville Power Administration	P
Consumers Power	I
Central Maine Power	I
Duke Power	I
Eugene Water and Electric	I
Florida Power	I
Georgia Power	I
Idaho Power	I
Green Mountain Power	I
Kansas City Power and Light	I
McMinnville Water and Electric	I
New England Electric	I
Northwest Power Planning Council	P
Nevada Power	I
Pacific Corp	I
Portland General Electric	I
Public Service of Colorado	I
Puget Sound	I
San Diego Gas and Electric	I
Tennessee Valley Authority	P
Utili-Corp United	I
Wisconsin Electric	I

PUCs

California Public Utilities Commission

Research Laboratories

Oak Ridge National Laboratory: Robert Honea, Eric Hirst, Martin Schweitzer

Transportation Organizations

Federal Highway Administration

Patrick DeCorla-Souza, Planning and Analysis Division

Mort Oskard, Office of Policy Development

Sheldon Edner, Metropolitan Planning Division

Transportation Research Board: Ralph Erickson

National Cooperative Highway Research Program: Tom Pasco

Texas Transportation Institute: Tim Lomax

Institute for Transportation and the Environment: Dick Nelson

Todd Litman, Independent Consultant

City of Portland: Greg Jones

Resource System Group (Norwich, VT)

Michigan Department of Transportation

Maine Department of Transportation -case study of Maine

New York Department of Transportation

Syracuse Department of Transportation

California Department of Transportation

Washington State Department of Transportation

Additional information was gained from discussions and speeches of participants at the Least-Cost Transportation Planning Symposium held at SeaTac Washington in November, 1994. Since many of the participants were from the states of Washington and California, we did not make additional efforts to interview them by telephone.