Comparing Multimodal Alternatives in Major Travel Corridors

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In the past, metropolitan planning organizations usually compared transportation projects using measures of effectiveness that are uniquely applicable to a specific mode. But if highway and transit projects are to be compared, as will be necessary under the Intermodal Surface Transportation Efficiency Act of 1991, common measure of effectiveness applicable across modes must be used. Another problem that will arise in such a comparison involves accounting for costs. For valid comparisons across modes, the full costs of each alternative must be taken into account. Public costs incurred by non-transportation public agencies, fixed private costs, and external social and environmental costs cannot be ignored. A new approach for cost-effectiveness evaluation of multimodal transportation alternatives in urban areas is presented. The approach is applicable at the levels of system planning as well as corridor or subarea planning. The advantages of the new approach are that it allows (a) cross-modal comparison, (b) comparison of investment as well as policy alternatives, and (c) comparison of alternative scenarios or policies that could affect rates of future aggregate regional growth, with respect to their cost impacts. The approach is demonstrated through application of a simplified analysis technique using a microcomputer spreadsheet and travel demand model output data from a multimodal transportation corridor study. It is suggested that the approach can be a useful tool for comparing multimodal investment and policy alternatives.

A new approach for evaluating the cost-effectiveness of multimodal transportation alternatives in urban areas is presented. The approach is applicable at levels of system planning as well as corridor or subarea planning. This paper focuses on the corridor/subarea application of the approach.

The advantages of the new approach over other commonly used approaches are that it allows (a) cross-modal comparison, (b) comparison of investment as well as policy alternatives (e.g., land use or pricing strategies that may involve no major public investment as well as a "do-nothing" policy can be evaluated), and (c) comparison of alternative scenarios or policies that could affect rates of future aggregate regional growth, with respect to their cost impacts.

BACKGROUND

Evaluation Issues in the 1990s

Recent changes in federal policy and mandates are making it necessary to give new thought to the technical procedures used by metropolitan planners to evaluate transportation alternatives. Comparisons must be made among modes because of the new intermodal funding flexibility provided by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). Federal regulations (Section 450.318, 23 C.F.R.) state that "corridor and subarea studies shall evaluate the effectiveness and cost-effectiveness of alternative investments or strategies .... The analysis shall consider the direct and indirect costs of reasonable alternatives." ISTEA also requires consideration of efficiency and socioeconomic and environmental factors in the evaluation process.

Future evaluation procedures will need to (a) give adequate consideration to economic efficiency and social and environmental impacts, (b) allow comparisons across modes as well as across infrastructure investment and management strategies, and (c) provide a means for performing consistent evaluations from the system level down to the project level.

Need for Common Effectiveness Measures

In the past, metropolitan planning organizations usually compared transportation projects using measures of effectiveness that are uniquely applicable to a specific mode. For example, measures of highway project effectiveness commonly used are improvement in highway level of service (LOS), including increases in highway speed, reduction in highway volume-to-capacity ratios, and reduction in congested highway mileage; reduction of highway accidents; and savings in highway user costs. Transit project effectiveness, on the other hand, is usually measured by increases in transit ridership and savings in travel time for existing transit riders. Mobility for the disadvantaged is an important measure of transit effectiveness, but it seldom appears in evaluations of highway projects.

If highway and transit projects are to be compared, as will be necessary under ISTEA, common measures of effectiveness applicable across modes will have to be used. And if cost-efficiency measures are to be emphasized, benefits must be converted to dollar terms to the extent possible.

Need for Comparable Methods of Cost Accounting

Another problem that will arise if highway and transit projects are to be compared involves accounting for costs. In computing the costs for transit alternatives, for example, analysts include vehicle capital and operating costs and costs for garaging the vehicle but seldom consider the costs of roadway use by buses. On the other hand, analysts computing the costs for highway travel may include the variable portion of vehicle operating costs (i.e., costs for gas and oil, maintenance, and tires) but exclude the fixed costs (i.e., vehicle ownership costs and parking or garaging costs at each end

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of the trip). In highway widening projects, opportunity costs for using existing rights of way may also be ignored.

Most evaluations, both highway and transit, exclude any form of economic valuation of environmental costs. In transit analysis, indirect effects are assumed to be proportional to transit or high-occupancy vehicle (HOV) use. However, it is incorrect to assume that the environmental and social impacts of rail, bus, and HOV modes are equivalent. Costs for many types of public services provided for the transportation system (e.g., police, fire, emergency medical services, and court system costs) are often ignored. Economic valuation of other social costs, such as community disruption or loss of cultural and recreational resources, is rarely attempted.

For valid comparisons across modes, the full costs of each alternative will eventually have to be taken into account. Public costs incurred by non-transportation public agencies, fixed private costs, and external social and environmental costs cannot be ignored. From a societal point of view, it is irrelevant whether costs are borne privately, publicly, or socially. Partial accounting of costs may be acceptable for within-mode comparisons, since costs not accounted for are roughly the same for each alternative. But costs not accounted for are vastly different across modes, and therefore correctly defined cross-modal comparisons will require full accounting of all costs for each alternative.

Need for Realistic Base

The base to which alternatives are compared in current practice also poses a problem. In current practice, the base used for comparison is usually a future year "do-nothing," or "no-build plus transportation system management (TSM)" alternative. Benefits of the alternatives are calculated on the basis of savings with respect to the future base condition. However, the savings estimates will not be real if the base itself could never exist in reality, which is often the case. For example, before the large delays forecasted under base conditions could ever occur, it is probable that travelers would change their travel patterns (traveling at different times of the day, by different modes, to different destinations, or by different routes); they may even decide not to make the trip. Patterns of activity and land use growth would also change, or overall regional growth itself might be suppressed. Although these behavior and growth changes would involve economic costs, the costs could be much less than the costs reflected by the unrealistic delays estimated for the base case. It is therefore possible that benefits claimed for alternatives by comparing them to the base are inflated.

NEW APPROACH

An Analogy

The new approach to evaluating alternatives is best explained through an analogy based on the decision-making process used by a family in making an investment decision.

Assume that a certain family of four, consisting of two parents and two children, owns a home with three bedrooms. They are expecting a new child in 9 months and must decide among three alternatives to accommodate the third child in their home:

1. Have two children share a bedroom,
2. Add a bedroom to their existing home, or
3. Move into a four-bedroom home.

The family would total all the costs for each alternative and compare them. The lowest-cost, or TSM, alternative (i.e., Alternative 1) would not necessarily be chosen, although it would achieve their main objective of accommodating the third child. The incremental costs of the higher-cost alternatives (i.e., Alternatives 2 and 3) would be traded off against any benefits (e.g., family comfort or pride in home) achieved by the alternatives over and above the basic need to accommodate the third child, which is "efficiently" accomplished by the first alternative.

This paper demonstrates how such a process may be extended conceptually to an evaluation of transportation alternatives. The objective to be achieved is the accommodation of new travel demand—both person trips and freight trips—to be added during the period between the current year and the future horizon year for which alternatives are being evaluated. The least-cost alternative is first identified; then additional impacts (i.e., net benefits or costs that cannot be easily monetized) are compared with the cost differences and trade-offs are evaluated. Although it is not the subject of this paper, a break-even analysis can be conducted to determine how much any additional net benefits resulting from higher-cost alternatives would have to be worth in dollars to make decision makers indifferent between the lowest-cost alternative and the alternative being considered. Such an analysis allows trade-offs between cost-efficiency and unpriced community benefits.

New Approach Versus Current Practice

The approach attempts to overcome many of the problems and pitfalls of current practice discussed earlier. The major differences from current practice in this new approach are discussed as follows.

Base

Incremental costs of alternatives are calculated relative to a real base—that is, the existing system and existing travel demand and system performance. This base replaces the future do-nothing or no-build plus TSM base used in conventional analysis. Problems related to using a future do-nothing base with unrealistic forecasts of congestion are avoided. (Note that if evaluation of a do-nothing alternative is desired, the new approach allows for computing its total costs along with the other alternatives. This is not feasible under current practice.)

Costs

The approach involves a comprehensive accounting of the full costs of the current base as well as the alternatives, to the maximum extent possible. The full costs of each alternative include both economic and non-economic or unpriced costs. Methods for computing individual cost components are discussed in a later section of the paper. Only impacts of uncertain social welfare (e.g., community pride) are excluded from the cost accounting, for separate consideration in evaluating trade-offs among alternatives.

Effectiveness

The effectiveness of alternatives is measured as "person trips served." This measure of effectiveness measures the ability to accommodate the increment in demand for trips above the base (existing) demand. Each alternative is capable of providing for the new demand, but at differing incremental cost; this reduces the problem to one of finding the least-cost alternative. Differences among alternatives with respect to performance are incorporated into the cost measure—the full costs include costs for travel time and vehicle operation (thus measuring the cost impacts of highway congestion or poor transit service levels), and accident costs.

Management Strategies

The approach can be used to compare incremental costs of alternatives that involve little or no differences in public investment, only policy differences (e.g., land use plan and zoning changes, trip reduction ordinances, and parking surcharges). Note that when policy changes induce commuters to shift modes, the commuters may shift to a slower mode. However, the valuation of travel time does account for the higher time costs that may be incurred by the use of slower modes.

Comparison of Future Growth Alternatives and Across Urban Areas

Incremental costs for the future alternatives are computed against the current base. The incremental cost per added trip above the base may therefore be computed. Incremental cost per added trip is computed by dividing the incremental costs by the increment of trips served. If the alternatives represent different aggregate future regional growth scenarios, the impacts of alternative regional growth rates on incremental costs per added trip can be evaluated. For national studies, the measure allows comparisons among urban areas. The use of the "incremental cost per added trip" measure assumes the following:

- Trips served are equivalent irrespective of the mode of the trip (although the cost of the trip may differ by mode). In other words, the quality of the trip in terms of comfort, convenience, and reliability is ignored, although travel time is included as a cost component. Note that this could be an important issue if unequal inducements or disincentives for alternative modes exist (e.g., larger subsidies for one mode versus another), or if trip makers cannot freely choose their modes because of regulation (e.g., "no drive" days).
- If new trips are induced by an alternative over and above the basic future demand served by other alternatives, the value of each induced trip is assumed to be the same as all other trips to be accommodated in the future year. This simply means that if one alternative serves more trips than another, each additional trip served by it is assumed to be of equal value relative to all other "uninduced" trips. (Since most travel demand models do not forecast trips induced on the basis of supply characteristics of alternatives, all alternatives will generally serve the same number of person trips. However, some new transit service may be designed to specifically "induce" new trips, e.g., new work trips from the economically disadvantaged groups in inner cities to employment locations in the suburbs, and society may actually place a higher-than-average value on these trips.)
- Where policies to shift person travel demand to telecommuting, walk, or bicycle modes are to be evaluated, it is assumed that walk and bicycle trips as well as "eliminated" trips from telecommuting are included in the total of trips accommodated and that their costs are also included. (Generally, travel models do not estimate telecommute and non-motorized trips).

CALCULATION OF COSTS

Travel Markets

Unit costs of travel differ depending primarily on two primary variables: time of day (e.g., peak or off-peak) and type of trip (e.g., personal or freight travel). The value of a trip (or value of benefits from a trip) tends to vary by trip purpose (e.g., work versus non-work). These variables can be used to categorize travel demand into various travel markets. Other variables, such as location within the urban area (i.e. downtown, central city, suburb, or fringe) conceivably can be used to classify markets on the basis of trip origin, destination, or origin-destination pair. For their purposes, the authors have identified six markets, as indicated in the following table. The application example demonstrated in this paper focuses on the peak-period work (person) travel market.

	Peak	*Off-Peak*
Work (person)	x	x
Non-work (person)	x	x
Freight	x	x

Disaggregation by these market segments allows the comparison of the value of trips to their costs. Costs for accommodating higher-value trips (e.g., freight trips and work person trips) may be higher than costs for non-work trips, but they may still be acceptable as long as costs do not exceed the value of the trip produced.

Cost Components

All costs for providing mobility are included in the evaluation of costs for accommodating future trips, whether or not the trip maker bears them directly. Costs may be categorized by whether or not they have market prices. Market-priced costs include dollar costs borne privately by system users and publicly by transportation or other agencies. Costs that have no market prices include travel time costs, environmental costs, pain and suffering components of accident costs, and other social costs such as community disruption. They may be borne by system users (e.g., travel time costs) or externally (e.g., environmental costs).

Typical values of the magnitude of market and non-market cost components are given in Table 1.

Market-Priced Costs

It is important to ensure that only true costs, in terms of economic resource costs, are included. For example, transit fares are not costs but transfer payments, as are gasoline taxes and highway tolls. Similarly, it is not the price paid by highway users for existing parking, in terms of parking charges, that should be considered (since these costs are usually subsidized by employers), but the actual cost of providing new parking spaces.

Vehicle Costs

Only avoidable costs for the specific travel market under consideration should be included. An example of an avoidable cost is the variable component of automobile operation costs—the cost of gas and oil, maintenance, and tires—which are related to amount of use. These were estimated at 8.4 cents per mile in 1990 by the *Characteristics of Urban Transportation Systems* (CUTS) (*1*). Fixed costs for automobile operation such as depreciation, registration, and finance charges may be avoidable costs under certain circumstances. For example, provision of new transit service may allow a three-car family to get rid of one car or enable it to avoid having to buy a fourth car. Fixed costs were estimated by CUTS to average 32.6 cents per mile, which amounts to $3.26 for a 10-mi trip.

Similarly, in the long run, parking costs are avoidable, since reduction in projected future demand will allow fewer new spaces to be built or existing spaces to be redeveloped for other use. The CUTS estimates for parking construction costs per space amount to about $1.00/day for a surface lot and $4.00/day for a parking garage with three or more levels. Land and maintenance costs are not included in the estimates.

Highway Facility Costs

Highway facility costs are borne publicly (i.e., by public agencies) for building, operating, and maintaining highway systems. Development of estimates of highway facility costs associated with peak travel requires particular attention. Costs per added vehicle mile traveled (VMT) (above base year VMT) for providing new capacity can be estimated by taking all highway system costs associated with providing adequate capacity for peak travel and dividing the total by the increment in peak-period VMT. Note that total capital costs must be annualized and then converted to daily costs before dividing by peak-period VMT.

TABLE 1 Example Unit Costs

Cost Component	Unit Cost	Source
Market-Priced Costs:		
Vehicle		
Operation	7.4 cents/VMT	Ref.1 (less 1 cent fuel tax)
Ownership	$ 3.12/trip	Ref.1 (less acc. insurance)
Parking -- Downtown	$ 3.00/trip	Ref.1 (plus land cost)/2 trips
-- Other	$ 1.00/trip	Ref.1 (plus land cost)/2 trips
Highway		
Oper. & Maint. -- auto	1.8 cents/VMT	Ref.2
-- bus	2.9 cents/VMT	Ref.2, bus/car equivalency=1.6
Added capacity -- auto	62 cents/added VMT*	Ref.2, Los Angeles Plan data
-- bus	99 cents/added VMT* (* = not used for I-15 study)	Ref.2, bus/car equivalency= 1.6
Public Transportation		
Bus system -- line-haul	$ 3.00/trip	Ref.3, in current dollars
-- feeder	$ 1.50/trip	Ref.3, divided by 2
Subway system	$ 4.25/trip	Ref.3, in current dollars
Safety & Security		
Public services -- auto	1.1 cent/VMT	Ref.4, in current dollars
-- bus	1.1 cent/VMT	Ref.4, in current dollars
-- rail	0.22 cent/VMT	Ref.4, adj. for acc.rate in Ref.1
Accident (market) -- auto	4.2 cents/VMT	Ref.5
-- bus	8.4 cents/VMT	Ref.5
-- rail	1.68 cents/VMT	Ref.5 adj. for acc.rate Ref.1
Costs With No Market Prices		
Travel time	$ 4.50/hour	Estimated
Environmental		
Air pollution	2.4 cents/VMT	Ref.4, in current dollars
Water pollution	0.2 cent/VMT	Ref.13
Noise	0.16 cent/VMT	Ref.4, in current dollars
Solid/chemical waste	0.2 cent/VMT	Ref.6
Oil extraction	1.5 cent/VMT	Ref.6
(Subtotal)	4.46 cents/VMT	
Accidents (non-market) -- auto	7.8 cents/VMT	Ref.5
-- bus	15.6 cents/VMT	Ref.5
-- rail	3.12 cents/VMT	Ref.5

DeCorla-Souza and Kane have estimated highway maintenance costs at 1.8 cents per VMT on the basis of national data (*2*). Their estimates of the general scale of additional highway capacity costs per peak-period VMT for added lanes on existing rights of way range from 10.1 cents for freeways in outlying areas to 30.8 cents for collector facilities in built-up areas. On the basis of cost and peak-period VMT information from the transportation plans for three urban areas in the United States (*2*), costs for new capacity to serve peak-period users on some combination of existing and new rights of way range from 24 to 62 cents per VMT added above base year VMT.

Public Transportation System Costs

A study by Charles River Associates estimated peak-period costs net of revenues (capital and operating) per passenger trip for transit service to average about $1.98 for rail and $1.33 for bus systems (1983 dollars) (*3*). Corresponding estimates for off-peak service were $1.56 and $1.05, respectively.

Safety and Security Costs

Public costs are also incurred for providing certain types of public services for system users, such as costs for police, fire, emergency medical services, and court costs related to safety and security on the transportation system. FHWA's 1982 *Federal Highway Cost Allocation Study* estimated costs for public services at 0.7 cent per VMT (1980 dollars) (*4*). Another FHWA report estimated accident costs at 12 cents per VMT for automobiles and 24 cents per VMT for buses (*5*). Of these costs, about 35 percent were out-of-pocket costs and losses in wages and household production.

Costs with No Market Prices

Costs that have no market prices may be categorized as travel time costs, environmental costs, pain and suffering components of accident costs, and other social costs.

Travel Time Costs

Travel time unit costs vary by income group, with higher-income groups valuing time at a higher rate. This suggests that travel time unit costs may be lower for HOV and transit modes. Travel time costs are generally converted to dollar terms by valuing time between 33 and 50 percent of the average wage rate of work commuters.

Environmental Costs

Environmental costs may be occasioned during system expansion, system operation, or both. FRA has identified a taxonomy of costs that includes under the environmental category costs for air pollution, water pollution, noise, hazardous materials (hazmat) spills, land use, and electromagnetic radiation. To these may be added the costs of motor vehicle solid and chemical waste disposal.

Various studies have been done to estimate unit environmental costs. FHWA's 1982 *Federal Highway Cost Allocation Study* estimated unit costs per automobile VMT for air pollution and noise pollution at 1.5 and 0.1 cents, respectively (1980 dollars) (*4*). A 1992 study (T. Litman, unpublished data, *Transportation Cost Survey*, Feb. 1992, Victoria, B.C., Canada) did a survey of 15 studies and found that estimates of costs per automobile VMT range as follows:

	Cost (¢)
Air pollution	1.0–7.2
Noise pollution	0.1–0.3
Water pollution	0.16–0.2
Oil extraction, distribution, and use	1.5–4.0

Litman found estimates of land use costs (termed "urban sprawl") to range from 3.5 to 6.3 cents per automobile VMT. He also arbitrarily assumes a cost of 0.2 cents per automobile VMT for solid and chemical waste disposal. The literature does not provide comparable estimates for vans or buses, but most of these cost elements can be expected to be higher for van or bus VMT.

A Natural Resources Defense Council study estimated societal costs per person mile of travel (PMT) for various environmental cost components as indicated in Table 2 (*6*). A World Resources Institute study has also developed national-level estimates of the economic costs of various external impacts of highway use, including costs of air pollution, national security, accidents, noise, and risks of climate change (*7*). No estimates of costs for hazmat spills and electromagnetic radiation are available at this time, but they could probably be developed through research.

Accident Costs

Non-market costs of accidents include pain and suffering and losses in quality of life. They account for 65 percent of accident costs, as estimated in an FHWA study (*5*).

Values of Other Social Impacts

It is unlikely that dollar values can be developed to value social impacts other than travel time, accident, and environmental costs.

TABLE 2 Societal Costs by Mode (¢/VMT)

	Auto (urban)	Bus	Rail
Energy	1.5 to 5.0	0.85 to 2.8	0.39 to 1.3
Noise	0.14 to 0.23	0.05 to 0.1	0.16
Air pollution	4.0 to 7.0	1.6 to 4.5	1.5 to 5.0
Water pollution	0.13	Not estimated	Not estimated

They will simply have to be listed for consideration and traded off against monetized incremental costs in the decision-making process. Examples of these impacts are national defense implications for protection of oil sources; community cohesion or disruption; community pride; aesthetics; accessibility of disadvantaged segments of the population; loss of cultural, historic, recreational, and natural resources; loss of open space and depletion of nonrenewable energy resources.

A recent study by Greene and Duleep has attempted to estimate costs for carbon dioxide emissions (which contribute to global warming) (*8*). A range of $10 to $100/ton of carbon was estimated. (A gallon of gasoline contains 5.38 lb of carbon.) The study also estimated costs for energy security at $10/barrel, including costs associated with the effects of sudden oil price changes and costs associated with maintaining stability in the Persian Gulf region.

Simplified Cost Estimation Procedure

A simplified microcomputer spreadsheet was developed to compute costs. The application of the spreadsheet for system analysis was demonstrated in a recent paper (*9*). This paper demonstrates its application for a corridor example in following section. More detailed methods for calculating costs could certainly provide more accurate estimates of costs, but simplified techniques were used in the example application since the purpose of the example is simply to demonstrate how the approach may be used in real-world situations. A basic assumption of the simplified technique is that conditions in the single future horizon year represent consistently proportional conditions for all previous and subsequent years.

The basic process for computation of costs is indicated in Figure 1. The process relies heavily on output from the four-step travel demand modeling process (*10*), for the base year condition as well as for future year alternatives. Although base cost information could be estimated without travel model output data (for example, by using monitored data for the current year), it is important to use travel model output for the base in order to maintain consistency for comparison with travel measures and costs estimated for future year alternatives.

Basic Inputs for Travel Models

Future socioeconomic and demographic projections used as input to the models should normally vary in their geographic distribution within the urban area for each of the alternatives, although regionwide aggregates of population, employment, and dwelling units should not generally vary by alternative. If aggregate regionwide population estimates differ by alternative, comparing incremental costs of the alternatives will not be appropriate. Valid comparisons of average costs per added trip, per added person, or per added dwelling unit could still be made.

The other travel model inputs are the data relating to investments or policies specific to each alternative.

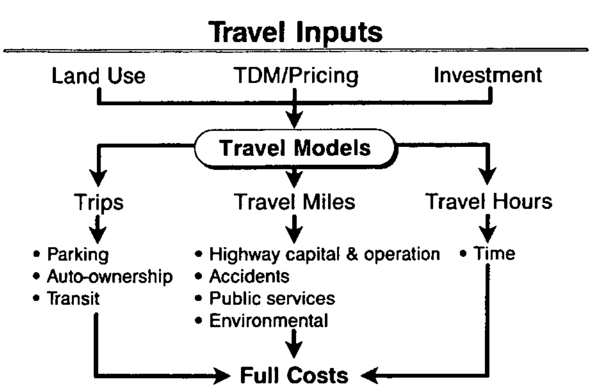

FIGURE 1 Full cost accounting.

Travel Model Outputs

As Figure 1 indicates, the outputs from the travel models needed for input into the costing procedures are the following, for each person travel market:

1. Person trips (from trip generation) as well as person trips by mode (from mode choice).
2. Travel miles (from trip assignment) by mode. This includes PMT on bicycle, walk, automobile, and transit modes as well as VMT.
3. Travel minutes (also from trip assignment). Again, travel time is needed by mode for the base and the alternatives. Alternatively, future travel times can be computed by calculating a "delay" or "time saved" component based on differences between future year and base year average speeds; this component can then be combined with base year travel time to get total travel time. Estimates of travel time on access modes can be based on PMT on these modes and average speeds by mode.

To ensure that travel distance and travel time measures output by the models are realistic, the travel models must be capable of providing accurate estimates of travel speed. In other words, travel models should have been calibrated for speed as well as volume. Also, if significant changes from accessibility levels assumed in model inputs are reflected in the assignment output, these changes should be fed back into earlier steps of the modeling process (i.e., trip distribution and mode choice). The accessibility changes should also be checked against assumptions about the distribution of land use activity.

Cost Models

As Figure 1 indicates, the travel measures output from the travel models are input into cost models that provide unit cost parameters for the various cost components. Unit costs may be costs per trip, per PMT, per VMT, or per minute of travel time. Table 1 presents unit cost parameters that were developed on the basis of estimates from the literature. Costs excluded in Table 1 are environmental costs for land use, hazmat spills and electromagnetic radiation (for which reliable estimates are unavailable at this time), and the "other social impacts" category discussed earlier. These impacts can be considered in trade-off analysis.

CORRIDOR APPLICATION

Data Sources

The application of the spreadsheet model is demonstrated in this section for the peak-period work travel market, for a case study example using data obtained from a multimodal transportation corridor study (*11*).

Travel Measures

The model output data were obtained from a report prepared by the local transportation planning agency. Therefore, it was not possible to get all of the relevant data that would usually be obtained from a travel model run, since all of the information from the model runs was not included in the report. In cases where needed information was not available from the report, national averages from the Nationwide Personal Transportation Study were used (*12*).

Cost Parameters

Where the study report did not provide local cost estimates, national average cost parameters from various sources (*1–4*), as indicated in Table 1, were used. Owing to the liberal use of national average cost parameters, the results from the spreadsheet computations presented in this paper should not be construed as being definitive estimates of the total costs and cost-effectiveness indexes of the alternatives. They are presented here purely for demonstration purposes.

In using the spreadsheet procedure for corridor analysis, the travel demand and cost changes are estimated for the entire urban area, although only alternatives within the corridor are compared. This is because it is difficult, if not impossible, to separate corridor impacts from impacts on the rest of the system, and any corridor improvements are bound to affect the rest of the system in varying degrees.

Alternatives

For this demonstration of the application of the spreadsheet, 3 alternatives were selected from a series of 12 alternatives designed to serve future (year 2010) travel demand in a major travel corridor (Interstate 15) in the Salt Lake City, Utah, metropolitan area.

The alternatives selected for evaluation using the spreadsheet were as follows:

1. Addition of two mixed-flow lanes in each direction on I-15.
2. Addition of one mixed-flow lane in each direction and one reversible HOV lane on I-15.
3. A light rail line on existing rail right-of-way parallel to I-15, along with miscellaneous TSM-type improvements.

The results of the application are given in Table 3, and travel data inputs for the cost estimation procedure are presented in Table 4. In this example application of the spreadsheet, capital costs included in the analysis are only those costs associated with corridor alternatives. Capital costs per peak-period VMT used in the spreadsheet were estimated by dividing total capital costs for each alternative by total peak-period VMT systemwide. Conceivably, capital costs for all other improvements proposed in Salt Lake City's transportation plan could be added across the board for all alternatives. However, since those costs would not vary by alternative, differences between total costs of alternatives would not change relative to the results given in Table 3. (However, costs per added trip are underestimated for all alternatives, since they exclude infrastructure costs for the portion of trips outside the corridor.)

Table 3 indicates that the light rail alternative would save about $30,000 daily relative to Alternative 1 (which added two new mixed-flow lanes), whereas the HOV alternative would save about $13,000 daily. Both estimates are based on travel time's being included in aggregate costs. A large part of the savings would be enjoyed by transportation agencies: $23,000 and $9,000 a day, respectively, or about $6.0 million and $2.3 million a year.

Incremental costs per added peak-period work trip regionwide were also significantly lower for the light rail alternative: $6.18, versus $6.25 for Alternative 1. As stated earlier, these incremental costs would have been higher had capital costs for other regional transportation projects been included in the analysis.

CONCLUSIONS

This paper has explained the need, principles and theory in support of a new approach that can be used in urban areas to evaluate (a) transportation investment alternatives across modes, (b) significant changes in land use and travel demand management policies, and (c) alternative aggregate regional growth scenarios. The approach is based on assessing the relative economic efficiency of alternatives by determining which alternative involves the least total cost for providing mobility for various travel markets.

The approach has been demonstrated through application of a simplified analysis technique using a microcomputer spreadsheet and travel demand model output data from a multimodal transportation corridor study. Results from the analysis have been presented for demonstration purposes only. The application of the approach to the case study suggests that the approach can be a useful tool for comparison of multimodal investment and policy alternatives.

The spreadsheet, with further development, can be a useful tool for transportation planners. However, in its current form, as used for the analysis presented in this paper, it has many limitations about which interested analysts should be cautioned:

- It attempts to monetize many social and environmental costs that are, at best, difficult to monetize. National averages of unit costs, which may not be applicable to any specific urban area, are used.
- The spreadsheet as developed cannot be directly used for analysis of costs for accommodating trips in other travel markets: peak non-work and freight trips, and off-peak trips for work, nonwork, and freight.
- It is useful only as a screening tool in its current form. More detailed techniques for estimating impacts and costs will be needed for major investment analysis.
- It is clear from Table 1 that highway and other capital costs comprise a large portion of the total costs of mobility. The sensitivity of the results to differing discount rates should therefore be incorporated in the evaluation procedure.
- The evaluation can be only as good as the demand forecasts and unit cost estimates that underlie the analysis procedure. An analysis of the sensitivity of the results to uncertain forecasts and unit cost parameters should be included in any application of the procedure.

TABLE 3 Costs for Peak-Period Work Travel, Salt Lake City, Utah (million $/day)

		BASE (1986)	2 LANES (2010)	1L + HOV (2010)	LRT (2010)
Market costs:	Vehicle(incl.P/R)	0.592	1.718	1.714	1.713
	Hwy Facility(auto)	0.036	0.173	0.164	0.134
	Hwy Facility (bus)	0.000	0.001	0.001	0.001
	Subtotal hwy fac	0.036	0.174	0.164	0.134
	Public transport	0.044	0.123	0.124	0.146
	Safety/sec.(auto)	0.106	0.307	0.307	0.306
	Safety/sec.(bus)	0.001	0.002	0.002	0.002
	Subtotal safety	0.107	0.309	0.309	0.308
Summary by mode: (market costs)	Subtotal for auto	0.733	2.198	2.184	2.153
	Subtot for transit	0.045	0.126	0.127	0.149
	Total market costs	0.778	2.324	2.311	2.302
	Cost/auto trip ($)	3.343	3.452	3.432	3.390
	Cost/trans trip($)	3.320	3.327	3.326	3.768
	Cost/added auto trip ($)		3.509	3.479	3.415
	Cost/added transit trip ($)		3.330	3.221	4.002
Non-market costs:	Travel time (auto)	0.344	1.000	1.000	0.997
	Trav time(transit)	0.050	0.141	0.142	0.137
	Subtot trav time	0.395	1.140	1.141	1.135
	Environmental	0.089	0.260	0.259	0.259
	Accident pain, etc	0.157	0.456	0.455	0.454
Total costs, including time cost		1.419	4.179	4.166	4.149
Total costs, excluding time cost		1.025	3.039	3.025	3.014
Average cost/trip, $ (incl.time)		6.094	6.195	6.177	6.150
Average cost/trip, $ (excl.time)		4.399	4.505	4.485	4.468
Average cost/added trip, $ (incl.time)			6.249	6.220	6.180
Average cost/added trip, $ (excl.time)			4.561	4.530	4.504
Transportation agency costs -- total		0.067	0.260	0.251	0.237
Transportation agency costs -- incre			0.193	0.184	0.170
Transp. agency costs/trip, $		0.287	0.385	0.372	0.351
Transp. agency costs/added trip, $			0.436	0.417	0.384

TABLE 4 Travel Data Inputs

Travel Data (millions daily)	BASE (1986)	2 LANES (2010)	1L + HOV (2010)	LRT (2010)
Trips:				
Auto trips	0.191	0.555	0.554	0.554
Auto person trips	0.219	0.637	0.636	0.635
Transit trips	0.014	0.038	0.038	0.039
VMT:				
Auto VMT	1.988	5.774	5.764	5.757
Auto P/R access VMT	0.008	0.024	0.024	0.025
Bus VMT	0.008	0.021	0.022	0.017
Total VMT	2.004	5.820	5.809	5.799
Travel time (minutes)	0.395	1.140	1.141	1.135

• The spreadsheet evaluates a single target year. The effects of the timing of costs and of benefits need to be considered.

• Valuation of time is also difficult. Disutility values of time have been shown to differ by travel mode, in-vehicle versus out-of-vehicle time (walk and wait time), and trip purpose, but a single value of time is used in the spreadsheet. An analysis of the sensitivity of the results to different assumed values of time will be needed.

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