

WHAT'S IT WORTH?

Economic Evaluation For Transportation Decision-Making

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Abstract

This paper discussed the application of economic analysis techniques to transportation planning and management. It describes specific techniques including Cost-Effectiveness, Benefit-Cost Analysis, Lifecycle Cost Analysis, and Multiple Accounts Analysis. It discusses common problems associated with economic analysis techniques used in transportation decision-making, particularly when comparing investments in alternative modes or evaluating Transportation Demand Management options. This paper describes specific solutions to these problems, and provides recommendations for producing analysis that is accurate and useful. It discusses specific factors that should be considered when evaluating transportation policies and programs.

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What's It Worth?

“It is unwise to pay too much, but it is worse to pay too little. When you pay too little, you sometimes lose everything because the thing you bought was incapable of doing the thing you bought it to do.” John Ruskin (1819-1900)

Context

This section describes the context for performing economic analysis.

Economic evaluation (also called *economic analysis* or *appraisal*) refers to methods for determining the value of a policy, project or program. It is an important component of planning and management. Other important components include information collection and distribution, a decision-making process, public involvement, institution development, and negotiation between stakeholders.

We frequently perform economic evaluation. Virtually any consumer, business or public policy decision involves some sort of economic analysis. For minor decisions it may be sufficient to perform such analysis in your head or to use standard guidelines, but when making major decisions it is helpful to follow a more explicit and comprehensive process to insure that all significant impacts (costs, benefits and equity effects) are considered.

Economic evaluation can be performed well, or it can be performed badly. Transportation decisions are frequently criticized for inadequate and biased economic analysis. This paper describes techniques for performing comprehensive and objective evaluation, and identifies ways to avoid common problems.

Planning and Evaluation Techniques

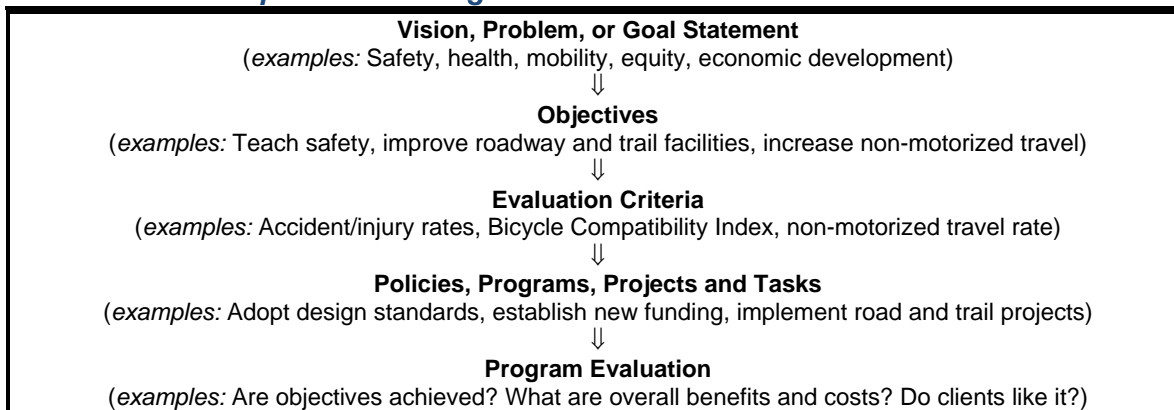
This section describes planning and evaluation techniques, and discusses how different perspectives, goals and measurement units can affect analysis outcomes. For more information see Litman, 2006.

The Planning Process

It is helpful to begin any planning process with a vision, goal or problem statement (these are essentially the same thing from different perspectives). Goals describe what you ultimately want to achieve, but are often difficult to measure. The next step is to establish specific, achievable objectives, with suitable evaluation criteria. For example, if the goal is to improve access, objectives may include a particular reduction in traffic congestion delay, an increase in transit trip speeds, or a reduction in barriers to non-motorized travel. Evaluation criteria can include quantitative factors such as cost per unit of output (e.g., dollars per additional passenger trip), and qualitative factors such as public acceptance. It is usually best to select several objectives that range from general (e.g., improve travel choices for non-drivers) to specific (e.g., a 50% reduction in potholes within two years).

Once objectives and evaluation criteria are established, policies, programs, projects and tasks can be selected. A *policy* is a general course of action. A *program* is a coordinated effort with specified resources (funding, staff, etc.) and responsibilities. A *project* is a program with a specific deadline. A *task* is a specific mission or activity. Each of these should incorporate evaluation criteria. It is useful to start collecting baseline data before projects are implemented. Box 1 illustrates steps in a planning process. Of course, this is an idealized outline that often must be adjusted to account for particular circumstances.

Box 1 Steps in a Planning Process



Creating an Evaluation Framework

An *evaluation framework* specifies the basic structure of the analysis for clear and consistent evaluation and comparison. A framework usually identifies:

- *Evaluation method*, such as cost-effectiveness, benefit-cost, lifecycle cost analysis, etc.
- *Evaluation criteria* are the factors and impacts considered in a particular analysis. Impacts can be defined in terms of *objectives* or their opposite, *problems* (for example, congestion

reduction is an objective because congestion is considered a problem), or they can be defined in terms of *costs* and *benefits* (for example, congestion reduction benefits can be measured based on reductions in congestion costs). Planners tend to use the terms *objectives* and *problems* (which are more qualitative), while economists tend to use the terms *benefits* and *costs* (which are more quantitative), all of which can be considered different approaches for evaluating the same impacts, as illustrated below.

Table 1 Ways to Describe An Impact

| | Positive | Negative |
|--------------|-----------|----------|
| Qualitative | Objective | Problem |
| Quantitative | Benefit | Cost |

Objective, Problem, Benefit and Cost are different ways to describe an impact.

- *Modeling techniques*, which predict how a policy change or program will affect travel behavior and land use patterns, and measure the incremental benefits and costs that result.
- *A Base Case* (also called *do nothing*), the conditions that would occur without the proposed policy or program.
- *Reference units*, such as costs per lane-mile, vehicle-mile, passenger-mile, incremental peak-period trip, etc.
- *Base year and discount rate*, which indicate how costs are adjusted to reflect the time value of money.
- *Perspective and scope*, such as the geographic range of impacts to consider.
- *Dealing with uncertainty*, such as whether sensitivity analysis or statistical tests will be used.
- *How results are presented*, so that the results of different evaluations are easy to compare.

Measuring Transportation

How transportation activities are measured can affect the evaluation process. There are three common ways to measure transport, representing different perspectives and assumptions (VTPI, 2006, "Measuring Transportation"):

1. *Traffic* refers to vehicle movement. It is measured using vehicle-miles and vehicle-trips, roadway Level-of-Service (LOS), average traffic speeds, vehicle delay, and vehicle operating costs. It assumes that transport improvements consist of vehicle travel. It is the easiest way to measure transportation and is commonly used in transport planning.
2. *Mobility* refers to the movement of people and goods. It is measured using person-miles, person-trips and ton-miles, average trip speeds, and cost per person- or ton-mile. It recognizes automobile, transit, ridesharing, and to a lesser degree, non-motorized improvements to transportation problems. It is moderately difficult to measure.
3. *Accessibility* refers to the ability to reach desired goods, services and activities. It is the ultimate goal of most transport (except the small portion of travel with no destination). It is measured using generalized cost (money, time and discomfort) per trip. Accessibility is relatively difficult to measure and so is not often used in transport planning.

Which is used can affect analysis conclusions. Consider school transport, for example. Analysis based on *traffic* assumes that transportation is improved by accommodating more vehicle traffic and parking. From this perspective, the best school location is on a major arterial with abundant parking. Analysis based on *mobility* also values transit, ridesharing and cycling. From this perspective, the best location is on a busy arterial with transit service and bikelanes. Analysis based on *access* allows both mobility and land use strategies to be considered. From this perspective the best location may be in the middle of a neighborhood, where walking and cycling are convenient, although automobile access and parking may be limited. These objectives may conflict: *traffic* improvements may result in solutions that degrade other forms of *mobility* and *access*.

Accuracy Versus Precision

Anybody involved in economic analysis should understand the difference between *accuracy* and *precision*. Accuracy refers to the correctness of information. Precision refers to the level of detail in measurements. A measurement can be very precise but inaccurate. With modern computers it is easy to calculate results to several significant figures, implying a far greater degree of accuracy than the original data actually provides.

It is important to base analysis on comprehensive and accurate information, even if they are not the most convenient or precise data. For example, planners often have better information on motor vehicle conditions (e.g., vehicle mileage, roadway Level-of-Service ratings, traffic speeds, etc.) than on non-motorized (pedestrian and walking) conditions. As a result, it is easier to identify problems motorists face, and to predict how a program or project will impact motorists, than to identify problems and impacts related to non-motorized travel. This tends to skew planning decisions to favor automobile-oriented improvements over nonmotorized modes. Incorporating impacts on nonmotorized travel into transportation planning may involve less precision but greater overall accuracy. Similarly, indirect and non-market impacts are often undervalued in transportation decision making simply because they are relatively difficult to measure.

Types of Economic Analysis

This section describes different economic analysis techniques often used in transport planning.

Economic Analysis

Economic analysis refers to the evaluation of economic impacts. These impacts are not limited to *market resources* (goods traded in a conventional market), they can be any scarce and valued resource, which may include money, land, time, health, safety, comfort, and environmental services such as clean air and water, as discussed in the box below.

Non-Market Values

You are far wealthier than you may realize. In addition to your financial wealth, such as income, savings and investments, you probably have generous amounts non-market wealth, including things like your health, friendships and community, personal time and aesthetic enjoyment. Although it may be difficult to determine the total value of these non-market resources, it is possible to determine the value that people place on a marginal changes in them, for example, how much extra you might be willing to pay for a more attractive view, or the financial savings that you would demand before you would accept a noisier home location.

Put another way, income is just one factor affecting your overall welfare. Others important factors include your health, community, freedom and opportunities for enjoyment. Two people may have the same income, but one enjoys much greater overall welfare due to differences in health, lifestyle or attitude. Or consider this question: how much additional income would you need to be paid to willingly move from a community where you have a nice home, family, friends and acquaintances, to another community where you will live in an ugly home and be lonely? These are all indications of the importance of non-market resources.

As incomes increase, non-market resources tend to become relatively more important. People need a certain amount of material wealth to purchase necessities such as basic food, housing and health care. However, once these basic physical needs are satisfied, additional material wealth provides declining marginal benefits. For example, a person who earns \$20,000 annually is likely to benefit substantially from an additional \$5,000, but a person who earns \$100,000 annually will perceive far less incremental benefit from the same additional \$5,000. The wealthier person may gain more by having 10% more free time than having 10% more income.

Decision-making is often biased by a tendency to focus on easy-to-measure impacts and undervalue more-difficult-to-measure impacts. This skews policy decisions to favor direct, short-term, market benefits, at the expense of indirect, long-term, non-market impacts. For this reason, is important to monetize (measure in dollar values) non-market impacts in order to more easily incorporate them in economic analysis. Impacts that are not monetized (sometimes called *intangibles*) tend to be overlooked and undervalued in economic evaluation.

Some researchers have developed more comprehensive indicators of social welfare, which give greater weight to non-market factors such as health and opportunity (Cobb, Halstead and Rowe, 1998). Others have developed techniques for measuring specific non-market impacts (Delucchi, 1996-98; Litman, 2002). These can help decision-makers better consider all impacts.

Economic analysis can be performed from various perspectives, such as an individual consumer, a particular group, a jurisdiction, a region, all of society (everybody), or current and future societies (which can be considered *sustainability evaluation*). For example, individual consumer generally evaluate a vehicle's safety from the perspective of occupants – risks to other road users are given less weight. Similarly, a particular group generally evaluates taxes and fees based on their cost burden, and may consider it desirable to shift costs to other groups.

Generally, economic analysis should account for all significant impacts to anybody, including people in distant places and times, although impacts on a particular group can be highlighted. For example, a road toll evaluation should consider total costs and benefits to all users, but can identify the portion of costs borne by local residents. Similarly, an air emission reduction strategy implemented in one region may also benefit people outside the region; all these benefits should be considered, although benefits to regional residents may be given extra weight.

Economic analysis generally considers two types of objectives: *efficiency* and *equity*. *Efficiency* assumes that policies should strive to maximize *social welfare*, that is, total benefits to everybody in society. *Equity* assumes that policies should insure that benefits and costs are distributed in some way that is considered most fair, as described below.

Equity Analysis

There are several ways to evaluate equity (Litman, 2003). *Horizontal equity* assumes that everybody should be treated equally. *Vertical equity* assumes that physically, economically or socially disadvantaged people should be favored compared with relatively advantaged people. Below are common equity objectives that can be used for evaluating policies and programs.

- *Treats everybody equally.* A policy does not arbitrarily favor one group over others.
- *User-Pays Principle.* Individuals bear the costs they impose unless a subsidy is specifically justified.
- *Progressive with respect to income.* Lower-income households benefit relative to higher-income households.
- *Benefits transportation disadvantaged.* Benefits people with disabilities, non-drivers, people who cannot afford a car, etc.
- *Improves basic mobility.* Helps satisfy basic mobility (travel that society considers valuable).

Economic evaluation should indicate the distribution of costs and benefits (such as by income and need), and the degree to which options tend to achieve or contradict equity objectives.

There is often overlap between efficiency and equity objectives, since benefits to disadvantaged people often provide relatively large increase in social welfare and productivity, due to “diminishing marginal benefits.” For example, transport service improvements that increase a non-driver's mobility from 4,000 to 5,000 annual miles probably provide larger welfare gains than an increase from 30,000 to 31,000 annual miles by a wealthy motorist, and if the non-driver's increased mobility improves their access to education and employment it can increase overall productivity.

Cost Effectiveness Analysis

Cost-Effectiveness is a relatively simple type of economic analysis. It measures the cost of achieving a specific objective, such as building a particular road or delivering a particular amount of freight. The quality of outputs (benefits) are held constant, so there is only one variable, the cost of inputs.

All relevant costs are converted into appropriate, comparable monetary units. For example, highway construction costs may be presented in costs per roadway-mile, cost per lane-mile, cost per additional vehicle-trip or passenger trip that uses the facility. An option is considered cost effective if its benefits outweigh its costs. The lowest cost option for achieving an objective is considered most cost effective. For example, if there are two possible routes for a new highway, the cheapest option is most cost effective.

The costs of adding capacity to alleviate congestion should be assigned only to peak-period travel (travel during congested periods) rather than all trips. Additional benefits from a project (such as increased safety or comfort) may be assigned to all users.

Benefit-Cost and Net Benefit Analysis

Benefit-Cost analysis compares total incremental benefits with total incremental costs. Unlike Cost-Effectiveness Analysis, Benefit-Cost Analysis is not limited to a single objective or benefit. For example, potential highway routes may differ in construction costs and the quality of service (speed and safety) they provide. Benefit-Cost Analysis places a value on each incremental benefit and costs of each option. These are summed and compared. The results can be presented as a ratio, with benefits divided by costs (which is why it is often called “Benefit/Cost” or “B/C” analysis). *Simple Payback* is similar to a Benefit-Cost Ratio. It indicates the time period required for benefits to repay an investment. However, these methods are affected by how benefits and costs are incorporated in the analysis. For example, some impacts can be considered either a reduction in benefits or an increase in costs, which is used will change the ratio.

Return On Investment (ROI) indicates the annual rate of return an investment provides if all impacts are monetized. For example, a \$1 million investment that provides \$250,000 annual benefits has a four-year simple payback and an ROI of 25%. It is often used for business analysis.

Net Benefits is defined as the sum of all benefits minus the sum of all costs. It provides an absolute measure of benefits (total dollars), rather than the relative measures provided by B/C Ratio, Simple Payback or ROI.

To perform Benefit-Cost Analysis it is necessary to monetize (measuring in monetary units) all relevant impacts. In recent years economists have developed techniques for monetizing non-market impacts, and some transportation agencies have adopted standardized values for travel time, crash damages and environmental impacts (Delucchi, 1996-98; FHWA, 1997; FHWA, 1998; Litman, 2002).

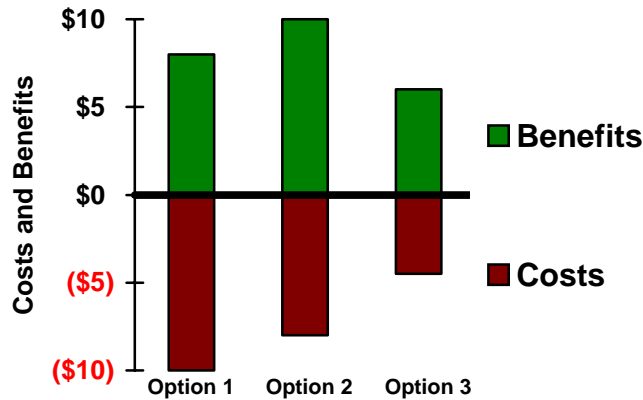
When using any of these analysis methods it is important to specify the *Base Case*, which refers to what happens without the proposed program or project. This allows the analysis to identify incremental benefits and costs. For example, if construction of an HOV or toll lane is being evaluated, the Base Case could either be no additional capacity on the roadway, or an additional general-purpose lane. Analysis of the program's benefits, costs and equity impacts can vary significantly depending on which Base Case is assumed.

Table 2 and Figure 1 illustrate a comparison between three options. Option 1 has \$8 million in benefits and \$10 million in costs. The B/C ratio is 0.8 and Net Benefits are negative. It is not cost effective, indicated by a B/C ratio less than 1.0, and negative net benefits. Option 2 has benefits of \$10 million and costs of \$8 million, resulting in a B/C ratio of 1.25 and \$2 million in net benefits. It is cost effective. Option 3 has benefits of \$6 million and costs of \$4.5 million. Its B/C ratio is 1.33 and its net benefits are \$1.5 million. It is also cost effective. Option 2 should be chosen if funds are unlimited (it has the greatest total benefits), but option 3 should be chosen if funds are limited (it has the highest B/C ratio).

Table 2 Three Options – Benefit-Cost Analysis Summary

| | Option 1 | Option 2 | Option 3 |
|--------------|---------------|--------------|--------------|
| Benefits | \$8,000,000 | \$10,000,000 | \$6,000,000 |
| Costs | -\$10,000,000 | -\$8,000,000 | -\$4,500,000 |
| B/C Ratio | 0.8 | 1.25 | 1.33 |
| Net Benefits | -\$2,000,000 | \$2,000,000 | \$1,500,000 |

Figure 1 Benefit-Cost Analysis Summary Figure



This figure illustrates the benefits and costs of three investment options. Bars above the baseline indicate benefits, and those below the line indicate costs.

Lifecycle Cost Analysis

Lifecycle Cost Analysis is Net Benefit Analysis that incorporates the time value of money (Flintsch 2008). It is usually the preferred method for economic evaluation. Lifecycle Cost Analysis allows programs or projects to be compared that have benefits and costs occurring at different times. For example, you may want to compare an option that has high capital costs and low operating costs with an alternative that has lower capital costs and higher operating costs. Similarly, it can identify the value of practices that shorten the amount of time required to implement a project, thus delivering benefits sooner.

The value of impacts generally decreases the further in the future they occur, so the current value of future impacts are *depreciated* or *discounted*, for these reasons:

1. *Inflation*. Most economic analysis excludes the effects of inflation, and therefore reflects “nominal” dollars.
2. *Inverse of Savings Interest*. Financial investments tend to appreciate in value. A dollar you have now can be invested and become worth more in the future. For that reason, a dollar is worth more now than if you received it a year later. As interest rates increase, so do depreciation rates.
3. *Risk*. The chance that an investment may provide no benefits reduces its current value. For example, the future value of a highway improvement should take into account the possibility that it may be destroyed in a disaster or made obsolete due to changes in technology or consumer preferences. The greater these risks, the more future benefits should be discounted.

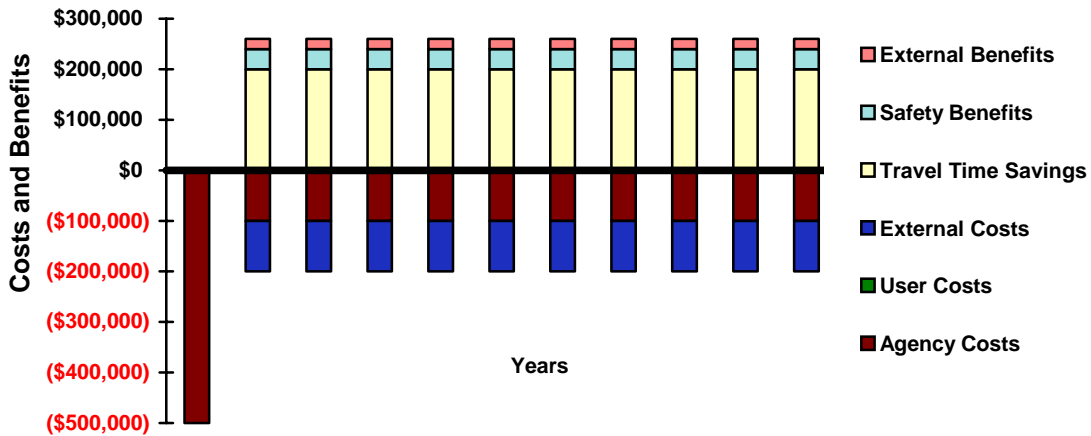
A higher discount rate places less value on future benefits and costs. Typical discount rates used for evaluating public investments range from 4-12%, depending on circumstances and agency policy.

Not all impacts should be discounted at the same rate. Although it makes sense to discount financial impacts at market rates, many experts believe that human health and irreversible ecological impacts should be discounted at a low or zero rate. For example, it is inappropriate to value deaths or illnesses imposed on future generations at a lower rate than if the same risks were imposed on the current generation.

To perform Lifecycle Cost Analysis, benefits and costs are calculated for each time period (usually a year), applying a discount factor to convert all values to a base year. These are summed to obtain each option's *Net Present Value* (NPV). This is the full value (benefits minus costs) of the option over the analysis period reflected in one unit.

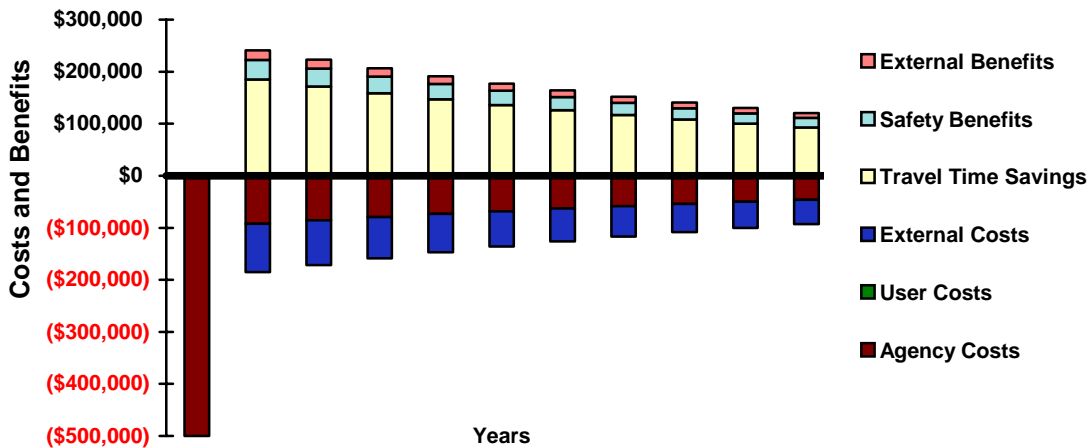
Lifecycle Cost Analysis is easily performed using a spreadsheet, with costs and benefits for each year incorporated into a separate column. This is illustrated below. Figure 2 shows an analysis without discounting. Figure 3 show the same analysis with a 7% discount rate. Note that discounting reduces the magnitude of both benefits and costs over time. In this example, the project is considered cost effective when analyzed without discounting, but not when discounting is applied.

Figure 2 Lifecycle Cost Analysis – No Discounting



This figure illustrates the benefits and costs of a road improvement over ten years, without discounting.

Figure 3 Lifecycle Cost Analysis – With Discounting



This figure illustrates the benefits and costs of a proposed highway improvement, with discounting. The magnitude of impacts declines over time.

Optimization

Optimization refers to solutions that provide the best balance between multiple, conflicting objectives. Transport planning is sometimes *reductionist* (evaluation that considers just one or two objectives), which can result in non-optimal solutions that may make society worse overall. For example, decision-makers overwhelmed by the perceived complexity of considering multiple planning objectives sometimes ask planners to focus on just one or two problems. This can result in decisions that address certain problems (such as congestion or pollution) which exacerbate other problems (such as accidents and inadequate mobility for non-drivers), and tends to undervalue solutions that provide multiple benefits. More comprehensive optimization tends to be best for society overall. Fortunately, new computer-based analysis tools are available that allow more complex analysis (“Comprehensive Transport Planning,” VTPI, 2006).

Multiple Accounts Evaluation

Multiple Accounts Evaluation is an analysis method that uses various rating and ranking systems (CCS, 1993; Spackman, Pearman, Phillips, 2001). Each option is evaluated relative to various objectives, as illustrated in the table below. Rankings can be developed by technical experts, a public survey or an advisory committee. Many people consider this easier to understand and more transparent than a purely quantitative analysis, but it tends to be less precise and more susceptible to errors such as double-counting.

Table 3 Evaluation Matrix Example

| | Cost Effectiveness | Equity | Environmental | Public Acceptability |
|----------|---------------------------|---------------|----------------------|-----------------------------|
| Option 1 | High | High | Medium | High |
| Option 2 | Medium | Very Harmful | High | Medium |
| Option 3 | High | Medium | High | Low |
| Option 4 | Low | High | Harmful | High |

Each option is evaluated according to how well it helps achieve each objective.

A more quantitative system can be used. For example, each option can be rated from 5 (best) to -5 (worst) for each objective. These ratings are then summed to create total points for each project, as illustrated in Table 3. This gives each objective equal weight.

Table 4 Evaluation Matrix Example – With Point Ratings

| | Cost Effectiveness | Equity | Environmental | Public Acceptability | Total Points |
|----------|---------------------------|---------------|----------------------|-----------------------------|---------------------|
| Option 1 | 4 | 4 | 3 | 4 | 16 |
| Option 2 | 3 | -4 | 5 | 3 | 7 |
| Option 3 | 5 | 3 | 4 | 1 | 13 |
| Option 4 | 2 | 4 | -3 | 5 | 8 |

Each option is evaluated according to how well it helps achieve each objective.

The objectives can be weighted, as shown in Table 5. The weight factors are multiplied times each rating, which are summed to give weighted total points. This approach begins to converge with standard Benefit-Cost analysis if point are considered to represent dollar values.

Table 5 Evaluation Matrix Example – With Weighted Points

| | Cost Effectiveness | Equity | Environmental | Public Acceptability | Total Points |
|---------------|---------------------------|---------------|----------------------|-----------------------------|---------------------|
| <i>Weight</i> | 5 | 4 | 2 | 5 | |
| Option 1 | 4 (20) | 4 (16) | 3 (6) | 4 (20) | 62 |
| Option 2 | 3 (15) | -4 (-16) | 5 (10) | 3 (15) | 24 |
| Option 3 | 5 (25) | 3 (12) | 4 (16) | 1 (5) | 50 |
| Option 4 | 2 (10) | 4 (16) | -3 (-6) | 5 (25) | 40 |

Each option is evaluated according to each objective, and each objective is assigned a weight. These are multiplied (values in parenthesis) and summed to obtain total points for each option.

Reference Units

Transportation economic evaluation often involves comparing different types of activities, and investments that have very different cost and benefit profiles. For example, highway investments typically consist primarily of a large capital expense, while mobility management programs typically consist of ongoing operating expenses. Highway capacity expansion tends to provide large short-term congestion reduction benefits, but these decline over time due to generated traffic, while mobility management programs tend to provide smaller short-term benefits, but these often increase over time as programs develop.

It is therefore important to choose appropriate *reference units* for comparison. *Reference units* are measurement units normalized to help people understand and compare impacts. Common reference units include per capita, per mile, per trip, per vehicle and per dollar. Reference units for transportation program economic evaluation should allow costs and benefits that occur at different times to be compared. Lifecycle Cost Analysis and Net Present Value do this, but often result in very large numbers that are difficult for most people to comprehend. For example, the lifecycle costs of a private home (total capital and operating expenses its operating life) may total millions of dollars, and the lifecycle costs of a roadway project or transit service improvement may total tens or hundreds of millions of dollars. It is therefore useful to convert these numbers into annualized costs or annualized costs per capita, or other reference units specific to transportation.

For example, a transportation project costs might be measured per capita, to compare them with other expenditure categories, other years, and other communities. The costs of highway capacity expansion may be measured per lane-mile, to compare with other highway projects, or per additional peak-period person trip, to compare with other ways to accommodate increased travel demand. Which reference units are used can affect how problems are defined and which solutions are considered, as described below.

- *Annualized Cost Per Capita* is a useful reference unit to help decision-makers and consumers compare projects and programs with other common expenses, such as the cost of owning and operating an automobile.
- *Vehicle-mile* units reflect a *traffic* perspective that gives high value to automobile travel.
- *Passenger-mile* units reflect a *mobility* perspective that values automobile and transit travel, but gives less value to nonmotorized modes because they tend to be used for short trips.
- *Per-trip* units reflect an *access* perspective which gives equal value to automobile, transit, cycling, walking and telecommuting.
- *Travel time* units reflect an *access* perspective that gives higher priority to walking, cycling and transit travel, because they represent a relatively large portion of travel time.
- *Exposure time* reflects the amount of time that a particular person or groups uses a particular facility or is exposed to a particular impact. Slower modes and people who stay along a street have greater exposure time than motor vehicle passengers.

Typical Economic Evaluation

A typical economic evaluation involves the following general steps (ECONorthwest and PBQD, 2002). This is a hybrid approach that includes lifecycle cost analysis of impacts that are suitable for monetization, plus a rating system for impacts that are unsuited to monetization.

1. Describe each option, including a base-case and one or more alternatives.
2. Define the evaluation framework (described above), which identifies all impacts (costs and benefits) and objectives to be considered in the analysis. Classify impacts to avoid double-counting.
3. Quantify and monetize (measure in monetary value) impacts that are suitable for each option.
4. Calculate the total monetized benefits and costs for each year that is being considered (typically 10-20 years for a major investment project), and apply a discount value to future impacts. Sum the present value of benefits and costs to determine the Net Present Value.
5. Describe, and measure as much as possible, impacts that are unsuited for monetization (such as equity and effects on strategic community development objectives). Rates each alternative according to how much it supports or contradicts the objectives.
6. Conduct sensitivity analysis to determine how changes in key assumptions affect outcomes.
7. Develop various ways to important differences between the options. For example:
 - Produce graphs that illustrate differences in key impacts.
 - Produce a table or matrix that compares each alternative in terms of its costs, benefits and rating in terms of objectives (such as whether it supports or contradicts equity and strategic community development objectives).
 - Identify the distribution of impacts (which individual or group bears costs or gains benefits).
 - Produce short summaries that describe key differences, and factors that may affect these differences.

Of course, these steps can be adjusted and repeated as needed. For example, stakeholders may sometimes request that additional options, impacts or objectives be considered, or that additional analysis be performed to determine the distribution of impacts.

Issues To Consider

This section discusses important issues to consider when performing economic evaluation.

Comprehensive Consideration of Impacts

It is important to be comprehensive when evaluating benefits and costs. Transportation agencies traditionally consider a limited set of impacts, focusing primarily on agency expenses, travel time, crash risk and vehicle operating costs (TTI, 1997). This may be adequate when comparing similar options, such as alternative highway routes, but causes significant errors when comparing alternative modes or TDM programs that affect total motor vehicle travel. Conventional analysis often ignores the following impacts:

- *Downstream Congestion.* Increasing highway capacity often increases total vehicle traffic volumes, increasing congestion on surface streets. This impact may be avoided by transit or TDM options that avoid increasing traffic volumes.
- *Parking Costs.* Widening a highway to accommodate additional vehicle trips can result in additional parking demand, while transit improvements or TDM programs that reduce total automobile trips can provide parking cost savings.
- *Roadway Impacts.* Large, heavy vehicles such as buses impose relatively high traffic congestion and road wear costs, and sometime require special facilities, such as pull-out lanes. These costs should be considered when evaluating transit and freight options.
- *Traffic Impacts on Nonmotorized Modes.* Traffic congestion is usually defined and measured in terms of the delays that motor vehicle traffic imposes on other motor vehicles. Delays, discomfort and crash risk to cyclists and pedestrians is often ignored. The tendency to undervalue nonmotorized travel impacts skews decisions toward automobile travel and away from alternatives, including transit, since most transit trips involve nonmotorized links.
- *Vehicle Ownership and Mileage-Based Depreciation.* Economic evaluation often assumes that incremental vehicle costs consist only of fuel, oil, and tire wear (totaling about 12¢ per kilometer). It ignores mileage-based depreciation (reduced vehicle resale value and operating life from vehicle use) and repairs (which typically total about 12¢ per kilometer). Also ignored is the possibility that improved transportation choices may allow some households to reduce the number of vehicles owned, or a vehicle may be used by another household member, providing additional benefits.
- *Transportation Choice.* Economic evaluation often assumes that travelers can drive and have an automobile. Little or no additional weight is given to transportation options that improve access for non-drivers (Litman, 2001).
- *Environmental Costs.* Economic evaluation often ignores significant environmental impacts. Although some economic studies place a value on some air pollutants (particularly criteria tailpipe emissions), other air pollutants (e.g., non-tailpipe emissions), water pollution, noise pollution and wildlife habitat destruction are often ignored.
- *Land Use Objectives.* Evaluation of individual transportation projects often fails to consider whether they support or contradict a community's overall strategic land use objectives, such as efforts to reduce sprawl.
- *Construction Delays and Impacts.* The evaluation of transportation projects (particularly highway improvements) should take into account delays to travelers and other costs associated with project construction (McCann, et al, 1999).

What's It Worth?

Conventional traffic models often use simplified travel time cost functions which assume that any shift from a faster mode (driving) to a slower mode (transit, cycling, walking, etc.) increases consumer costs. This is wrong for two reasons. First, alternative modes are sometimes as fast as driving. Second, consumers do not always consider additional travel time a cost. Time spent walking and cycling is sometimes considered a benefit, as indicated by the popularity of recreational strolling and cycling. Similarly, sometimes people prefer ridesharing or riding transit to driving, particularly under congested conditions.

Travel behavior changes that result from positive incentives, such as improved travel choices, reflect consumer benefits, because consumers will only change modes or route when they are directly better off. For this reason, newer transport cost models use consumer surplus methods to measure the incremental costs and benefits of travel changes. This applies willingness-to-pay for travel time changes to existing travelers, and the *Rule of Half* to calculate consumer benefits from changes in total trips (Small, 1998).

Table 6 and Figure 4 compare conventional and comprehensive analyses that evaluate a highway project and transit service improvements to improve mobility on a congested corridor. A conventional analysis only considers travel time costs, agency expenses, vehicle operating expenses, and transit fares. It concludes that the highway improvement provides the greatest net benefits, and that the transit improvement is not cost effective because consumer benefits are less than costs.

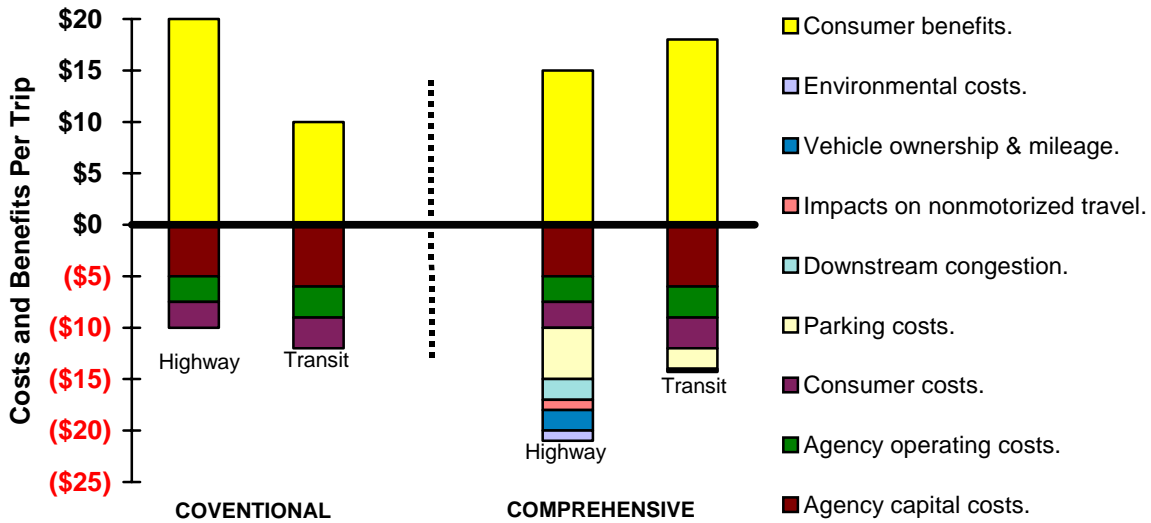
Table 6 Conventional and Comprehensive Cost Analysis (Dollars Per Trip)

| Impact | Highway | Transit |
|---|-----------------|-----------------|
| Conventional Analysis | | |
| Agency capital costs. | -\$5.00 | -\$6.00 |
| Agency operating costs. | -\$2.50 | -\$3.00 |
| Consumer costs (vehicle operating expenses and transit fares). | -\$2.50 | -\$3.00 |
| <i>Total Costs</i> | <i>-\$10.00</i> | <i>-\$12.00</i> |
| Consumer benefits (based on standard travel time costs). | \$20.00 | \$10.00 |
| <i>Net Benefits</i> | <i>\$10.00</i> | <i>-\$2.00</i> |
| Comprehensive Analysis | | |
| Agency capital costs. | -\$5.00 | -\$6.00 |
| Agency operating costs. | -\$2.50 | -\$3.00 |
| Consumer costs (vehicle operating expenses and transit fare). | -\$2.50 | -\$3.00 |
| Parking costs (assumes some Park & Ride transit trips). | -\$5.00 | -\$2.00 |
| Downstream congestion (costs to accommodate additional vehicle travel on surface streets). | -\$2.00 | -\$0.10 |
| Impacts of additional vehicle traffic on nonmotorized travel. | -\$1.00 | -\$0.10 |
| Vehicle ownership and mileage-based depreciation. | -\$2.00 | \$0.00 |
| Environmental impacts (transit has some environmental impacts, but less than automobile travel per passenger-trip). | -\$1.00 | -0.10 |
| <i>Total Costs</i> | <i>-\$21.00</i> | <i>-\$14.30</i> |
| Consumer benefits (using willingness-to-pay and Rule-of-Half). | \$15.00 | \$18.00 |
| <i>Net Benefits</i> | <i>-\$6.00</i> | <i>\$3.70</i> |

A conventional analysis only considers a limited number of impacts. It favors the highway option. A more comprehensive analysis incorporates more impacts. It finds the transit option most cost effective. Costs are presented as negative values, benefits as positive values.

The more comprehensive analysis uses consumer surplus to calculate consumer benefits. It incorporates parking costs, downstream congestion, impacts on nonmotorized modes, additional vehicle costs, and environmental impacts, all of which can be reduced when travel shifts to alternative modes. This analysis indicates that the transit investment provides the greatest net benefits, while the highway option is not cost effective.

Figure 4 Conventional and Comprehensive Cost Analysis



This figure compares conventional and comprehensive analysis. Bars above the baseline indicate benefits, and those below the line indicate costs.

Economic Principles

Efficient markets must reflect certain principles, including consumer choice, marginal cost pricing, economic neutrality, and competition (VTPI, 2006, “Market Principles”). This is not to say that subsidies, underpricing and monopolies are always bad, they may be justified for various reasons (e.g., to minimize transaction costs, for equity, to stimulate a certain type of economic development). However, markets that reflect these principles tend to maximize productivity, consumer benefits and fairness. Transportation policies and programs that support market principles can provide additional economic benefits that are not usually reflected in conventional economic analysis.

For example, funding road and parking facilities with user charges tends to be more efficient and fair than indirect funding, and variable fees that increase during congested periods are more efficient and equitable than flat fees. Similarly, strategies that improve transport choices (particularly improvements to “basic mobility”) can provide broad economic benefits that may be difficult to measure (Litman, 2001). Economic evaluation should indicate how a proposed policy or program impacts market principles, explicitly identify market distortions, and highlight opportunities to achieve transportation objectives in ways that reflect market principles and improve consumer choice.

Incorporating Generated Traffic Impacts

Generated Traffic refers to additional vehicle traffic resulting from road improvements, particularly added capacity on congested highways. Generated traffic reflects the tendency of urban congestion to maintain a self-limiting equilibrium: congestion tends to limit further growth in peak-period vehicle trips, so if road capacity increases, peak-period vehicle trips tend to increase. A portion of generated traffic consists of automobile travel shifted from other times or times, but over the long run a significant portion usually consists of induced travel (additional vehicle mileage). Generated traffic has several impacts on roadway project evaluation (VTPI, 2006, "Takeback Effects"):

1. Generated traffic tends to reduce the predicted congestion reduction benefits of increased road capacity.
2. Generated traffic imposes external costs, including downstream congestion, accidents, parking costs, pollution, and other environmental impacts, particularly if it leads to more automobile dependent transport systems and land use patterns.
3. The additional travel that is generated provides relatively modest user benefits, since it consists of marginal value trips (travel that consumers are most willing to forego).
4. Traffic models that ignore the tendency of congestion to maintain equilibrium overstate the magnitude of future congestion problems if roadway capacity does not increase or is reduced.

Transportation economic evaluation that ignores the impacts of generated traffic tends to overestimate the magnitude of future traffic congestion problems, overestimates the congestion reduction benefits of increasing roadway capacity, and underestimates the benefits of alternative solutions to transportation problems such as TDM strategies, modal alternatives and land use management.

Economic Development Impacts

Transportation projects are often intended to support economic development. This is particularly appropriate in undeveloped regions. If an area lacks basic access, paving a highway can significantly increase economic productivity and development. But once a basic road system exist, projects that provide marginal increases in traffic capacity or speed tend to provide small economic development benefits, and can even reduce local economic activity (SACTRA 1999). Increased highway capacity tends to shift economic activity from one location to another (for example, favoring regional retail centers over neighborhood shops, and urban fringe housing over infill development), but often provides little increase in regional productivity or economic development (Helling 1997; Boarnet 1999).

In most situations, the majority of economic benefits of transportation improvements can be measured in terms of direct user benefits, such as travel time and vehicle cost savings. It is generally a mistake to include construction employment benefits (these are economic transfers, consisting of tax revenue collected throughout a jurisdiction devoted to a particular transportation project), property value increases, or macroeconomic benefits (Luskin 1999).

Incorporating Uncertainty

Estimates of benefits and costs often incorporate uncertainty and variability. For example, it may be difficult to obtain accurate information on vehicle costs, crash risk and the value that consumers place on their travel time, and these may vary significantly depending on individuals and conditions. Environmental and external crash costs can be particularly difficult to quantify. This is not a unique problem; individuals, businesses, and society often face uncertainty and variation when assessing costs and benefits. One way to deal with uncertainty is to use cost ranges rather than point estimates. Sensitivity analysis can be performed using high- and low-range values. Other statistical analysis techniques can be used that incorporate variability and risk.

Uncertain costs are sometimes excluded from quantitative analysis on grounds that this is *conservative* (i.e., cautious). Use of the word conservative in this context is confusing because it results in the opposite of what is implied. Undervaluing damages and risks is less cautious and conservative than using higher range estimates, leading to increased costs. For example, low estimates of pollution costs reduce the justification for control measures, resulting in more emissions. Costs excluded from quantitative analysis because they are difficult to quantify should be described qualitatively.

Evaluating Alternative Modes and Transportation Demand Management (TDM)

Until recently, most transport economic evaluation compared relatively similar options, such as alternative highway or transit routes. The analysis assumed that total travel would not change significantly between options. Such models are unsuitable for evaluating options that change travel behavior, such as the development of a new travel mode, a TDM program, or pricing strategies (VTPI, 2006, "Evaluating TDM").

When evaluating such options it is important to identify each transport impact (changes in trip scheduling, route, mode, destination, trip frequency, vehicle ownership, land use patterns, etc.), and the incremental benefits and costs that result. Indirect impacts should be identified as much as possible. For example, parking pricing can cause spillover problems in other areas, and strategies that encourage use alternative modes can improve the overall diversity of the transportation system, providing equity benefits. Some TDM strategies increase user fees. These are economic transfers. Their economic and equity impacts depend on how revenues are used.

Evaluation Perspective

Ideally, economic evaluation should reflect all impacts to society, meaning every person. However, there may be practical limits to the scope of analysis. For example, a local transportation agency may be more concerned with costs, benefits, and economic development impacts within its jurisdiction. Funding from higher levels of government may appear to be "free" money: either a jurisdiction gets a share of from a central account or it loses out. Similarly, benefits to residents outside the jurisdiction may be considered of little value. In general, an economic evaluation study should identify all impacts to society, but it can also define impacts from particular perspective, such as that of a particular agency, jurisdiction or social group.

Presenting Results

This section discusses how results of economic evaluation can be presented so they are understandable and useful.

Too often, transportation economic evaluation is presented as a “black box,” in which evaluation details and limitations are poorly conveyed to users. It is important that reports accurately describe the analysis in ways that are both understandable to a general audience and technically comprehensive. Although most users only read a report summary, the following information should be readily available, either in the body of the report, in appendices, or in an associated technical document.

- Program goals, objectives, evaluation criteria and scope, with references to any official documents in which these are defined.
- Who performed the analysis, when it was performed, and for what client.
- Description of process used to develop alternatives and assumptions, including discussion of any public input and peer review.
- Description of analysis model and related references (with Internet addresses if possible).
- Sources of all input data (with Internet addresses if possible).
- Description of each alternative being evaluated, including how they were developed.
- Definition of the Base Case and how “incremental impacts” are calculated.
- Assumptions concerning travel demand (person or vehicle trips, and mileage) and how these may vary between options.
- Definition of all cost and benefit categories, including those that are not monetized.
- Sources of cost and benefit values (with full references and Internet addresses if appropriate).
- Discussion of impacts that are excluded because they are difficult to quantify or monetize.
- Discussion of possible spillover effects and costs to other agencies or jurisdictions.
- Direct consumer impacts (using consumer surplus if possible).
- Distribution of impacts, and discussion of equity impacts (including various equity objectives and perspectives if appropriate).
- Assumptions concerning sources of funding and use of revenues.
- Discussion of impacts with regard to market principles, including consumer choice, efficient pricing, economic neutrality and competition.
- Impacts on land use patterns and transportation system (such as long-term changes in transportation system diversity).
- Discount rate used for analysis.
- Sensitivity analysis.
- Discussion of how alternative perspectives and assumptions may affect conclusions.
- Full references, with Internet addresses whenever possible.

Conclusions and Recommendations

Economic evaluation is an important component of transportation decision-making. It can help identify the value of a policy or program. Cost-Effectiveness, Benefit-Cost Analysis, Lifecycle Cost Analysis and Multiple-Accounts Analysis are specific economic evaluation techniques used in transportation planning.

Most transportation economic evaluation practices were developed to evaluate similar options and assume a limited set of objectives. They are generally unsuitable for comparing options that involve different modes or TDM strategies. They tend to overstate the benefits of highway capacity expansion and understate the benefits of strategies that encourage more efficient use of existing transportation resources.

This paper describes specific techniques for effective economic evaluation of transportation decisions. It identifies common problems and recommends ways to provide more accurate and useful analysis. Below is a list of specific factors to consider when applying economic analysis to transportation policy and program evaluation.

- Develop a vision, problem or goal statement that describes what you want to achieve.
- Use *access* as the ultimate goal of transportation improvements. *Traffic* and *mobility* improvements should be treated as objectives rather than ends in themselves. This allows consideration of the widest possible range of solutions to transportation problems.
- When evaluating transportation improvement alternatives, include a variety of options, including TDM and “do nothing” options.
- Define the Base Case that is used to calculate incremental costs and benefits.
- Assign roadway capacity expansion costs only to peak-period vehicle users.
- Use comprehensive estimates of costs and benefits, including all road and parking expenses, downstream congestion, impacts on nonmotorized transport, vehicle ownership costs, environmental impacts, impacts on travel choice and strategic land use objectives.
- Describe impacts that are not quantified in the analysis because they are difficult to quantify.
- Indicate market efficiency impacts, including how a policy affects travel choices, subsidies, price efficiency and competition.
- Use consumer surplus analysis rather than travel-time cost values to calculate consumer impacts of changes in route, mode and trip frequency.
- Incorporate generated traffic impacts.
- If economic development objectives are considered, use rigorous analysis that avoids exaggerating benefits.
- Indicate the distribution of benefits and costs, and evaluate impacts on equity objectives.
- Use sensitivity analysis and other statistical techniques to explicitly incorporate uncertainty and variability in economic evaluation.
- Describe how different perspectives and assumptions could effect evaluation conclusions.
- Produce reports that are understandable to a general audience and include all relevant technical information.

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