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Applying Electrical Utility Least-Cost Approaches to Transportation Planning

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Applying Electrical Utility Least-Cost Approaches to Transportation Planning

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Executive Summary

Members of the energy and environmental communities believe that parallels exist between electrical utility least-cost planning and transportation planning. In particular, the Washington State Energy Strategy Committee believes that an integrated and comprehensive transportation planning process should be developed to fairly evaluate the costs of both demand-side and supply-side transportation options, establish competition between different travel modes, and select the mix of options designed to meet system goals at the lowest cost to society.

Comparisons between travel modes are also required under the Intermodal Surface Transportation Efficiency Act (ISTEA). ISTEA calls for the development of procedures to compare demand management against infrastructure investment solutions and requires the consideration of efficiency, socio-economic and environmental factors in the evaluation process.

Several of the techniques and approaches used in energy least-cost planning and utility peak demand management *can* be incorporated into a least-cost transportation planning methodology. The concepts of avoided plants, expressing avoidable costs in levelized nominal dollars to compare projects with different on-line dates and service lives, the supply curve, and the resource stack can be directly adapted from the energy sector.

Transportation least-cost planning most closely resembles the electric utility's targeting of demand-side management or peak reduction approaches to eliminate the need to upgrade a distribution line or substation. Such planning requires detailed information on end user loads, is extremely site specific, and generally is conducted on a decentralized basis. Similar to the electricity sector, incentives may be designed and offered to increase participation and market penetration rates for transportation demand management activities.

This paper is written for an audience of transportation planners and presents a least-cost transportation planning methodology that is suitable for corridor and subarea planning. The concept is designed to fully consider an array of transportation mode switches in order to defer or eliminate the need for structural improvements necessitated by increasing levels of congestion. The authors also indicate how least-cost transportation planning principles could be applied to a proposed roads improvement project located in Olympia, Washington.

Transportation least-cost planning is anticipated to be most effective when:

- the deferrable or avoidable infrastructure improvement is capital intensive;
- commuters constitute the majority of the peak-period traffic volume;
- average vehicle ridership is low;
- the duration of the congested peak is short;
- typical commute distances are lengthy;
- trip origins and destinations are clustered; and
- funding is available to provide incentives to encourage mode shifting actions.

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Section 1

Introduction

Parallels exist between electrical energy and transportation planning, and many in the energy and environmental communities believe that lessons learned in the energy field regarding least-cost or integrated-resource planning hold substantial promise for the transportation sector.

Electrical utility least-cost planning attempts to place efficiency, conservation, and load management techniques on an equal footing with new generation when utilities determine how best to meet future peak demand and energy requirements.¹ Environmental and social costs can readily be incorporated into the utility capacity expansion planning process so that it evolves towards a least-social-cost resource acquisition plan.

"*Washington's Energy Strategy: An Invitation to Action*," notes that "energy planners in the Northwest have pioneered 'least-cost planning' as a way to meet our electricity needs at the lowest cost."² The State Energy Strategy Committee believes that many lessons learned in the energy field hold substantial promise in the transportation sector. An integrated and comprehensive transportation planning process can be energy efficient and better serve the public through:²

- Fairly evaluating the costs of both demand-side and supply-side transportation options to meet clearly defined goals while considering social costs, energy consumption, and environmental costs;
- Integrating planning for different modes of travel so there is competition among modes in the planning process; and
- Selecting a mix of options designed to meet overall system goals at the lowest cost to society.

While utility least-cost planning creates a level playing field for conservation, integrated least-cost transportation planning requires planners to compare costs of constructing and maintaining additional infrastructure (road building) with expanded public transportation systems, Transportation Systems Management (TSM) approaches, and Transportation Demand Management (TDM).

Comparisons between travel modes are required under the Intermodal Surface Transportation Efficiency Act (ISTEA). ISTEA calls for the development of procedures to compare demand management against infrastructure investment solutions and requires the consideration of efficiency, socio-economic, and environmental factors in the evaluation process.

While parallels do exist between the energy and transportation sectors, decision-making processes for these sectors do not correspond exactly. The planning processes and approaches described are not offered as a formal model to be duplicated but as a framework for evaluating transportation supply and demand reduction alternatives. They are specifically intended to be used to help defer or eliminate the need for structural improvements aimed at reducing congestion. Once all choices are on the table, the transportation planner can readily identify and select alternatives that maximize societal benefits or minimize costs.

Section 2 of this paper provides an introduction to the concept of least-cost planning as it has developed in the energy industry and discusses, in general, how the concept might "fit" the transportation sector.

Section 3 discusses TDM, including TDM actions and specific program results. Similarities and differences between TDM actions and conservation measures considered when undertaking electrical least-cost planning are illustrated.

Section 4 indicates how electrical utility least-cost planning principles may be applied to the transportation sector. The concept of a mode-switch or TDM action "supply curve" is introduced.

Section 5 illustrates how transportation least-cost planning can be applied to a specific road segment, corridor, or sub-area improvement project. Also introduced are approaches for treating environmental externalities and considering increases or decreases in travel time.

Section 6 identifies attributes of projects that maximize the potential for least-cost planning to be successful and discusses how the methodology might be transferred to other classes of transportation-related projects. Conclusions are presented in Section 7.

Section 2

Electrical Integrated Resource Planning

Resource planning in the electrical industry has evolved and continues to evolve over time. In addition to the use of least-cost principles, several other planning concepts or approaches have been tested by energy planners. Some of these have been retained and integrated into the overall planning process while others have been discarded because they have failed to meet industry or societal requirements.

Significant concepts or approaches that are currently or have been a part of electrical industry planning but are not actually a part of formal least-cost planning include: avoided cost, avoided plants, and competitive bidding. Because these concepts interface or have interfaced with the least-cost planning process, they are discussed in this chapter.

2.1 Energy Least-Cost Planning Concepts and Approaches

Annual energy consumption is akin to annual vehicle miles traveled. Electrical utilities have an obligation to serve new loads, and acquisition programs are designed to secure new generating or conservation resources. Acquisition planning is generally conducted in a centralized manner, with least-cost principles applied to determine the optimal mix of resources to acquire.

Direction for energy resource acquisition planning in the Northwest is centralized and provided by the Northwest Power Planning Council (NWPPC). The Power Council has pioneered the incorporation of least-cost planning principles in utility resource acquisition programs, and is responsible for developing the Northwest Conservation and Electric Power Plan. The goal of this plan is to ensure an adequate, efficient, economical, and reliable electrical energy supply well into the next century. Recommended actions chart the least expensive, both in economic and environmental terms, yet most flexible course the region can take down an uncertain path.³ The Regional Power Plan consists of several elements, including:

- Load growth forecasting;
- Constructing generating and conservation resource "supply curves;"
- Development and testing of a series of alternative resource portfolios;
- Examining consistency with environmental mandates, including the council's fish and wildlife program; and
- The development of an action plan.

In the planning process, each element or step is built on the former. Thus, it is important that each of the preceding steps be made with full and accurate information. An incomplete forecast or resource supply curve will ultimately result in a poor action plan.

It is important to note that, unlike the energy sector, planning in the transportation sector (and the development of the preceding elements) would have to be done on a decentralized basis to be truly meaningful. If there were to be a "regional least-cost transportation plan," it would be the sum of numerous plans developed for specific sites or roadway segments in the region.

2.1.1 Forecasting the Future

Forecasting electrical loads is similar to forecasting traffic volumes. An electricity load growth forecast examines how fast the use of electricity will grow in a region's residential, commercial, industrial, and agricultural sectors. The forecast must also examine the contribution that the region's existing generating mix can make towards meeting both existing and new loads. Will coal and nuclear power plants continue to be available? Are generating plants scheduled to be retired? Is life extension a possibility? Must the hydroelectric system be de-rated due to operational constraints, such as minimum instream flows and reservoir drawn-down requirements?

The load growth forecast must also consider price elasticity and feedback responses such as the degree to which programmatic or price-induced conservation measures will be installed. The performance of conservation measures must also be known. Assumptions must be made regarding the price and availability of natural gas and fuel oil. Customer switches to natural gas or oil could significantly decrease electrical load projections.

Care must be taken to include non-programmatic (or "spillover") conservation actions that consumers are likely to take. For instance, when consumers purchase a new refrigerator, appliance efficiency standards will ensure that the one in the store is more efficient than their old model. If efficiency improvements are not built into forecasts, double-counting of future conservation savings and over-estimation of the need for new resources occurs.⁴

Variable stream flows are also modeled and a hydropower system operating regimen determined. The "firm energy" output of the Northwest's hydro-based system is established through modeling the system using historical and synthetically-derived stream flows.

The Power Council's 20-year load-growth forecast is derived with econometric computer models. Economic growth and the costs of electricity and alternative fuels serve as the basis for the demand forecast.⁴ Load growth and economic uncertainty is dealt with by considering four scenarios:

- "economy booms" (the high scenario);
- "growth moderates" (the medium-high scenario);
- "economy slows" (the medium-low scenario); and
- "recession deepens" (the low scenario).

Thus, there is no single electricity load-growth forecast. Simulation modeling is used with stochastic stream flows and variable economic assumptions to provide a set of expected load growth values.

In constructing its resource acquisition plan, the Power Council values flexibility--the ability to alter course or scale-up programs to adapt to changing or unexpected future conditions. The least-cost acquisitions approach must be both robust and resilient. It should be optimal over a broad range of economic conditions and not a significant loser should unexpected conditions materialize.

2.1.2 Avoided Costs, the Avoided Generating Plant, and Competitive Bidding

The load-growth forecast indicates how much resource to acquire in a given time span to maintain load resource balance. Balance is defined as the ability to satisfy projected energy, peak, and spinning reserve requirements with an acceptable level of service reliability or loss of load probability.

Traditionally, electric utilities met their load requirements through the construction of large scale hydropower or central station, coal, natural gas, oil fired, or nuclear facilities. Characteristics of these projects, in addition to size, include long developmental lead times, capital intensiveness, substantial environmental impacts, and a significant risk of cost overruns.⁴ Business as usual began to change for the electric utilities with passage of the Public Utility Regulatory Policies Act of 1978 (PURPA, P.L. 95-619). PURPA removed barriers against the private development of small power production facilities by requiring electric utilities to:⁵

- Interconnect with and purchase power from qualified small power production facilities (QFs);
- Pay a rate for QF electrical output which is based upon the utility's full avoided costs; and
- Supply retail electric service, including backup power to QFs at non-discriminatory rates.

"Full avoided costs" are defined as the costs to an electric utility for an additional block of energy or capacity that it would generate itself or purchase from another source.⁵ For utilities with rapid load growth, *avoided costs* were often based on the deferrable costs to the utility of building, operating, fueling, and maintaining an *avoided plant* over its useful service life. Since utility expenditures are typically non-uniform, a levelized nominal dollar life cycle costing approach is frequently used to compare resource alternatives.

PURPA was originally conceived as a means of reducing oil consumption and reliance on foreign imports. PURPA was also viewed as a preferred way for utilities to acquire resources to satisfy load obligations by regulators who were weary of dealing with utility cost overruns. Power purchase contracts based on avoided costs would leave the consumer indifferent while stabilizing rates and minimizing risks through transferring them to the private developer.

PURPA fell victim, in part, to its shortcomings and to its own success. Under PURPA, utilities were forced to acquire on a first-come, first-served resource acquisition basis. Uncertainty abounded as no penalties were levied against developers to discourage them from walking away from a project or contract. Utilities were over-subscribed. Planners had not recognized the enormous potential for both biomass or gas-fired cogeneration and renewable generating plants.

PURPA also failed to address energy conservation activities. In some cases, PURPA avoided-cost-based contracts resulted in windfall profits to the developer--and unacceptable cost increases passed on to the utility customers. Regulators began to sense that instead of the "no worse off" costing philosophy contained within PURPA, rate payers could actually benefit or "share the savings," given the development of a comprehensive resource acquisitions program. Utilities also began to shift their avoided plant from large-scale central thermal generating stations to small-scale renewable and cogeneration plants similar to those proposed by private developers.

Least-cost planning--and competitive bidding--evolved to bring order to this disorderly market. With least-cost planning, utilities consider *all* potential resources, both supply and demand-side, to meet forecasted loads.⁶ Once the lowest cost resources are identified, acquisition approaches can be designed, including rebates, targeted requests for proposals (paying for performance), or conservation grant or low-interest loan programs. Utilities found that it was in their ratepayers and stockholders interests to provide

incentives to customers to cover all or a portion of the costs of acquiring and installing energy-saving devices. Such least-cost planning, of course, requires that the utility compile complete and accurate information regarding all reasonably available resource choices.

Competitive bidding evolved as a way for utilities to bring all resource acquisition choices to the table at one time. "All-source" competitive bidding can establish a "level playing field" that encourages competition between generating and conservation resource types and among resource providers.⁴ Purchasers can reduce uncertainty and risk by making choices based on developer track record, fuel supply characteristics, project performance, environmental consequences, economic factors, and perceptions of risk. Risks to rate payers are reduced as the utility offers performance-based contracts. In other words, payments are based on energy actually produced and/or services delivered.

Competitive bidding also eliminates centralized power planning risks--those involved with selecting the wrong resource based on faulty, incomplete, or inadequate information. Competitive bidding may reveal a least-cost resource path not included in the formal least-cost plan. If that is the case, the information can be used during the development of the next scheduled least-cost plan. Competitive bidding enables utilities to identify their actual avoided costs and better pursue least-cost planning objectives.

Utilities are now progressing towards "integrated resources planning." Under this concept, natural gas and electrical utilities would use consistent and compatible assumptions when expanding their distribution system, preparing least-cost plans, and forecasting future load growth.

2.1.3 Constructing Resource Supply Curves

Generating and conservation resource supply curves are the foundation of a least-cost plan. The supply curve shows the potential amount of power or energy that can be purchased at less than or equal to a stated price.³ The supply curve illustrated in Figure 1 provides a representation of "how much resource is available at what cost?" To create a supply curve, the generation or load-reduction capability, and total levelized cost of every conservation or generation resource must be known.

Figure 1
Resource Supply Curve
How Much Is Available At What Cost?

Savings for individual measures or conservation actions can be combined into savings due to operating conservation programs. A supply curve can be constructed for a facility, a technology, or for all resource choices available to a purchaser. Often measures exist which are interactive or mutually exclusive. To avoid "double-counting," the power planner typically assumes that the lowest cost measures are installed first. The system supply curve thus indicates the incremental costs and energy savings given that the least-cost package of measures is installed.

Finally, the supply curve presents the technical potential or quantity of resource that is theoretically available. In actuality, not all households will participate in weatherization programs. The achievable resource potential is equal to the technical potential multiplied by development probabilities, customer participation factors, or appliance purchase penetration rates.

2.1.4 The Resource Stack

The Resource Stack shows the potential and cost for each available conservation or generation opportunity consistent with a given forecast.

The stack ranks the energy conservation and generation opportunities in ascending order of levelized nominal cost per unit of energy delivered. A least-cost resource portfolio or mix for a given load forecast can be assembled by simply beginning at the top of the stack and continuing to acquire resources until the utility load obligation is met. In practice, additional values or constraints are incorporated into the analysis, including fish and wildlife considerations, environmental price adders, generation seasonality, dispatchability, resource location, transmission requirements, and fuel supply diversity. A portion of the Resource Stack for the 1991 Northwest Conservation and Electric Power Plan is indicated in Table 1.³

Table 1
Resource Stack
1991 Northwest Electric Power Plan

<u>Available Resource</u>	<u>Average Megawatts¹</u>	<u>Levelized Nominal Cost, cents/kWh</u>	<u>Cumulative Megawatts</u>
1. Conservation Voltage Regulation	100	1.4	100
2. Hydro Efficiency Improvements	110	2.2	210
3. Industrial Conservation	491	2.6	701
4. Water Heat Efficiency	472	3.5	1173
5. New Commercial Model Conservation Standards	647	3.7	1820
6. Irrigation Improvements	43	4.6	1863
7. Commercial Building Conservation (Renovation and Remodel)	144	4.6	2007
8. Small Scale Hydropower	90	5.0	2097
9. Transmission and Distribution Efficiency Improvements	200	5.1	2297
10. Industrial-2	308	5.3	2605
11. Existing Commercial	859	5.4	3464
12. Residential Model Conservation Standards	213	5.6	3677

1. One average megawatt is equivalent to 8,760 megawatt - hours.

2.1.5 Resource Portfolios and the Action Plan

Through developing and testing a series of alternative resource portfolios, power planners are able to identify significant load and resource-related risks. This type of sensitivity testing incorporates judgments regarding the amount of each resource that is likely to be available and indicates the power systems response to changes in resource availability, price, and performance assumptions. The goal of testing alternative resource portfolios is to ensure an adequate and reliable power supply and to identify immediate actions that are common to several portfolios.³ Such actions are given high priority in an Action Plan.

For its 1991 plan, the NWPPC constructed four resource portfolios, then modeled hundreds of scenarios within each of the four load-growth forecasts in an effort to identify a resource mix that could economically respond to an uncertain future. The portfolios were constructed to address load uncertainty, nuclear and coal power plant unavailability, conservation uncertainty, and the event of a rapid increase in natural gas prices.

In sum, there is no magic or "best" solution which applies over all forecasts and scenarios. Actions which encourage diversity and flexibility are of value--in particular, shortening the lead time to acquire and fully develop a resource. This improves the region's ability to respond quickly to load growth or changing patterns of energy use.³

2.1.6 Incorporating Least-Cost Energy Planning Principles into the Transportation Sector

Elements of energy least-cost planning adaptable to transportation least-cost planning include the avoided plant concept, supply curves, and use of levelized costs to compare projects with different on-line dates and variable service lives. In the transportation arena, the avoided plant analog is the capital and maintenance costs associated with the avoided or deferrable structural fix or roads improvement project.

Supply curves--indicating "how much resource is available at what cost?"--can be constructed for transportation mode switches, such as single-occupancy vehicle (SOV) to carpool or transit. As in the energy planning arena, care must be taken to consider interactive effects, define participation rates, and avoid double counting.

It must be emphasized that least-cost planning is information intensive. Many energy conservation demonstration projects (Thermabilt, RSDP, RCDP, IBP, Energy Edge, Hood River) had to be conducted in the Northwest to document the price and performance of individual conservation measures, packages of measures, or delivery approaches.

Differences between the energy and transportation fields exist in the areas of performance and pricing. Conservation measures, such as installing attic insulation, tend to have a well defined cost--so many dollars per square foot to go from R-0 to R-38, with energy savings dependent on weather conditions. In contrast, the cost to the planning authority of encouraging transportation mode switches is related to the value of incentives offered.

Both energy and transportation planners can use "push"--energy codes, commute trip reduction ordinances--or incentive based "pull" techniques to achieve goals. Transportation planners have great flexibility to create innovative incentives to modify travel behavior. Once attic insulation is installed, however, it is likely to continue to perform for many years. Transportation coordinators must constantly work with mode switch participants to maintain levels of participation and establish program persistence.

In contrast to the \$/kW and \$/kWh price indices used in a least-cost energy plan, transportation planning embraces multiple objectives such as congestion, emissions, fuel consumption, delay, land use, and quality of life indicators such as pedestrian friendliness. Performance objectives are measured in terms of roadway volume-to-capacity ratio, level of service, vehicle miles traveled (VMT), VMT/hour, number of trips, trips/peak period, tons per day/season/year of priority pollutant, and gallons of gasoline or diesel fuel. Here, performance objectives do not have uniform value. A VMT reduction in a rural area is obviously not valued the same from an emissions or congestion standpoint as a VMT reduction in a congested urban area. Transportation planning thus involves the use of many performance objectives, with values not easily expressed in common terms, such as average megawatts or dollars.

2.2 Electric Utility Peak or Demand-Side Management Planning

Peak or demand-side management (DSM) planning is relatively new to the electric industry but has already been shown to produce significant financial benefits. The approach is most effective when targeted to specific geographic areas. Of the planning tools now in use by electric utilities, it may be the one that most closely translates to the transportation sector.

2.2.1 Peak Reduction and Deferrable Transmission and Distribution System Upgrades

Electrical utilities must have sufficient capacity to accommodate both system and individual distribution feeder peaks. System upgrades or load controls are necessary, for example, when an industrial process requires more horsepower than the transformer, incoming lines, switches and protective relays are rated to provide. To a great degree, an electrical distribution system is analogous to a road network, with the electrical current parallel being traffic volume and the feeder capacity similar to roadway capacity.

Utility peak-load management planning can occur at the regional, utility, or distribution feeder level. At the utility system level, new capacity or peaking plant additions, interruptible loads, plus conservation programs are usually considered to maintain peak-load/resource balance. For peaking plants dispatchability is desirable--it is not uncommon for a generating plant to be used for only 100 to 1,000 hours per year. For conservation actions, coincidence of energy savings with projected peak periods is critical. No peak reduction benefits are possible if energy is not typically used during the forecasted peak period. For instance, street and area lighting efficiency programs would provide no peak reduction benefits if the historical peak occurred at 9:00 a.m. in winter mornings due to residential space and water heating, or at 6:00 p.m. in the summer due to air conditioning loads.

At the regional level, the Electric Power Research Institute (EPRI) states that "Demand-Side Management (DSM) measures, when properly targeted to specific geographical areas, can significantly defer the need for capital spending on transmission and distribution (T&D) systems. By cutting peak loads on overloaded components of the T&D system, DSM can reduce the need for new transmission lines, substations, feeders, and secondary service equipment....targeted DSM can produce substantial savings." ⁷

Peak management has been employed by some electric utilities. In its "*Puget Sound Area Electric Reliability Plan*," the Bonneville Power Administration (BPA) evaluated voltage support, fuel switching, targeted-demand reduction conservation programs, combustion peaking turbines, local generation, and contracted or voluntary curtailment as alternatives to a proposed 500 kilovolt double-circuit transmission line crossing the Cascade Mountains to the Puget Sound area.⁸ The transmission line was successfully deferred by providing additional voltage support and by upgrading the capacity of an existing line.

California's Pacific Gas and Electric Company (PG&E) operated a Model Energy Communities Pilot Program designed to demonstrate that targeted and aggressive DSM is a cost-effective and reliable alternative to capital investment in transmission and distribution. PG&E's Delta District study shows that "high concentrations of DSM programs carefully matched to local area costs and timing of loads, can cost-effectively defer investment in T&D facilities." ⁹ With targeted DSM, PG&E was able to reduce its projected overall investment in local T&D capacity from \$112.3 to \$76.4 million over a 30-year planning horizon--a 32 percent reduction that resulted in a \$35 million savings from a total resource cost perspective.

Oregon's Portland General Electric Company (PGE) has conducted macro- and micro-perspective assessments of the benefits of using DSM to displace T&D expansions. At the macro or utility level, targeted DSM benefits occur due to the following:¹⁰

- elimination of the need for wheeling;
- deferred transmission lines and bulk power banks;
- deferred distribution transformers;
- avoided reconductoring;
- line transformer savings;
- avoided operating and maintenance costs; and
- reduced transmission and distribution system losses.

The macro-level cost savings from deploying DSM on PGE's T&D system is estimated to range between \$15.69 to \$17.30/kW per year in present value dollars. Benefit contributions are summarized in Table 2.¹⁰ At the micro-scale, PGE examined the benefits of aggressively targeting DSM at suburban substations, the downtown grid network, and individual buildings. Surprisingly, DSM benefits were found to be low for feeders associated with substations in rapidly growing urban areas. The reason for this finding is that, with rapid growth, substation capital improvements can only be deferred for five years. Targeted DSM benefits were much greater for buildings needing expanded service in the urban core. The downtown grid network is also attractive due to moderate electrical load growth and the relatively high cost of deferrable actions, such as installing underground transformer vaults or buried distribution lines.

Table 2
DSM Impacts on Utility T&D Investments
Portland General Electric

<u>Deferrable Action</u>	<u>Benefits, Present Value</u> \$/kW per year
Wheeling	\$5.09
Bulk Power Bank	\$1.54
Transmission Line	\$0.87
Distribution Transformers	\$6.42
Reconductoring	\$0.17
Line Transformers	\$0.00-\$1.11
TOTALS:	\$15.69-\$17.30

2.2.2 Targeting DSM for T&D Benefits

Achieving significant DSM savings means tailoring DSM programs to geographically-specific needs of a utility's T&D system. DSM impacts at the feeder level must be assessed by carefully studying customer's electricity usage patterns, local T&D expansion plans, anticipated per-customer DSM impacts, and likely DSM measure-market penetration. Typically, hourly loads at the substation or feeder level are necessary as a starting point in desegregating loads into end uses, such as residential air conditioning, water heating, or commercial lighting.⁷ A feeder specific load-growth forecast is also necessary as the use of utility average forecasts can be misleading. The procedure for an area-specific DSM analysis is indicated in Table 3.

Feeder load profiles, per-participant DSM load impacts, likely market penetrations, and estimated costs of DSM programs for a given area are data-intensive and site-specific in nature. As a result, DSM targeting for T&D benefit accrual is done at the decentralized or utility level, rather than at the regional or central power planning authority level.

To date, using targeted DSM to defer T&D upgrade capital costs has not been widely incorporated into the least-cost energy plans required of investor-owned-utilities by state regulatory authorities. It is likely that this practice will change as of a projected cumulative \$131 billion utility construction outlay over the 1993-1997 period; over \$90 billion will be spent on T&D improvements.¹¹

Table 3
Procedures for Area-Specific DSM Analysis

- Develop area-specific hourly peak load data;
- Examine base case transmission and distribution system expansion plans;
- Estimate area and time-specific marginal T&D costs;
- Disaggregate area loads by customer class and end use;
- Assess DSM load impacts, market penetrations, and costs; consider interactions of multiple DSM measures targeted for the same population of customers; and
- Select and analyze an area-specific DSM program portfolio. (The major component of this step involves the construction of an Integrated Plan by completing a side-by-side comparison of the price and performance of supply-side and demand-side alternatives.)

2.2.3 Electric Utility DSM Techniques and Technologies

Methods of managing demand-side electrical loads include: 1) direct load control; 2) strategic energy conservation; 3) use of storage technologies; 4) fuel switching; 5) time of use or interruptible rates; and 6) distributed utility concepts.

Direct load control techniques include radio-controlled domestic hot water heaters, space heaters, and air conditioners. Load shedding typically occurs only during periods when loads approach historical utility peaks. For hot water heaters, peaks are clipped and valleys filled by locking the heating elements out for the duration of the peak period. Staggered restart algorithms are used to avoid the production of a secondary peak caused by coincident water heating demands.

In contrast, space heaters and air conditioners cannot be locked out for extended time periods without causing occupant discomfort since typical monthly peaks occur during extreme weather events, such as heat waves or snowstorms. These units are usually cycled at 30-minutes on, 30-minutes off intervals, or with the cycle modified to 40-minutes on, 20-minutes off when there are customer complaints. Peak

savings from employing cycling patterns are also tempered by increased energy consumption or "take back" during the energized portion of the timing cycle.

Strategic energy conservation measures may be applied in the residential, commercial, industrial, or agricultural sectors. Appropriate measures are those that reduce energy consumption over all or a portion of the duration of the utility peak. For example, in the Pacific Northwest, winter peak loads occur during the 7:00 a.m.-10:00 a.m. and 5:00 p.m.- 8:00 p.m. periods due to morning and evening space and water heating requirements. Methods of reducing these loads include building envelope weatherization, such as increased attic, under-floor or wall insulation; double or triple-paned windows with thermal breaks, insulated doors, and caulking and sealing to reduce air infiltration. Hot water consumption is minimized by employing low-flow shower heads, faucet aerators, and water heater wraps. Commercial lighting loads can be reduced with the use of low-wattage, energy-saving fluorescent lamps, high-intensity discharge lamps, electronic ballasts, specular reflectors, occupancy sensors, and daylighting/photocell dimming approaches.

Industrial process loads can be decreased through the use of energy-efficient motors, variable-speed drives, high-coefficient-of-performance heat pumps, screw compressors, and improved refrigeration system controls. Plug loads can be minimized through the purchase of energy-efficient appliances and office equipment.

Energy storage techniques include oversize water heaters equipped with timeclock lock-outs, and a host of residential and commercial scaled heat, chilled-water and ice storage systems. With thermal storage, loads are completely shifted to off-peak periods as the units are generally charged during the late evening and early morning hours.

Fuel switching is another method of eliminating or displacing loads. Converting electric hot water heaters to natural gas can completely remove selected loads from a distribution feeder. In the commercial/institutional building area, the installation of boilers capable of operating on multiple fuels can allow the building operator to select the lowest priced fuel during seasonal or peak periods.

Time-of-use or interruptible rates can be used to reduce loads by conveying the proper price signals to consumers. Here, decisions regarding what loads to reduce are made on a decentralized basis by building operators or industrial facility managers. Time-of-use rates are particularly effective when the utility is able to provide a signal to an on-site energy management system. Loads can then automatically be shed or restored based on real-time cost-of-service information. Interruptible rates are useful for customers who are willing to accept a reduced degree of utility service in exchange for a lower electrical rate. These loads can be taken off line for a contractually agreed upon number of hours or occurrences per month. Some industrial, commercial, or institutional customers restore reliability and continue production by installing emergency or backup generating capability.

The Distributed Utility concept involves strategically locating new generating units, either gas turbine or diesel engine/generator peaking or cogeneration plants, photovoltaic units, landfill or wastewater treatment facility biogas plants, or fuel cells along or adjacent to stressed feeders or substations. With appropriate generating plant performance and reliability characteristics, substation, switchyard, and feeder improvements can be deferred or eliminated.

The point is that there is no "one size fits all" solution. Distribution systems planning is conducted in a routine and continuous basis by *local* utility staff. Detailed, site specific information is required for the utility planner to properly determine both the costs and benefits of individual DSM actions or portfolios of measures. Network or systems analyses must also be made as modifications to one distribution feeder tend to affect currents and voltages on adjacent lines. Lastly, both energy and DSM planners are still

grappling with means of incorporating environmental externalities into a comprehensive least-cost planning process.

A wide variety of complementary, competing, and interactive techniques are available to the electricity demand-side management planner. The optimal mix of techniques to achieve a given load reduction heavily depends upon site-specific parameters such as the avoidable costs of the system upgrade, seasonality and duration of the peak load, the composition of the loads making up the peak, customer class mix, the degree to which conservation measures have already been employed, coincidence of loads with the system peak, and the willingness of customers to participate in DSM programs or accept a reduced level of service.

2.2.4 DSM Evaluation Factors

A great deal of customer information must be accessed before a least-cost DSM planning process can begin. Residential utility meters typically only record monthly energy consumption. Peak load data are frequently available only at the feeder or substation level. To assess potential DSM benefits, assemble a marketing program, and implement resource acquisition programs, the utility planner must know how many central electric forced air systems, baseboard heaters, or domestic hot water heaters are served by a given feeder. Demographic and behavioral information are also necessary to verify that loads coincide with the peak and match DSM measures to the requirements of both occupants and the electrical system. Sub-metering of a sample population of residential and commercial sector loads may be required. The starting point for the DSM least-cost planning process is thus a detailed customer survey.

Marketing plans and market penetration are key phrases for power planners. Incentives must be designed to secure adequate market penetration and customer participation. Resource portfolios might be graded on the basis of do-ability and deliverability, as well as an environmental matrix, and with respect to capital, operating, and maintenance costs. Evaluation programs must be designed to verify that peak reduction benefits are obtained and to monitor persistence--the degree to which DSM benefits are maintained over time.

DSM marketing, monitoring, and evaluation efforts incur administrative expenses which must be included into the measure costs when evaluating least-cost alternatives to a T&D system upgrade. Finally, utilities might have to offer educational programs or address equity issues or rate payer concerns when it is perceived that an attractive "deal" is only available to consumers situated along a certain feeder or located in a specific geographical area.

2.2.5 Applying DSM Least-Cost Planning to the Transportation Sector

The closest analogy to least-cost transportation planning in the electric utility sector is in distribution system feeder upgrading. Options open to the electric utility include improving system efficiency/reducing losses through:

- reconductoring (similar to traffic light synchronization);
- boosting capacity through line voltage increase (similar to adding a lane);
- fuel switching (similar to single occupancy vehicle mode switching to car pools, van pools, or transit); or
- peak load management (similar to telecommuting or teleconferencing).

Like transportation planning, T&D system upgrade least-cost planning is site-specific and extremely data intensive. 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. In both planning arenas, incentives may be offered to increase participation or market penetration rates.

The evaluation process and handling of savings persistence issues are also similar. Infrastructure improvements can only be avoided or deferred as long as DSM benefits continue to materialize. Changes in housing stock, occupancy, industrial processes, levels of production, and increased use of office equipment can overwhelm projected savings and place the capital improvement back on the drawing board. Portfolios of DSM or transportation demand management (TDM) measures will likely require sustained intervention with constant refinement or "tinkering" as new technologies emerge over the life of the avoided capital improvement.

Finally, the approach applicable to least-cost transportation planning is very similar to that employed in T&D system expansion planning:

- understand the capital and maintenance cost benefits associated with the avoidable capital improvement;
- obtain information regarding the composition, nature and coincidence of loads/roadway users relative to system electrical peaks or highway congestion;
- identify DSM/TDM measures that may be employed to offset the present or forecasted need for the infrastructure expansions;
- design incentives which are adequate to recruit sufficient numbers of electrical end users/motorists to achieve planning goals;
- assemble a portfolio of measures designed to achieve the desired peak load or congestion reductions at the least social cost; and
- monitor, evaluate, and update the implementation of the least-cost planning approach as required.

Section 3

Transportation Demand Management

To meet obligations to serve new loads but avoid "new" infrastructure, electric utilities employ energy conservation or demand reduction measures. In the same way, transportation planners use transportation demand management (TDM) options to manage vehicle trip demand.¹³

Transportation demand management is a series of actions, or a process, whose purpose is to alleviate traffic problems through improved management of vehicle trip demand.¹² TDM involves the art of modifying travel behavior, usually to avoid a costly expansion of the roadway infrastructure.¹³ TDM actions have primarily been directed at commuter travel and have historically been structured to either reduce the dependence on and use of single occupant vehicles or to alter the timing of travel to less congested time periods.¹²

TDM involves taking actions to shape travel behavior. Command and control regulations or ordinances, road pricing or parking availability constraints, or a variety of incentives can be offered to achieve program goals. TDM can be used to reduce vehicle trips, assist in the attainment of air quality standards through reducing emissions within a given airshed, save fuel, or eliminate congestion on a specific highway or road segment. Depending on program goals, TDM may require innovative legal and institutional approaches and the cooperation of many stakeholders, including developers, landowners, employers, business associations, and municipal, county, regional, and state levels of government.^{12, 13}

In some areas, congestion itself serves as a restraint mechanism or barrier to increased traffic levels. Congestion, however, is not considered an economically, socially, politically, or environmentally viable long-term solution to the problems of increased travel demand or traffic growth.¹⁴ The goal of a TDM approach to congestion management is to better distribute traffic, both spatially and temporally, on the existing road network. Understanding the individual commuters behavior--knowing why and how they make their travel decisions--is critical to any demand-side congestion relief strategy.¹⁵

When faced with traffic congestion, tripmakers can:¹⁶

- change their destination (redistribution);
- change their route (reassignment);
- change their time of departure (rescheduling);
- change their travel mode (mode switching);
- change their vehicle occupancy (carpooling); or
- change the frequency of their trip making or opt out entirely (trip suppression or elimination).

Planners can also limit traffic volume through accessing such TDM techniques as road congestion pricing, restrictions on the parking stock, exclusionary zones or prohibitions on vehicle use in certain areas, or through using traffic "calming" devices such as collars, throats, closed cells, or mazes to make selected routes less desirable.¹⁴

In addition to modifying the travel behavior of trip makers, transportation and land use planners can affect trip generation by limiting the timing and extent of new development to that which can be absorbed by the community including existing and planned transportation infrastructure (growth

management); allowing a higher density of development; zoning changes to co-locate residential and commercial development (jobs/housing balance); and promoting technologies, such as telecommuting, teleshopping, and teleconferencing that eliminate the need for trip making.^{13,17}

3.1 TDM Actions

Controlling the demand for transportation infrastructure expansions through trip generation focuses on the elimination of trips by land-use actions or making attractive substitutes for travel available. Accomplishing TDM objectives via trip distribution focuses on shifting trips from more to less congested roadways. This can be accomplished by shifting the location of activities within urban/suburban areas and chaining trips.¹⁷

TDM efforts involving mode choice attempts to shift trips from low-occupancy modes of travel such as single-occupancy vehicles to higher-occupancy modes such as carpools, vanpools, transit, or light-rail systems. Mode choice opportunities can be encouraged by increasing development densities to improve the availability and levels of service offered by higher occupancy vehicles. Incentives for mode switching may include increased parking prices for single-occupancy vehicles, free transit passes, offering carpool matching services, subsidized vanpools, providing bicycle and pedestrian amenities, and offering guaranteed rides home.¹⁷

Spatial route selection actions involve a shift in trips from a more to a less congested route. Trip reassignment approaches may be effective if the planning goal is to abate congestion but ineffective if the goal is to save fuel or reduce vehicle emissions. Activities that influence spatial route selection include traffic-calming devices or barriers to remove through traffic from selected streets; the use of permanent or temporary barriers to divert traffic to less congested locations; and the use of instantaneous route information with intelligent vehicle and highway systems.¹⁷ The availability of real time traffic information can allow a driver to select the alternative route with the shortest travel time when the preferred route is congested.

Temporal route selection actions involve the shift of trips from more to less congested time periods. Strategies to implement temporal route selection include alternative work schedules such as flexible working hours, staggered work shifts, and compressed work weeks.¹⁷ Temporal route selection can be an effective tool for promoting congestion relief but offers less benefit when air quality improvements are of concern. Temporal route selection and departure time switching are strongly influenced by workplace lateness tolerance and individual characteristics, such as preferred arrival time and job position.¹⁵ The benefits obtainable through temporal route selection may also be dependent upon the duration of the peak use or congested period. Lastly, encouraging temporal route selection actions may actually hamper the recruitment of individuals into mode-choice alternatives such as carpools.

The benefits of employing TDM techniques are dependent upon the transportation system supply (roadway carrying capacity versus current and projected level of use) and transportation system efficiency (degree of TSM actions taken). TDM and TSM approaches can be complementary rather than competing strategies to achieve reductions in congestion and promote more efficient transportation system utilization. TDM approaches, objectives, and implementation strategies are summarized in Table 4.¹³

Table 4
**Transportation Demand Management
 Objectives and Implementation Strategies**

<u>Aspect of Travel</u>	<u>TDM Objective</u>	<u>TDM Implementation Strategies</u>
Trip generation	<i>Trip suppression:</i> Eliminate trip entirely	Land use: Growth control (eliminate specific activities associated with trip making). Transportation: Telecommunication substitutions for travel (telecommuting, teleshopping, teleconferencing), eliminate trip making associated with specific activities.
Trip distribution	<i>Redistribute trip:</i> Shift trip to a less congested destination.	Land use: Zoning restrictions that limit the density of development, shifting the location of activities within urban or regional areas. Transportation: trip chaining, satellite activity locations (satellite work locations, on-site daycare facilities, personal services, cafeterias, restaurants, etc.)
Mode choice	<i>Mode switch:</i> Shift trip to a higher-occupancy mode of travel.	Land use: Increasing allowable density of development (to improve the market for high occupancy vehicle facilities). Transportation: Mode-specific incentives and disincentives, such as parking pricing, carpool, vanpool, and transit subsidies; bicycle and pedestrian amenities; and guaranteed-ride-home programs.
Route selection (spatial)	<i>Reassign trip:</i> Shift trip to a less congested route.	Land use: Street quieting (removal of through traffic from residential streets through creation of permanent or temporary barriers). Transportation: Smart highways and vehicles (technologies capable of the instantaneous delivery of current route information, including identification of the route with the shortest travel time, based on ambient traffic conditions before or during the trip).
Route selection (temporal)	<i>Reschedule trip:</i> Shift trip to a less congested time period.	Land use: Mixed use development, jobs/housing balance (where different land uses exhibit different peaking characteristics of trip generation). Transportation: Alternative work schedules (flexible work hours, staggered work shifts, and compressed work weeks).

3.2 Trip Reduction Ordinance Results

Transportation management associations have been established and Trip Reduction Ordinances (TROs) passed for the purposes of current or future congestion relief, controlling growth, and improving air quality. Most TROs seek to mitigate existing traffic congestion, although county and regional TROs tend to be oriented more towards air quality improvements.¹³ Many believe that future solutions to traffic congestion will require more of a behavioral and organizational response than a technical fix.¹⁷

Current TROs and TDM actions are directed at commuter travel since the most significant demands on the transportation infrastructure usually occur during weekday morning and evening peak periods. This time period is dominated by commuter travel which is characterized by low vehicle occupancy rates.¹² The regularity of commute trips, high travel densities, and common destinations make regulation through the workplace appealing.

California's South Coast Air Quality Management District (SCAQMD) Regulation XV is designed to reduce emissions from mobile sources and requires employers to take responsibility for encouraging workers to consider alternatives to driving to work alone.¹⁹ Regulation XV requires public and private employers, with over 100 employees at any worksite, to appoint a transportation coordinator and to submit a plan showing how they intend to increase the Average Vehicle Ridership (AVR) to a specified level within one year of the plan's approval.¹⁹ The package of measures, constraints, and incentives necessary to provide the desired transportation behavior changes is left to the individual employers.

Monitoring of commute trip reduction program effectiveness could consist of traffic counts, vehicle occupancy counts, and a variety of employer, employee, and household based surveys.²⁰ SCAQMD's AVR index may roughly be defined as the quotient of the number of employees arriving at work between 6:00 and 10:00 a.m., divided by the number of motor vehicles driven by those employees. The AVR ratio is calculated over a five-day work week with adjustments made to the ratio to account for employees who telecommute.¹⁹ AVR targets are determined by geographical location: 1.75 for the central business district (where transit access is available and extensive ride-sharing is already practiced); 1.5 for urban and suburban areas, and 1.3 for outlying, low density zones. At the inception of SCAQMD's TRO program, the regional average AVR was between 1.1 and 1.2.¹⁹

A two-year study of the Southern California program produced some interesting results. In the first year, 1100 sites with approved TRO plans were reviewed. The most frequently offered employer incentives included preferential parking for carpools and vanpools, financial incentives for transit users, a guaranteed ride home, and prize drawings. For the entire sample, the mean AVR increased 2.7 percent, from 1.213 to 1.246, for the first year of the program implementation period. AVR increased at 69 percent of the sites and actually decreased at 31 percent of the sites. The proportion of workers driving to work alone decreased from 75.7 percent to 70.9 percent, with transportation mode shifts resulting in a reduction of four motor vehicle trips per 100 employees.¹⁹

Virtually all of the improvement was due to single occupancy vehicle drivers shifting to carpools. Changes in mode share attributable to transit, walking, biking, telecommuting, and using a compressed workweek were negligible. Change in mode shares are summarized in Table 5.¹⁹

Table 5
Employee Trip Reduction Program
Mode Share Changes

<u>Mode</u>	<u>Baseline</u>	<u>After One-Year</u>	<u>Percent Change</u>
Single Occupancy Vehicle	.757	.709	-6.3
Carpool	.138	.184	33.3
Vanpool	.021	.024	14.2
Bus	.032	.032	0.0
Walk/Bike	.029	.028	-3.4
Telecommuting	.006	.005	-16.7
Compressed work week	.016	.019	18.8

In the second year, 243 worksites of the original 1100 were studied. AVR increased an additional 3.6 percent, with most of the increase attributed to further increases in carpooling. While vanpooling also increased, it constituted a very small portion of commuter trips. As indicated in Table 5, other modes provided little beneficial impact because their use did not increase to an appreciable extent.¹⁹

Table 6
Mode Splits After Two Years of TRO
Program Implementation

<u>Mode</u>	<u>Baseline</u>	<u>After One-Year</u>	<u>After Two-Years</u>
Single Occupancy Vehicle	.751	.697	.654
Carpool	.142	.194	.231
Vanpool	.006	.010	.014
Bus	.039	.038	.044
Walk/Bike	.032	.032	.033
Telecommuting	.005	.003	.003
Compressed work week	.025	.027	.022
AVR	1.216	1.258	1.304

From an employer's perspective, an emphasis on carpooling makes sense as it is minimally disruptive to existing organizational patterns and is easy to market through regional ride-sharing programs. From the employee's perspective, door-to-door travel time differentials might be longer for carpools than for single occupancy vehicles, but more attractive than bus or mass transit alternatives. Travel times have been reported in Los Angeles County of 21 minutes for solo drivers, 27 minutes for carpools, and 42 minutes for transit riders (1980 census).¹⁸

It is evident that commute trip reduction programs will have to operate for several years if the AVR rates desired by transportation planners are to be achieved. Studies are underway to identify how to improve the effectiveness of commute trip reduction and ridesharing programs. Participants in ridesharing programs are likely to:

- have a longer commute (14.8 miles) than single-occupancy vehicle users (11.4 miles);
- have fewer than the average number of cars in the household;
- work for larger companies;
- work for companies that provide ridesharing assistance;
- be on a fixed work schedule; and
- choose this option because of cost savings.

"Switchables" (individuals most likely to change from a drive alone to a ridesharing mode) are likely to be found in homes where the number of licensed drivers is low, where there is a male head of household, and the individual is a blue collar or non-professional, or managerial worker.²¹ Drawbacks to increased carpool participation include incompatible schedules and frequently changing schedules. "Attraction," or how much carpools like one another is cited as a favorable interpersonal index of carpool success.²¹

Washington State's Commute Trip Reduction law was adopted by the 1991 Legislature with the intent of improving air quality, reducing traffic congestion, and reducing the consumption of petroleum fuels. The law requires the establishment of employer-based programs that encourage the use of alternatives to the single-occupant vehicle for the commute trip. The law applies to employers with 100 or more full-time employees at a worksite, who are scheduled to begin their work day between 6:00 a.m. and 9:00 p.m. weekdays, and that are located in counties with a population exceeding 150,000 (Clark, King, Kitsap, Pierce, Snohomish, Spokane, Thurston, and Yakima counties).²²

Washington's law establishes goals for reducing commute trip vehicle miles traveled by the employees of affected employers. These goals are a 15 percent reduction by 1995, a 25 percent reduction by 1997, and a 35 percent reduction by 1999, measured against a 1992 baseline. Like SCAQMD, Washington law requires employers to prepare and implement trip reduction plans.

The impacts of Washington's existing law must be considered when assessing the role of future transportation demand management activities. First, the program's vehicle miles traveled and trip reduction goals must be taken into account when preparing transportation forecasts. This entails making assumptions regarding mode splits and future travel behavior. Second, the incremental impacts of additional TDM actions must be considered with respect to a modified baseline--the 1992 baseline corrected to account for mandated CTR program goals.

3.3 Comparing TDM and Electrical Least-Cost Planning

To date, TDM has primarily been directed at commute travel through the passage of local or regional trip reduction ordinances. Employers are typically charged with assembling plans that comply with the TRO program goals: emission benefits, congestion relief, fuel savings, or a combined goal. Employers provide incentives and offer services designed to facilitate desired mode shifts and changes in average vehicle ridership. If monitoring indicates that program goals are not being met, the employer must produce an enhanced plan. Decision making is decentralized with employers presumably making choices that minimize their costs and administrative burdens.

In contrast, electrical energy least-cost planning is centralized and carried out by utilities, public utility commissions, or power planning councils. Demand forecasts and assumptions regarding resource price and availability are debated in public forums. Forecasted needs are expressed in average megawatts that must be acquired in a given year to meet system reliability and reserve requirements. In the Northwest, there is little difference-- except for seasonal, environmental externality, and peak reduction benefits-- between a megawatt supplied by conservation, conventional thermal, or a renewable resource. Similarly, except for minor transmission losses, a megawatt produced in Idaho provides the same benefits to the region as a megawatt produced in Washington. A cap on "willingness to pay" for electrical energy is generally established through the deferral or offset of an "avoidable" generating plant. Least-cost plans are typically updated on a two-year interval. If acquisition targets are not met, the region can cover the shortfall by importing energy from outside the region. Finally, competitive bidding has evolved as a means of transferring risks to the private sector; of creating a level playing field; and for placing all resource choices on the table.

The closest analogy to least-cost TDM/TSM planning in the utility sector is peak load management applied to distribution-system-feeder upgrading. A comparison between transportation and electric utility demand management measures is shown in Table 7.^{13, 17}

Distribution system planning is done routinely and continuously by local utility staff and not at a regional or state level. The utility planner needs a great deal of information to properly determine both costs and benefits of the available alternatives. Improvements or modifications to one distribution feeder also tend to affect currents and voltages on adjacent lines.

Transportation planning is similarly *site-specific* and *extremely data-intensive*. Forecasts must consider growth in population and population density. A trip generation model is necessary within an affected boundary so that planners know where the populace wants to go and when. Assumptions must be made concerning current and future land uses, travel modes and fuel prices. Traffic counts must be made at 15-minute intervals so periods of oversaturated operation can be identified and to enable model calibration.

With this information in hand, planners can examine needs for expanded capacity and construct TDM supply curves that may or may not be mutually exclusive. Impacts on adjacent roadways or infrastructure must also be considered when investigating all capacity expansion alternatives. Finally, cost information or results obtained from one road segment are not directly transferable to other segments. There is no analogy between road segment or area-specific TDM actions and a state or regional energy "supply curve."

Table 7
**Transportation and Energy Demand Management Measures
 Categorized by Goal and Type**

<u>Transportation Demand Management (TDM)</u>		<u>Electrical Demand-Side Management (DSM)</u>
	<u>Objectives and Implementation Strategies</u>	
Trip Generation (Eliminate Trips)	Growth control, substitution for travel, telecommunications.	Eliminate Loads: Residential and commercial building codes, appliance efficiency standards.
Mode Choice	Shift from a lower to a higher occupancy mode of travel.	Strategic load and demand reduction. Targeted conservation to reduce end use energy consumption.
Trip Distribution	Shift trips from a congested to a less congested destination.	Fuel switching. Convert from electric to natural gas-fired space and water heat.
Temporal Route Selection	Shift trips from a more to a less congested time period	Peak chopping, valley filling, load shifting. Use of energy storage technologies and control systems, including time clocks, radio-controlled loads, and energy management systems.
Spatial Route Selection	Shift trips from a more to a less congested route.	Trade offs in reliability and quality of service, including interruptible rates and time-of-day pricing.

Section 4

Designing an Integrated Least-Cost Transportation Planning Approach

A transportation sector least-cost planning approach can be constructed by extracting concepts developed for the Public Utilities Regulatory Policies Act (PURPA)-based generating resource acquisition policies, electrical energy least-cost planning approaches, and electric utility peak or demand-side management programs. Similar to the electrical supply arena, the transportation planner must:

- conduct transportation demand forecasts, taking future commute trip reduction mandates into account;
- identify the number of peak period vehicles/trips that must be eliminated on an annual basis for the corridor of interest to maintain acceptable levels of service;
- determine the capital and maintenance costs imposed by the avoidable road improvement or structural fix;
- obtain information regarding the users of road segments during congested periods;
- identify barriers, constraints, and incentives that encourage changes in behavior, such as shifting single occupancy motorists to alternative travel modes;
- construct "supply curves" for TDM measures that may be used to offset the need for the infrastructure expansion. Benefits due to the capture of environmental externalities can be indicated on the supply curves;
- assemble a least-cost portfolio of TDM measures designed to achieve the desired congestion reductions or emissions benefits. Cost savings occur as: 1) The TDM program is stageable or may be ramped up so that only the number of participants necessary to achieve program goals are recruited in a given year; and 2) Participants that require minimal incentives are selectively and preferentially recruited into the TDM program to maximize societal benefits;
- prepare and implement a least-cost TDM marketing plan for the corridor or subarea of interest; and
- monitor, evaluate, and refine the least-cost transportation improvement plan as required.

4.1 Forecasting Transportation Demand

Future traffic volumes must be projected with a land-use-based traffic forecasting model. The traffic forecasting model should account for all arterials and collector roads in the study area and be capable of accurately simulating intersection turning movements.^{23,24} The model must incorporate planned transit, bicycle and transportation infrastructure improvements, and incorporate low-cost/no-cost transportation system efficiency measures (such as optimized traffic light synchronization, turn-out lanes or turning restrictions). Optimal control measures must respond dynamically to future changes in traffic volume.

The model should consist of the following:

- a physical description of each road segment in terms of operating speed, number of lanes, hourly capacity, and intersection signal characteristics;
- a geographic inventory of households and employment zones; and
- human activity pattern descriptors, including:
 - trip generation per housing unit or job;
 - trip length characteristics. The trips originating in each traffic zone must be allocated to other zones as destinations; and
 - traffic assignment protocol for allocating trips between zones to specific paths through the road network. Individual driver decision-making must be simulated. Typically, the fastest route to each destination is selected accounting for congestion on all possible paths.

The model must be adjusted to account for present and future traffic reductions attributable to commute trip reduction ordinances. The model must also be calibrated so that existing traffic counts and mode splits are replicated.

The traffic forecasting model should indicate the increased vehicle demand over the carrying capacity of the existing transportation network. The model, thus, indirectly represents the number of vehicles/trips that must be eliminated for the existing system to continue to provide the desired level of service. Results of a traffic forecast are depicted in Figure 2. Level of Service (LOS) definitions, indicated in Table 8, are based on delay at key intersections. The definitions are provided in the Transportation Research Boards' Highway Capacity Manual.²⁴

Figure 2

Traffic Forecast Results

LOS D is typically used as a design criteria in urban areas with LOS E considered at capacity. Long delays associated with LOS F are to be avoided as the vehicle arrival rate exceeds the capacity of the intersection. Thus, the intersection fails to clear and a vehicle queue forms. Gridlock/gridcrawl occurs when the queue interferes with the vehicle progression at adjacent intersections.

Table 8
Level of Service Definitions

Level of Service A:	Describes operations with very low delay, i.e., less than 5.0 seconds per vehicle. This occurs when progression is extremely favorable and most vehicles arrive during the green phase. Most vehicles do not stop at all. Short cycle lengths may also contribute to low delay.
Level of Service B:	Describes operations with delay in the range of 5.1 to 15.0 seconds per vehicle. This generally occurs with good progression and/or short cycle lengths. More vehicles stop than for LOS A, causing higher levels of average delay.
Level of Service C:	Describes operations with delay in the range of 15.1 to 25.0 seconds per vehicle. These higher delays may result from fair progression and/or longer cycle lengths. Individual cycle failures may begin to appear. The number of vehicles stopping is significant at this level, although many still pass through the intersection without stopping.
Level of Service D:	Describes operations with delay in the range of 25.1 to 40.0 seconds per vehicle. At level D, the influence of congestion becomes more noticeable. Longer delays may result from some combination of unfavorable progression, long cycle lengths, or high volume/capacity (v/c) ratios. Individual cycle failures are frequent occurrences.
Level of Service E:	Describes operations with delay in the range of 40.1 to 60.0 seconds per vehicle. This is considered the limit of acceptable delay. These high delay values generally indicate poor progression, long cycle lengths, and high v/c ratios. Individual cycle failures are frequent occurrences.
Level of Service F:	Describes operations with delay in excess of 60.0 seconds per vehicle. This is considered unacceptable to most drivers. This condition often occurs with over saturation, i.e., when arrival flow rates exceed the capacity of the intersection. Poor progression and long cycle lengths may be contributing causes to such delays.

Source: Transportation Research Board 1985

4.2 Avoided Infrastructure Costs

The avoided infrastructure costs reflect the present value of designing, constructing, and maintaining the preferred infrastructure improvements, less upgrade costs that would otherwise be required. TDM benefits may be accrued due to completely eliminating the need to invest in an infrastructure expansion or from the deferral of the investment. Related infrastructure improvement costs, such as the provision of additional parking or auto-related municipal services, including police, emergency services, courts, and street lighting, should be considered when appropriate.

4.3 Developing Supply Curves for TDM Measures

In the electrical energy planning arena, the supply curve depicts how much energy supply resource is available at a stated price. This concept can easily be extended to the transportation field after recognizing that the measure cost in energy planning equates to the level of incentive offered to promote transportation mode switching.

Transportation sector supply curves also borrow from the targeted assessment techniques used in electric utility DSM programs. Here the DSM supply curves are constructed only for the loads in a building, customers on a distribution feeder or substation, or for all end users within a network. Supply curves for TDM actions are constructed for users of a congested roadway during peak periods or for mobile emission sources within a non-attainment airshed.

4.3.1 Available Mode Switches

Available TDM mode switches are indicated in Table 9. Obviously, some switches, such as vanpool to transit, would incur a much higher incentive cost than others or are unlikely to occur as they require collective action by a number of riders.

Table 9
Potential TDM Mode Switches

SOV to carpool (CP)	CP to VP
SOV to vanpool (VP)	CP to T
SOV to transit (T)	*CP to B/W
SOV to bicycle/walking (B/W)	*CP to TC
SOV to telecommuting (TC)	CP to CWW
SOV to compressed work week (CWW)	*T to B/W
*VP to T	*T to TC
*VP to B/W	*T to CWW
*VP to TC	
*VP to CWW	

*Indicates that this mode switch is unlikely to be cost effective or likely to occur in any appreciable numbers.

4.3.2 Determination of Incentives

In the electrical energy area, specific weatherization measures entail known costs and produce weather-dependent savings. Once installed, the measure is expected to continue to provide savings over its useful or service life. In contrast, in the transportation arena, changes in travel behavior or mode switches are to be induced through the creation of barriers or by offering incentives. Vehicle operators can elect to shift modes for all commutes or for a specified number of days per week or month. Over time, mode shifts and/or changes in the employee's participation rate are likely. Increases in incentives may also be required to attain least-cost planning program goals, and achieve trip reduction program persistence.

The biggest difference between energy and transportation planning is in the establishment of the incentives necessary to induce the required levels of mode shifts. Ample opportunities exist for both creativity and flexibility. Typical incentives might be prize drawings or a free bus pass (valued at \$18 to \$45 per month) to promote SOV-to-transit-mode shifting; free parking for carpools; use of a free computer, modem and dedicated phone line, or the establishment of a neighborhood work center for telecommuters; or a free mountain bike for SOV users who agree to bicycle to work a specified number of times in an agreed-upon time period. Incentives should be co-offered with education regarding least-cost transportation program goals and objectives.

Developers of transportation supply curves and incentive programs will also have to deal with "free-rider" and equity issues. Least-cost programs designed to eliminate congestion along a particular road segment, bridge, or corridor should address only those users of the affected infrastructure during the peak period of interest. If, however, a transit pass subsidy is made available to foster SOV to transit mode switching, it is likely that the subsidy will also have to be offered to existing transit users. Otherwise, they might convert to SOV use simply to qualify for an available incentive.

Equity concerns arise if and when employees discern that users of certain road segments are treated in a "preferential" manner. They might argue that they would use the affected roadway if it wasn't for existing congestion. An incentive might be necessary to prevent latent demand from materializing.

Finally, incentives should be designed so that they are not readily transferable to commuters outside of the congested zone. Perhaps a color-coded bus pass could be designed for express buses, shuttles, or routes serving congested areas.

Least cost also implies that the aggregate cost of eliminating trips through mode switching -- or nega-trips -- should be less on a per trip basis than the avoided transportation improvement measure. An index based on cost per trip eliminated obviously declines when the cost is fixed (i.e., \$30/month for a bus pass) and the participation rate is high. For instance, the cost per trip eliminated is \$1.50 given that an employee uses a bus pass 20 times per month; \$2.00 given 15 uses per month; and \$3.00 if the pass is used only 10 times monthly. As active participants are highly desirable, incentives might be structured based on mode-shift participation rates. Least-cost transportation planning requires that the transportation planner understand the motivations and behavior of the peak period trip makers and to structure a package of incentives that effectively recruits, yet does not "over-pay," the desired number of mode-shift participants.

Insight into peak period commuter and non-commuter actions can only be obtained through conducting intensive surveys. The surveys would involve the "target" population of motorists using a given roadway during congested periods. The survey would:

- identify the "technical potential" for mode shifts;
- identify the most likely shifts;
- establish the motorist's willingness to participate in a mode shift program; and
- determine the expected participation rate depending on the type and value of incentive offered.

This information is central to the construction of basic mode-shift supply curves.

When structuring the questionnaire and completing supply curves, the transportation planner must avoid "double counting" and accommodate individuals using multiple transportation modes. Double counting is avoided and least-cost planning principals followed when an individual is first assigned to the mode shift that awards the lowest priced incentive. More attractive incentives designed to increase participation rates, or incentives for more expensive alternative mode shifts can be explored when increased recruitment appears necessary.

4.3.3 Constructing the Supply Curve

A conceptual supply curve for a SOV-to-transit mode switch is depicted in Figure 3. The vertical axis indicates the number of round trips displaced through offering various levels of incentives to potential transit users. The horizontal axis shows the incentive cost in dollars per round trip per month. The supply curve is based on offering a free bus pass that costs \$30 per month.

Figure 3

Supply Curve For SOV-To-Transit Mode Switch

The supply curve shows both the technical or theoretical potential for SOV-to-transit mode shifting as well as the achievable potential--here based on a 50 percent penetration rate. Penetration rate is defined as the number of expected or actual participants, divided by the theoretical potential, and is dependent upon the nature and aggressiveness of the TDM marketing plan.

The SOV-to-transit mode shift supply curve indicates how many round trips, or single occupancy vehicles, can be removed from a targeted congested road segment given the willingness of transportation planners to provide a free monthly bus pass. Also indicated on the supply curve is the avoidable cost, in dollars per unit of additional peak period carrying capacity, of the structural improvement. The TDM mode shift measure is attractive as long as the magnitude of the incentive offered is less than the prorated round trip cost of the structural fix. Based on the supply curve shown, potential transit users willing to mode shift at least 11 days per month should be provided with a free bus pass and recruited into a TDM incentive program. Bus passes should not be provided to transit users with expected participation rates of less than 10 days per month.

Supply curves are "conditional" or correlated with sets of perceptions and assumptions. For instance, potential transit use might increase given improved service (15 versus 30 minute bus intervals), the provision of covered sheds at stops, or the availability of buses powered by clean-burning alternative fuels. Similarly, bicycle ridership might increase if bike storage and shower facilities were available at worksites and if a safe bicycle trail network were provided.

While the number of users is projected to increase in the above cases, the cost of providing amenities or improved levels of service must be included in the incentive package. These costs could be substantial. For example, a transit authority may be able to easily absorb a small number of additional riders due to vacant seats and the allocation of spare buses. If a substantial change in level of service is envisioned, new buses may have to be purchased, drivers and mechanics hired, and increased storage and maintenance facilities provided. The cost of subsidizing and providing improved levels of service must be weighed against the cost of the structural fix in a comprehensive societal least-cost planning framework.

Environmental externality benefits per trip for a given mode switch can readily be estimated if:

- age and type of vehicle driven by the commuter is known;
- travel distance is available; and
- airshed-specific externality values are available for each priority pollutant (carbon monoxide, nitrogen oxides, hydrocarbons, particulates, and sulfur dioxide).

Emission reductions are determined by multiplying the trip distance times gasoline-powered light duty-vehicle emission factors (in grams/mile), which are representative for the vehicle driven by the new transit user, then subtracting the emissions from the transit vehicle, which are divided by the number of riders. Environmental externality values are used to convert the weight of emissions reductions into benefit terms, i.e., dollars per round trip displaced or dollars per year.

Finally, care must be taken by the transportation planner to account for the seasonal performance of some mode shifts such as bicycling or walking. In the Northwest, non-motorized modes of transport typically occur in late spring, summer, and early fall. Participation drops dramatically during rainy seasons and winter cold snaps. Both congestion and emissions reduction benefits also reflect seasonal characteristics. Ozone formation preferentially occurs during the summer when temperatures exceed 90 degrees F. Bicycling and walking participation "fits" as an ozone reduction strategy. High carbon monoxide concentrations, however, typically occur in mid-winter when temperatures are in the 30s. Under these conditions, bicycle use plummets. Emission reduction benefits are not available at the time they are most needed. Congestion during the a.m./p.m. commute periods is also lessened during the summer, when 15 to 20 percent of the work force is on vacation at any given time and school is recessed.

4.4 Using Life Cycle Costing Methodologies

The present value of the avoided or deferrable structural improvement is determined by discounting both capital and maintenance cost streams into base year dollars. Generally, the loan or debt service interest rate serves as the discount rate. A levelized or "uniform annual cost" is determined through multiplying the present value by the capital recovery factor. The term of the analysis is the projected service life of the structural improvement. The levelizing process is expressed mathematically as:

$$\text{Uniform Annual Cost} = \frac{\text{Present Value} * i (1 + i)^N}{(1 + i)^N - 1}$$

Where: i = Discount rate

N = Useful life of structural improvement

The uniform annual cost is useful in that it establishes a "cap" for the payment of incentives used to induce TDM-related mode shifts. Society benefits and least-cost planning is achieved when the outflow of dollars used to provide incentives for TDM measures, while providing an equivalent level of service, is less than the annual cost of the structural improvement.

A mechanism for providing funding to implement a TDM-related package of measures would be to deposit all or a portion of the funds that would otherwise be expended on the structural improvement into an account. Establishing an annuity would provide a source of perpetual funding for mode switching incentives and least-cost transportation management program administrative costs.

4.5 Creating the Resource Stack and Identifying the Least-Cost Path

A TDM "resource stack" is produced by ordering all mode switching programs in ascending order of cost per peak period round trip displaced. The least-cost planning process then involves selecting programs from the top of the stack until the program participation goals are satisfied. Annual benefits or savings are the difference between the uniform annual cost of the avoided structural improvement and the aggregate amount of mode switching incentives offered plus TDM program administrative costs.

Alternatively, supply curves for each of the TDM mode shifts can be combined into a comprehensive TDM supply curve. The number of trip displacements required for a given year can be identified on the vertical axis, then the maximum incentive per round trip displaced found by observing the intersection of the supply curve with a horizontal line indicating the annual trip displacement target. The combined TDM supply curve can now be disaggregated as this maximum incentive can be used with individual TDM mode shift supply curves to reveal type of incentive, magnitude of incentive, and participation rates that are necessary for individuals to be included in the least-cost transportation management program.

Breaking down the combined TDM supply curve indicates targets for mode shift recruitment and provides the foundation for establishing a TDM marketing plan.

Early on in the development and use of least-cost transportation planning, it may be wise to over-subscribe trip displacements (perhaps by 20 percent) to account for possible mode shift program "drop outs." The degree of over-subscribing can be modified in the future as experience is gained regarding individual penetration, participation, and persistence rates.

The long-term response of participants to the continuous offering of TDM programs to encourage mode shifting is not known. It is expected that future transportation planners will become adept at minimizing

costs by structuring mode shift incentives and incentive packages. Perhaps, travel behavior will be altered to the degree that incentive levels can be reduced. Conversely, increasing levels of incentives may be required in the future as ever more reluctant participants must be enticed into mode switching to meet increasingly stringent program goals. Additional unknowns include technological changes and the use of "command and control" techniques by state and local government authorities to limit transport options or modify travel behavior.

Section 5

Applying Transportation Least-Cost Planning to a Specific Road Segment or Study Area

The best way to understand transportation least-cost planning principles is to apply them to an actual road improvement project. The Washington State Energy Office's least-cost planning working group selected the City of Olympia's Fourth and Fifth Avenue corridor congestion relief project to illustrate how least-cost planning might work. Reasons for selecting this particular study area include:

- it is timely;
- traffic volume, alternative cost, and commuter characteristics information are available and accessible; and
- Olympia's City Council rejected the Public Works staff's recommendation for a structural improvement (bridge widening) and opted to rely on TDM measures to ease traffic congestion.

Like those living in many small cities and urban areas, city and Thurston County residents envision a preferred future that includes "preserving the quality of life," "preventing urban sprawl," "developing vital city centers," "providing a wide variety of transportation modes and choices;" and "getting a handle on air quality, water quality, the growth of traffic congestion, and dependence on our cars."²⁵

The Thurston County Regional Transportation plan outlines policies, strategies, and projects that will result in the evolution of a balanced transportation system over the next 18 years. A full range of actions is proposed to achieve the goal of reducing the rate of increase in people driving to or from work during the most congested part of the day. A key belief is that actions taken now can prevent the emergence of difficult and costly problems in the future.²⁵

However, some roadways are filled to capacity and congested today. These conditions are expected to worsen in the future--even if the Washington Commute Trip Reduction law's goal of a 35 percent reduction in vehicle miles traveled is reached. Currently, 85 percent of people get to work in single occupancy vehicles. The SOV mode share is expected to decline to 60 percent by the year 2010. Current and projected 2010 mode splits are indicated in Figure 4.²⁵

The Fourth/Fifth Avenue bridge and its approaches serve as a bottleneck to motorists commuting from the west side of Olympia across Budd Inlet to businesses and state agencies located in the downtown area. The existing 4th Avenue structure can carry 1000 vehicles in each lane in each direction but stop signs and gaps in the westbound direction of 5th Avenue only allow for 800 vehicles per hour. The bridges were carrying their peak capacity of 1800 vehicles per hour by 1992. To carry more traffic, a lane must be added or the lane arrangements altered.²⁴ Approximately 2,650 vehicles are projected in the westbound direction during the afternoon peak hours in the year 2010. Traffic volume increases due to the growth of Olympia are expected to average approximately 20 percent throughout the study corridor.²⁴

Figure 4
Commuter Mode Splits
Thurston County, Washington

5.1 Proposed Actions for Olympia's Fourth/Fifth Avenue Corridor

The *Draft Environmental Impact Statement* for the Fourth/Fifth Avenue corridor evaluates three alternatives for specific improvements, as well as the "No Action" alternative. The preferred alternative, entitled *Westside Neighborhood Direct Connection*, would cost approximately \$10.4 million and result in the widening of the Fourth Avenue bridge from a two to a four-lane facility. A new off-ramp from the Fifth Avenue bridge would allow westbound traffic to access the southbound Deschutes Parkway from Fifth Avenue. The existing two-lane Fifth Avenue bridge would provide a direct, neighborhood use only connection to Fourth Avenue at the base of Hospital Hill and a new bicycle/pedestrian structure would connect the west side and the downtown areas.²⁴ These improvements would allow the conveyance of an additional 1,149 vehicles during the afternoon's peak hourly period.

The Fourth/Fifth Avenue corridor study area and the suggested improvements are indicated in Figure 5.

Figure 5
Olympia's Fourth/Fifth Avenue
Corridor Study Area

5.2 Avoided Infrastructure Improvement Costs

The recommended \$10.4 million Fourth/Fifth Avenue Corridor structural improvement is capable of conveying an additional 1,149 vehicles during the hourly peak period. If general obligation bonds are issued that carry a 7 percent interest rate over their 30-year life, an annual cost of \$838,100 is incurred. Assuming a useful life of the structural fix of 30 years and 260 working days per year, the capital cost component per unit of increased carrying capacity is \$2.80. Maintenance expenses are excluded in this example. This cost declines to \$2.52 and \$2.45 if useful lives of 50- and 80-years, respectively, are assumed.

The cost per additional trip made, however, is much higher if the bridge enhancement is not utilized to its full capacity during the early years of its life. If the bridge is lightly used and conveys only an additional 200 vehicles per peak hour, the cost per incremental vehicle accommodated during the heavy peak period increases to \$14.07 (assuming an 80-year structure life).

TDM can successfully be employed to avoid or defer the structural improvement for as long as the incentive or cost per trip displaced is less than the cost per unit of usable and used carrying capacity provided by the structural fix.

5.3 Commuter Characteristics and Requirements

Transportation choice behavior and commute characteristics were obtained from a sample of 507 individuals from West Olympia households. Participants were interviewed by staff from Herbert Research. The personal car was indicated as the most frequently used source of transportation by 87.8 percent of the respondents. Convenience was the primary reason cited by 43.0 percent of participants. The average (mean) time required for West Olympia residents to reach their destination is 15.6 minutes. The majority (85.9 percent) believes that the amount of time it takes them to reach their destination is reasonable. The average time required for individuals to return home from their destination is slightly longer at 17.8 minutes. The average West Olympia resident crosses the bridges 11.1 times per week with work being the primary reason for going to or through downtown Olympia (44.4 percent), followed by shopping (29.2 percent). Recent surveys conducted for the Environmental Impact Statement indicate that about 40 to 45 percent of peak hour traffic is work related.

5.4 Travel Time Considerations

Olympia is the state capital of Washington and is a mid-sized city with a 1992 population of 35,800. Average trips from the westside to and from downtown Olympia are of reasonably short duration (15-18 minutes) with a travel distance of two to six miles. Current levels of congestion are minimal, with delays of even a few minutes serving as an irritant. Increases or decreases in travel time associated with TDM-related mode shifts can serve as an incentive or deterrent to program participation. Travel time has value, both to the individual and to society, with the value of time unlikely to be linear. As less "free" time is available, it tends to become more highly valued.

If it is assumed that switching from SOV to transit would require an additional 30 minutes per day--to walk to the bus stop, wait for the bus, walk from the bus stop to work--and if time is valued at \$10 per hour, transit-mode switching may entail a time penalty or cost to the bus rider of as much as \$5 per round trip displaced.

Transportation planners will have to be extremely sensitive to commuting time requirements when structuring mode switch incentives or when establishing frequency parameters for transit service. Time, comfort, and convenience may serve as significant incentives for TDM participation or as program entry barriers.

5.5 Environmental Externalities

Emission reduction benefits are obtained when switching from SOV to high-occupancy vehicle or non-motorized travel modes. Light-duty vehicle emissions depend on vehicle age, state of tune, temperature, fuel composition, engine displacement, carburetion or fuel injection system design, and type and state of deterioration of the post-combustion treatment system or catalytic converter. New light duty vehicles must not exceed the Environmental Protection Agency's (EPA) mandated emission limits of 0.41, 3.4, and 1.0 grams per mile for hydrocarbons, carbon monoxide, and nitrogen oxides, respectively, when the vehicles are tested in accordance with the Federal Test Procedure urban drive cycle. Future vehicles must demonstrate the ability to attain the emission standards for a 100,000 mile service life and must be equipped with onboard diagnostic equipment that indicates the functional status of pollution control systems.

It is difficult to quantify health-related benefits or offset values for priority pollutant reductions in Olympia inasmuch as the area is in attainment for both ozone and carbon monoxide. The Washington Department of Ecology (WDOE) has used a general value of \$3,000 per ton for Best Available Control Technology expenditures within attainment areas. The WDOE does not distinguish between pollutant types. For comparative purposes, air pollutant environmental externalities adopted for the state of Massachusetts are given in Table 10.

Table 10
Environmental externality Values
(Massachusetts, \$/ton)

SO _x	\$1,700
NO _x	7,200
TSP	4,400
VOC	5,900
CO	960
CO ₂	24
CH ₄	240
N ₂ O	4,400

It will be assumed that a priority pollutant weight displacement of 10 grams per mile occurs for SOV to transit, vanpool or carpool mode shifts. This value is likely high for newer vehicles and under-represents the emissions benefits obtainable from displacing trips made in older vehicles. When an average six mile, one-way commute is assumed, an emission reduction of 120 grams occurs per round trip. This reduction is valued at 39.6 cents per round trip when additional pollutant controls are priced at \$3,000 per ton removed.

A detailed examination of emission reduction or environmental externality benefits can be made once data on mode shifts is available and a commute-vehicle ownership profile is complete. Our preliminary analysis indicates that travel time may be a more important consideration than TDM-related environmental externality benefits. The primary focus of conducting least-cost transportation planning for Olympia's Fourth/Fifth Avenue corridor is not based on air quality. The objective is to displace trips, provide congestion relief, and avoid the need to immediately invest in a capital intensive infrastructure improvement.

5.6 Allocation of Costs and Benefits

Costs and benefits of potential least-cost TDM measures should be examined from both the consumer (motorist's) and societal perspectives. Similar to the "no-losers" rate tests applied to energy conservation actions (where participants benefit and non-participants do not suffer), TDM programs are most likely to be embraced when the program participants, the implementing authority, and society benefit.

Direct and indirect, primary and secondary, and internal and external costs need to be considered. Care must be taken to distinguish among "income transfers," costs incurred, and benefits enjoyed. From the motorist's perspective, costs and benefits to consider include travel time differentials, fuel savings, farebox requirements, vehicle maintenance savings, health benefits, a possible increase in commute enjoyment due to decreased congestion, improved safety, possible lower automobile insurance rates, and decreased parking costs. The motorist may experience some loss of flexibility or mobility.

Societal benefits might include reduced air and water pollution, increased worker productivity, energy security, greater safety, and reduced infrastructure expenditures. Individual and societal benefits are summarized in Table 11.

Table 11
**Potential Costs and Benefits
Due to TDM Activities**

Motorist or Consumer Perspective	Societal Perspective
<ul style="list-style-type: none"> • Decrease or increase in travel time • Gasoline savings • Savings in vehicle maintenance • Reduced congestion/increase in commute pleasure • Farebox expenses • Loss of mobility • Lower insurance rates • Decreased tax rates 	<ul style="list-style-type: none"> • Reduction in air pollution • Water pollution benefits • Time savings due to low congestion • Increase in energy security • Reduced infrastructure maintenance costs • Lessened transportation service requirements • Decreased need for land for parking • Greater safety • Reduced urban sprawl

Not all costs or benefits are applicable to each and every project. In many cases, projected benefit streams could vary considerably over time. For example, the installation of electrically-preheated catalytic converters on future light-duty vehicles would significantly reduce cold start emissions and decrease TDM mode switch air quality benefits.

Other costs and benefits are extremely difficult or virtually impossible to quantify with any degree of accuracy. Benefits associated with incremental traffic volumes are difficult to value. Often, costs are embedded or sunk and cannot be recovered as savings.

In all cases, however, the transportation planner should be able to determine the capital and maintenance costs associated with the planned structural improvement. A portfolio of TDM activities offering lower costs or greater benefits over a given time horizon would achieve least-cost planning purposes. In this case, it may not be worthwhile for the transportation planner to expend a great deal of time, effort, or budget to attempt to quantify second and third-order benefit or cost impacts.

5.7 The Transportation Planning Process: Key Players, Hurdles, and Steps

Transportation Planning is a complex and fragmented process. The central planning authority in large population centers is the Regional Transportation Planning Organization (RTPO) or Metropolitan Planning Organization (MPO). The MPO or RTPO prepares a Transportation Improvement Plan (TIP) on a biennial basis. The TIP process is conducted in accordance with federal and state Department of Transportation standards and guidelines and must show consistency with regional, county, and municipal land use, growth management, and transit authority plans.

Another requirement under the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 is that each urbanized area with a population of 200,000 be designated as a Transportation Management Area (TMA). Each TMA is required to develop a Congestion Management System (CMS). A CMS is a

comprehensive and integrated set of policies, programs, and procedures that seeks to improve mobility and air quality through the development of an action plan to relieve existing and anticipated traffic congestion.²⁶ The CMS planning framework is designed to facilitate a uniform and effective approach to reducing the impacts of congestion across jurisdictional boundaries.

The City of Olympia is a member of an RTPO and MPO. The Thurston Regional Planning Council, under an intergovernmental agreement, provides planning staff for the Planning Department of Thurston County and the City of Olympia. The Thurston Regional Planning Council itself is a 16-member, intergovernmental board made up of local governmental jurisdictions within Thurston County, plus the Washington State Capitol Committee, The Evergreen State College, and Intercity Transit. The Council was established in 1967.

Transportation planners within the City of Olympia's Public Works Department conduct traffic counts, retain consultants to conduct traffic volume forecasts, identify congested areas, and evaluate transportation improvement alternatives. Federal and state financial assistance is sought after a preferred transportation improvement alternative is recommended to, and accepted by the Olympia City Council.

Just as electrical utilities had to create and staff new conservation departments during the 1980's, local governments may be required to form TDM departments or divisions. The new organizations must be empowered to effectively serve as TDM advocates, program developers, and implementers. TDM program monitoring, evaluation, and performance verification capabilities must also be developed.

Section 6

Transferring the Least-Cost Transportation Planning Methodology to Other Projects

Our proposed least-cost transportation planning approach is designed to provide a level playing field for the investigation of transportation supply and transportation demand management measures. The approach is particularly applicable when examining alternatives to expanding or upgrading infrastructure to provide emissions benefits or congestion relief. The least-cost methodology is best targeted to individual components of a Transportation Improvement Program (TIP) -- such as road or bridge widening projects or the need for additional transportation network links. A least-cost TIP occurs when the lowest cost TDM, TSM, and/or infrastructure improvement action is recommended for each project contained within the plan.

Given the fragmented and dispersed nature of transportation planning, the question is how to institutionalize least-cost planning principles into conventional planning practice. The most likely approach is to update federal TIP requirements and state regional transportation standards and guidelines to ensure that least-cost activities are identified, evaluated on a consistent basis with supply-side measures, and accepted when they provide societal benefits. Training for planners and their consultants will be essential to promote the acceptance of least-cost planning techniques and to establish consistency in analysis and evaluation.

6.1 Characteristics of Projects Offering the Greatest TDM-Related Benefits

Transportation related least-cost planning for congestion relief or emission reduction offers the greatest potential under the following conditions:

- the avoided infrastructure improvement is capital intensive. Obviously, eliminating 100 peak period trips that defer the need to invest in a 10-mile long road widening project provides greater benefits per trip displaced than a ¼-mile long transportation improvement project.
- commuters constitute the majority of the peak-period traffic volume.
- average vehicle ridership is low. Solo drivers that can be shifted to high-occupancy vehicle travel dominate the mode split. Commute Trip Reduction programs have not yet been employed.
- the duration of the peak is fairly short. Some TDM measures, such as staggered work times, are ineffective when the peak duration is broad.
- typical commute distances are lengthy. Emission reduction and fuel savings benefits correlate with cold starts and vehicle miles traveled.
- origins and destinations are clustered with participants for high-occupancy vehicle modes proximate to each other, such that desirable levels of service can be offered through transit alternatives.
- TDM participants are motivated through common or community goals.

- funding sources are available to provide the incentives necessary to encourage mode shifting actions. (Under the 18th Amendment, gasoline tax revenues collected within Washington State are dedicated to road projects.)

6.2 Integration of Road Congestion Pricing into Least-Cost Transportation Planning

Congestion prices are tolls or other road-use charges that vary with the level of congestion, so that they are higher during peak hours or peak directions than at other times or locations.²⁷ Congestion pricing is designed to reduce delay through imposing economic signals that encourage motorists to consider alternative routes, modes, and travel times. Recent interest in congestion pricing is, in part, due to advances in automatic vehicle identification and electronic toll-collection systems.

Congestion pricing raises the risk of being considered a gross, intrusive, and inefficient intervention, of being a "command and control" fix or of being a revenue-raising scheme that is perhaps worse than the problem it is trying to solve.²⁸ Some studies also suggest that commuter travel demand is inelastic and that effective pricing strategies would require peak charges of such magnitude as to be politically unacceptable. Conversely, with the imposition of politically acceptable rates, the impact of congestion pricing may be so insignificant as to not warrant the expense and inconvenience of attempting it.²⁹

An advantage of congestion pricing is that it can be applied to all drivers, while commute trip reduction programs are limited only to employees of large companies. Recent research indicates that three out of every four or five trips are non-work trips.^{28,29} On the other hand, downtown merchants may well resist efforts to impose a surcharge on their customer base. Motorists may well choose alternative destinations, such as suburban shopping malls.

As one Olympia merchant expressed it:

"I welcome increased traffic...I remember not long ago when you could shoot a cannon in town and not hit anyone...I would rather have the present 'traffic problem' than the alternative, when Olympia was dead, with empty storefronts."³⁰

An unresolved question is how to incorporate road congestion pricing into a least-cost transportation planning framework. The analogies to congestion pricing in the electrical planning arena are demand charges, tiered or inverted rate structures, and interruptible rates. Generally, electricity demand forecasts are prepared with rate structures embedded. Assumptions for economic health and both future electricity and alternative energy prices must be available and demand elasticities known in order to project future loads. Once the forecaster derives the quantity of resource that needs to be acquired in a given year, the least-cost planner examines the alternatives available for meeting this increased load.

In the transportation least-cost planning arena, it is likely that examinations of the sensitivity of travel volumes to user charges will fall into the hands of the traffic forecasters. It is also likely that upgraded models will need to be developed so that trips can be allocated on the basis of both travel time and travel costs. Once the modified traffic volumes are determined, the transportation planner can deploy a least-cost portfolio of TSM, TDM and infrastructure enhancement measures to eliminate the desired number of additional trips.

Congestion pricing should be considered when the social costs of implementing the congestion pricing scheme in conjunction with residual TSM, TDM, or structural improvements are less than that for all alternative portfolios of measures.

6.3 Land-Use and Least-Cost-Transportation Planning

Megabus and megarail options won't work without megariders. Reasonably dense clusters of workers are essential for commuter buses, carpools, and vanpools to be effective.^{28, 31} High density allows for an increased level of service to be offered without the need for route detours or time delays. Mixed use areas, where homes are built either within or near an office complex, present increased opportunities for walking or cycling to work.³¹

Land use changes, or the creation of high-density village-like settings in suburbia, are envisioned as a means of diminishing the auto's dominance by reducing the number or length of trips.³¹ Key infrastructures that influence urban transportation demand are the type, mix, and location of buildings and land uses, and the layout of the transportation infrastructure relative to these uses. Because land uses do not change rapidly, it is fruitful to regard land-use changes as a long-term rather than a short-term option for managing transportation demand.³²

It remains unclear, however, what kind of urban design might most reduce the future demand for transportation infrastructure or services and how best to transition to it from our existing infrastructure.³² Even if jobs and homes were linked, there are no guarantees that commuting distances would decrease or that workers would abandon their automobiles. At one Los Angeles mixed use center, project managers report that only about 8 percent of all residents living on the complex actually work there.³¹ Few employees may choose to live near their workplaces. One possible explanation is that workers prefer to separate home life and where they spend stress-filled working hours.³¹

Many researchers have proposed that changes in allowable land use activities be incorporated into least-cost transportation planning. While this concept appears straightforward, in practice it may be extremely difficult to achieve. Traffic volumes and congested road segments are determined through conducting traffic forecasts. Least-cost planning approaches can then be used to formulate transportation improvement plans that identify the optimal mix of TDM, TSM, and structural improvements to achieve congestion relief or emissions reduction goals.

If land uses change due to growth management actions, zoning restrictions, mixed use requirements, density bonuses, or if population growth lessens, the origin, destination, number of trips, and trip length will change. The location of congested zones, the amount of congestion, and the time period at which congestion levels become excessive will also change.

Least-cost TDM, TSM, and structural improvement approaches must now be devised for the new areas where congestion is expected to occur, with the costs and benefits of this set of actions contrasted with the base case. Unfortunately, the results are heavily dependent upon speculative assumptions regarding travel requirements of populations of future workers.

Incorporation of land use actions into transportation planning imposes requirements on the traffic forecaster and transportation planner to "model the universe." The planner must first consider population and job growth, plus wealth and demographic variables and then simulate travel behavior with respect to land use and roadway constraints. The optimal or least-cost mix of transportation management actions must then be identified for each congested road segment. Resource alternatives must, of course, be analyzed over the extended land use planning horizon. The entire exercise must then be repeated, given an alternative set of land use assumptions.

Section 7

Conclusions

For the most part, the least-cost transportation planning approach presented in this paper best addresses the "near term." The recommended least-cost planning approach is not a regulatory model. Instead, it is designed to assist transportation planners to consistently evaluate demand reduction alternatives to a roadway expansion project; to wisely allocate limited resources; and to obtain maximum congestion relief or emission reduction benefits per dollar expended. We certainly expect our approach to be modified and refined as we begin applying it to real-world transportation improvement projects. It took the Northwest Power Planning Council many years to produce credible generating and conservation resource supply curves. The outcome of a least-cost planning approach can only be as good as the quality of its input. The least-cost transportation planning techniques presented here are not finalized, but, similar to the evolving electrical resource acquisition arena, represent a first step in what will undoubtedly be a long and interesting journey towards comprehensive transportation decision-making.

In closing, we wish to express uneasiness with the widespread use of the term "least-cost." Least-cost planning is a subset of conventional benefit/cost analysis that is valid only when outputs (or benefits) are fixed. Net present value is then maximized by reducing inputs (or costs). Values or benefits to society are not necessarily fixed for the broad range of alternative solutions encountered in the transportation planning arena.

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