RESOURCE PAPER

Selecting Public Transportation Projects: Informational Requirements

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In the early days of development of our country's transportation infrastructure, the public sector was not as involved in transportation system development as it is today. Landowners and developers not only performed most local street and road development, but they also played important roles in developing regional and interregional facilities. These facilities included most of the first toll roads, turnpikes, and canals of our nation and, later, urban streetcar and bus systems.

Government was not completely uninvolved, of course. Government provided financial assistance to private transportation initiatives through land grants and postal contracts, for example. Government's aim was to encourage settlement, thereby providing access to natural resources and military advantage and stimulating economic activity. Nevertheless, to an important extent, the project selection process was in the hands of the private sector and was guided significantly by commercial motives.

With the development of the postal road network early in the 20th century, however, the transition toward public development of the transportation infrastructure accelerated. In the highway arena, road finance evolved away from toll-oriented systems to a reliance on broad-based tax levies, first on property, then on the sale of motor fuel. In the transit area, private bus and rail transit systems were acquired by the public sector and financed, increasingly, out of broad-based taxes rather than fare box revenues. Similarly, airports and sea- and river-port facilities came into public hands or were developed as public enterprises. Increased public ownership meant that investor scrutiny and the discipline of the marketplace no longer operated to guide (however well or poorly) the path of transportation development.

This paper is about the transportation planning process—the public-sector analog to the investment decision-making process of the private sector. The paper, prepared for this conference, is one of three papers whose purpose is to identify the looming informational deficits in measuring the impact of transportation on regional economic health, in estimating the revenues available to finance transportation system development and operation, and in evaluating transportation alternatives.

This paper examines the informational requirements of the transportation decision process. The process is viewed as a hierarchy of policies, programs, and projects. The paper first describes how transportation economists believe the decision process should function, identifying the analytic steps and key informational requirements of the process. It then goes on to identify key deficits in the informational resources that are available to decision makers and provides draft research statements in key areas.

The information resources available to transportation economists have improved significantly since the passage of the Intermodal Surface Transportation Efficiency Act of 1991 and its authorization of the Bureau of Transportation Statistics (BTS). The American Travel Survey and the Nationwide Personal Transportation Survey have improved information on both interregional and urban personal transportation. Information on freight transportation has improved with the Commodity Flow Surveys conducted in 1993 and 1997 and the Truck Inventory and Use Survey.

Although the recently enacted Transportation Efficiency Act for the 21st Century promises to expand the data development and publication activities of the BTS, important gaps remain in the available information on travel behavior and conditions, and they are likely to remain without special effort. The conference offers an opportunity to discuss with policy makers the fundamental goals of transportation planning and implementation and to draw policy makers' attention to the types and sources of data that are needed to improve transportation decision making.

The Transportation Decision Hierarchy

The transportation decision-making process is typically portrayed as a top-down process, evolving from policy, to program, and, finally, to project evaluation and selection, as depicted in Figure 1. The policy articulates the general aim of planning, the program marshals the resources to implement planning these aims, and the project selection methodology moves the process toward concrete action and implementation. At every stage, information (data and analysis) plays a role, as do political and social considerations. Although there are more detailed ways to characterize the process [see, for example, Nijkamp (*1*)], Figure 1 captures the basic decision hierarchy of transportation planning.

The conceptual advantage of following a decision hierarchy rigorously is that there is an expeditious direction of effort, with rapid winnowing of alternatives. Programs and projects that are incompatible with the policy of objectives are, theoretically, shed early so that valuable time is not wasted evaluating projects that are policy dead ends. There should be greater economy and effectiveness in the final implementation process if it is guided by policy, nurtured by programs, and scrupulous in evaluating alternative projects.

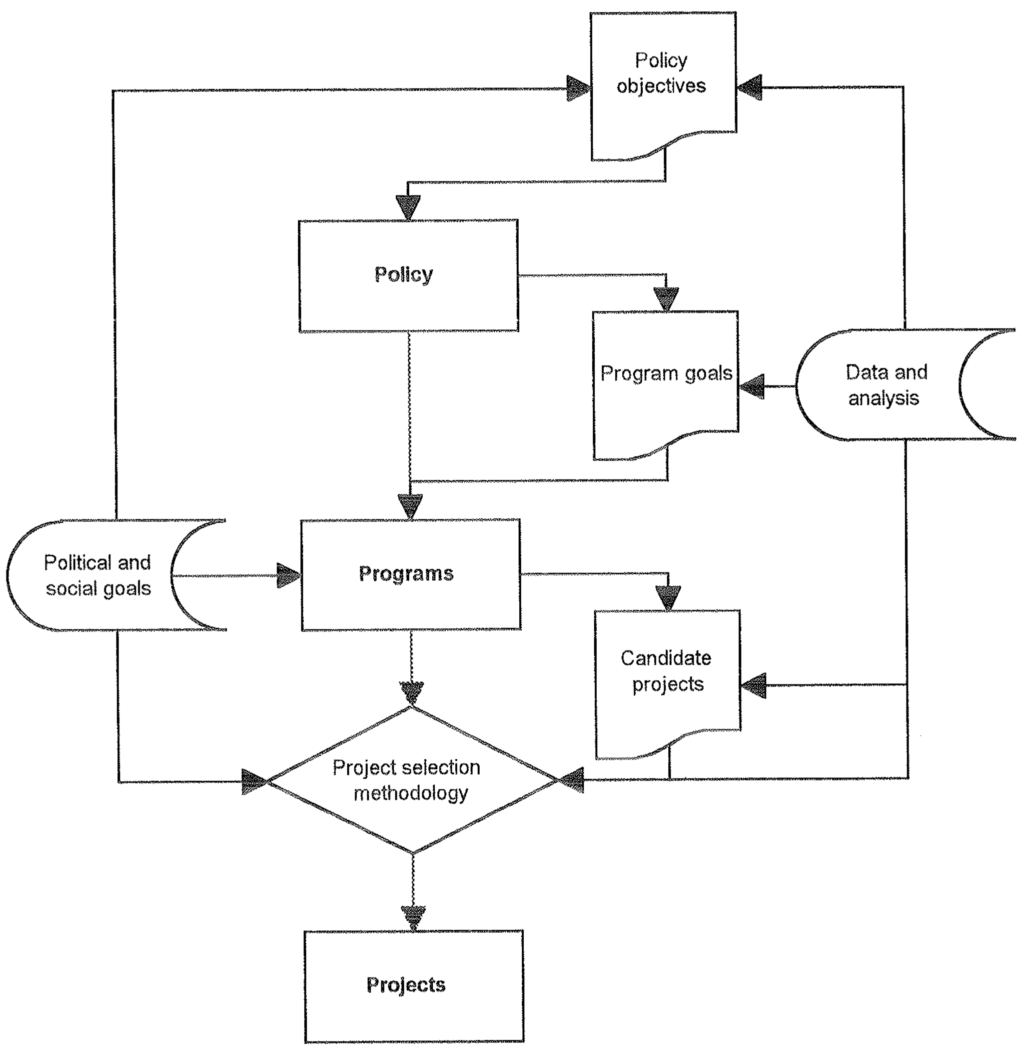

FIGURE 1 Schematic of the policy-program-project hierarchy.

Although most transportation planners probably subscribe to such a planning hierarchy in concept, the reality of transportation decision making is quite different. Optimizing transportation practice in all of these dimensions is difficult in the real world; at the project level alone, the location, scale, timing, and manner in which transportation improvements are implemented all can affect the effectiveness of the improvements, so that the potential menu of alternatives can be very large. Further complicating matters is the fact that policy makers live in a world in which purely technocratic decision making is rare. Considerations of equity, public acceptance, economic development concerns, and a variety of other practical constraints circumscribe the policy initiatives, program choices, and project menus of policy makers.

This phenomenon is observed even in Scandinavian countries, with a long tradition of technocratic planning. As Nyborg discovered in her recent survey (*2*), Scandinavian decision makers, too, tend to be guided by the transportation planning process in only a loose way, particularly at the level of project selection. Given the budgets involved and the risks associated with bad decisions, the weak role that formal project evaluation, in particular, plays in the decision-making process might be seen as anomalous. But the reality is that the planning process frequently is incompatible with the reward system and time horizons that decision makers face. In addition, and more relevant to the substance of this conference, there are areas of research that are not sufficiently well developed to support comprehensive transportation planning.

We turn first to the issues and informational challenges of the first two steps of the planning hierarchy: policy planning and program design.

Policy Planning and Program Design

Gaps in knowledge that exist at the policy level will necessarily propagate to program design and the identification and selection of programs. At the policy level, decisions are made about the objectives of the transportation system management. In order to articulate policy objectives and to design programs (and, ultimately, projects) to carry them out, there has to be general agreement about the evaluative principles that should guide policy making.

Transportation economists, for example, might argue that good policy in the transportation sector would have the same basic objectives as good economic policy in general:

- It would allocate scarce resources to transportation systems and services so as maximize the community's overall economic well-being. (Economists would call this an efficiency objective.)
- It would allocate cost responsibility so that those who benefit the most from transportation improvements, or impose the greatest costs on others, pay accordingly. (This is an objective that has both efficiency and equity implications.)

Given these policy objectives, program design then would be oriented toward identifying and screening high-productivity project alternatives and developing methodologies for measuring and assigning cost responsibility.

These notions are probably not too far from what most policy makers would articulate if asked how planning should be done. However, real-world decision processes frequently shortcut the project screening process, and institutional considerations and political goals often impose multiple (and sometimes conflicting) constraints on decision processes. Typical confounding forces that transportation decision makers face, for example, include the following:

- *Constitutional and legislative constraints.* Transportation funds often are earmarked or restricted in use. [California distributes highway funds, for example, using a complex, legislated revenue-allocation formula (*3*).]
- *Income redistribution goals.* Transportation policy often is used as a way to beneficially affect the cost of living of elderly, low-income, and student households. (Transit fare policy is one case in point.)
- *Financing considerations.* Broad-based taxes typically have greater political appeal than selective, user-based finance. (Since 1913, most U.S. roads have been financed with gasoline and general tax revenues, rather than tolls, for example.)
- *Status quo considerations.* It often is easier politically to build new facilities than to implement demand management of existing facilities.
- *Power barriers and power vacuums.* Decision-making authority often is not effectively placed.
- *Social planning objectives for transportation.* Transportation policy often is intertwined with policies toward land use, economic development and urban renewal, the disabled, organized labor, and so forth.

It is difficult to design effective programs, let alone select productive projects, if the objectives of the planning process are ill defined or conflicting. If the overarching policy basis of transportation cannot be clearly articulated, the process can become contentious, as individual actors in the process implicitly (or explicitly) assert their own policy interests. This, in turn, leads to conflict, delay, or deadlock downstream over particular program and project initiatives.

It is possible, of course, that the policy-program-project paradigm imposes an unnecessarily laborious framework on the transportation decision process. Might it be better, and ultimately more efficient, to invent and implement new projects one at a time, and not bog decision processes down with policy objectives, program planning, and other process overhead?

Examples of Policy and Program Dissonance and Its Effects

The state of the U.S. transportation system suggests otherwise, at least superficially. The project-first paradigm that has dominated U.S. transportation planning has not yielded a public transportation infrastructure that is either financially sound or efficiently configured. Most state departments of transportation (DOTs) report serious project backlogs, and the performance of urban interstates and arterials has continued to deteriorate in the past 5 years (*4*). The condition of public transit vehicles also worsened, as did transit's share of total trips. And while the private sector of the economy is booming, DOTs and transit agencies are almost uniformly financially weak. This at least implies that the projects and policies that have been yielded up by the existing transportation decision process fall short.

Closer inspection of transportation decisions and their outcomes in recent years supports this inference. The importance of building policy before projects, for example, is illustrated by the challenges that arose in the 1970s. In the 1970s, it was still common practice to include new highway routes in state and local transportation plans without first considering the rationale of the improvements. Indeed, for all practical purposes, transportation planning documents did not articulate transportation policy objectives; rather, they were blueprints for the road project developments of state and local jurisdictions. In essence, projects were leading road policy.

In the 1970s, citizens in many jurisdictions reacted to their sense that transportation system development was guiding economic and social development, rather than the other way around. In California, for example, this dissonance resulted in a rapid about-face concerning highway policy. In the mid-1970s, California state transportation policy was discernibly anti-road building, after decades of being proudly development oriented.

The lurch from pro- to anti-road sentiment that occurred in California and other states during this time undoubtedly had efficiency effects. Beneficial road projects suffered along with weak projects while road building was sidelined, and much-needed reform of highway finance was delayed. In my view, many jurisdictions still suffer from uncertainty about what compass to follow in defining, selecting, and implementing highway improvements.

Transit development is another area in which the consequences of the project-before-policy phenomenon have been apparent. In the 1970s and 1980s, many jurisdictions hastened to implement transit system improvements as alternatives to road development. I think it is fair to say that the enthusiasm for the capital-intense transit system development, in particular, was not the consequence of a considered transportation decision process. Transportation policy and program evaluation did not endogenously yield up most transit project proposals. Rather, the prevailing anti-road sentiment, the inducements of full or partial federal financing of certain types of transit improvements, and the public-works opportunities that such projects represented caused transit projects to appear in regional project agendas. Transit programs and policies were largely articulated after the fact; specific projects were the lodestars, and seldom even subject to comparisons with alternative projects. Because of funding compartmentalization, transit program spending and road program spending were typically not coordinated.

The ex-post review of the track record of transit investment suggests that something may have been lost in the departure from policy-directed decision making. Some analyses of the track record of the large transit investments in the past 20 years suggest that they were not particularly effective investments (*5,6*). These analyses are, understandably, disputed by transit developers and transit management. Resolving this debate is not our purpose here; rather, it certainly would not be surprising to learn that transit investments had low productivity if they were made by a process that did not have clearly articulated policy objectives.

Nor is the United States unique in having had a project-led transportation decision process yield up projects of debatable economic value. Similar decision processes, with similar consequences, have been observed in many other settings. A recent example is Spain's decision to embark on a high-speed rail program; though widely touted by transportation officials as a success, it apparently fails to generate benefits in excess of costs (*7*).

There has been considerable progress since the 1970s in establishing guiding policy principles as an element of the transportation planning process. In 1975, for example, California's State Transportation Board (an oversight body) urged the secretary of business and transportation to articulate its policy before the board would consider the project plan. The *California Transportation Plan* (and associated *Issue Papers*) that was published in 1977/78 presented the first fully developed articulation in a state plan of a state's role in transportation and the objectives and justifications for its policies (*8*).

Today, most state transportation plans have policy plan elements. However, like the original *California Transportation Plan* of 1977, there is a question of whether the existence of these documents has changed decision processes in a significant way. State transportation policy elements are much more coherent, and many modern plans (such as Oregon's) are built around reasonably good economic foundations. In addition, federal funding processes impose certain requirements for considering alternatives, measuring effectiveness, and so on. But the connection between policy plan goals and principles and implementation is still weak. It is still the case that transportation policy is largely project led.

Implications for the Role of Transportation Information Systems

In my view, there are two reasons for this state of affairs. First, political support for technical decision processes, in general, is weak. The performance of elected officials often is measured by their ability to garner projects and services for their constituents. Decision makers naturally prefer processes, therefore, that have some chance of being responsive to their individual efforts. The notion of identifying a project and advancing it in the planning process fits nicely into the real life of elected officials; the notion of overseeing a technically rigorous decision process does not. The importance and means of resolving this issue, however, is a matter for political science, and outside the realm of this paper.

Secondly, and more germane to the subject of the conference, there is not good information on the economic implications of broad policy alternatives, with the result that transportation policies and program orientations seldom are scrutinized critically:

- Is the conventional reliance on broad-based taxes for highway and transportation finance appropriate, or should there be increased reliance on user charges?
- What are the consequences of our failure (in many cases) to employ cost-benefit analysis as a guiding principle in transportation decision making?
- Is public ownership of transportation facilities necessary to achieve the appropriate ends of public policy?
- What are the economic consequences of selecting the wrong project or of emphasizing the wrong program?
- Is decision-making authority located at the appropriate levels of public authority?

Theorization and modeling help to understand the advantages and disadvantages of alternative policy stances and program structures to a certain degree. In the end, however, policy analysis must be made rigorous if established decision processes are to be disrupted in the name of improving the quality of planning outcomes. For that, information on actual transportation conditions and behavior is required.

Project Evaluation and Selection

As argued above, the purpose of the first two steps of the planning hierarchy (policy and program planning) is to identify candidate projects to be evaluated and considered for implementation. Though these benefit from better information in the same way that all policy research and program formulation benefit from good information, these steps are fundamentally process-oriented steps whose purpose is to ensure that all reasonable candidate projects with the potential to fulfill the policy objectives have been identified.

The last step of the planning hierarchy, project evaluation and selection, however, is a highly technical process with significant informational requirements. In this section, we will review the basic procedures for evaluating programs and projects and identify the basic types of methodological and data considerations needed to implement the procedures. The discussion will introduce the economic analysis framework to evaluating programs and projects. We will discuss, in particular, the fundamentals of benefit-cost analysis and how the process operates under (variously) unconstrained, fixed, or uncertain program budgets. Also discussed is how program and project prioritization is affected by the choice of policy objective. Later, we will discuss critical information and analysis needs and formulate research statements.

Economic Basis of Project Evaluation

The need to make decisions about which project or business venture to pursue is neither new nor confined to the public sector, let alone the transportation sector. The resources available to commit to new ventures have been, and always will be, limited. Project selection methodology is needed to make the best use of the limited resources.

Early business and government decision makers understood that the process involved weighing the pros and cons of alternatives. The economist Edward Gramlich once noted, for example, that even Benjamin Franklin employed what he called "prudential algebra" to organize his thinking about the pros and cons of alternative business opportunities. But early thinkers had only the most rudimentary understanding of how to implement "prudential algebra," and they were stymied by how to make decisions when some people were made better off, and some worse off, by a decision. Vilfredo Pareto, in the 1800s, offered the notion that a decision was clearly good for society if it made at least one person better off without impairing the well-being of others. This "Pareto principle" is not much help, though, in the real world where most projects create both winners and losers.

In the 1930s, two economists offered the more useful prescription that a project was worth doing if its benefits exceeded its costs and the winners could (at least conceptually) compensate the losers (*9,10*). This principle, called the Hicks-Kaldor principle after its authors, has evolved over time into the formal field of cost-benefit analysis. Cost-benefit analysis is very simple in principle: simply estimate the costs and estimate the benefits of each candidate project. Those projects for which benefits exceed costs, in the Hicks-Kaldor sense, are worth doing, and those that do not, are not.

Conceptual simplicity quickly gives way to technical complexity, however, when one attempts to practice cost-benefit analysis in the real world:

- How do you measure the benefits of something that does not yet exist, especially when it interacts in a complex way with other products or services?
- What do you do if some benefits or costs are not susceptible, at all, to measurement? What if the saving or loss of human life potentially is involved?
- What if the benefits and/or costs play out over a period of time? How should these delays be incorporated in the analysis?
- What if there is uncertainty about the measurements?
- What if many projects have positive net benefits, but budgets are limited? Which projects should be selected for implementation?
- What if a project has negative net benefits but is particularly effective at helping a targeted or protected class of user (such as the poor)?

Economists have developed at least partial answers to each of these questions. Much of the challenge in applying cost-benefit analysis in the transportation arena, however, arises from the fact that providing good answers in almost all cases requires specialized information and analysis techniques, most of which are only partially developed.

The discussion that follows summarizes the major elements of cost-benefit analysis. In the process, it tries to evoke the informational and analytical needs of the project selection process. Several of the most important of these needs will be discussed in detail in a later section of this paper, along with draft research statements designed to address these needs.

Measuring Transportation Benefits of Users

The benefits (and costs) of a transportation improvement redound to either users or nonusers. That is, they are enjoyed either by those who directly use the facility or service or by those who are affected in some indirect manner. A new road, for example, clearly benefits those who use the facility itself (users). However, if the new road reduces air pollution (say, because of reduced stop-and-go driving), it also may benefit nonusers (anyone who breathes the affected air). Of course, benefits can be positive or negative, and a negative benefit is the same as a cost in the cost-benefit framework.

Let us look at user benefits first. The measurement of user benefits might seem to be hopelessly complex; after all, by definition the project does not yet exist. What is there to measure? The answer is that all we need to do is characterize users' aggregate willingness to pay for transportation services at various quantities of those services. The willingness-to-pay relationship for, say, trips between A and B is a schedule of the aggregate quantity of those trips that the users would be willing to make at various levels of cost per trip. (Economists call the willingness-to-pay relationship the demand relationship.) The difference between what users (in the aggregate) would have been willing to pay and what they are asked to pay is called consumer surplus. When a transportation improvement reduces the users' cost of a trip between A and B, the willingness to pay remains the same, but since users' perceived cost of travel is less, consumer surplus will increase. Users who already were making the trip get to make the trip at a lower cost, and new users (those for whom the willingness to pay was less than the old cost of the trip) are induced to travel.

This leads to a simple way to calculate the benefits of the improvement: subtract the consumer surplus before the improvement from the consumer surplus after the improvement. To do so, we need to know only two things:

- The willingness-to-pay (demand) relationship that is involved, and
- The effect of the improvement on the users' perception of travel cost.

The process is sufficiently straightforward that user-benefit procedure manuals have long been available for use by transportation policy makers (*11*).

As it happens, we do not even have to know terribly much about the willingness-to-pay relationship to implement this procedure. A simple example is illustrated in Table 1, which depicts the schedule of willingness to pay at various trip levels and calculates the consumer surplus before the project improvement (when the cost per trip is 10 cents per trip) and after the project (which reduces the cost per trip to 5.9 cents per trip). Note that for the existing trips in the table, all we need to know to calculate the change in consumer surplus is the difference in the cost before and after the improvement (i.e., $10 - 5.9 = 4.1$). We do not need to know the demand curve.

To calculate changes in consumer surplus for new trips, however, we need to know how many additional users there will be after the improvement. Hence, we need to know how elastic the response of demand is to the travel cost reduction associated with the improvement. Economists measure the elasticity of travel demand relationships numerically as the percent change in the quantity of travel that results from a 1 percent change in the perceived unit cost of travel. The proper measurement of elasticity of demand with respect to travel cost is one of the key informational needs of transportation project selection

TABLE 1 **Stylized Calculation of User Benefits Resulting from a Reduction in Trip Cost**

Quantity of Trips	Willingness to Pay (cents per trip)	Consumer Surplus Before the Project (cost/trip = 10)	Consumer Surplus After the Project (cost/trip = 5.9)	User Benefit Change in Consumer Surplus
1.0	16.7	6.7	10.8	4.1
2.0	14.3	4.3	8.4	4.1
3.0	12.5	2.5	6.6	4.1
4.0	11.1	1.1	5.2	4.1
5.0	10.0	—	4.1	4.1
6.0	9.1	—	3.2	3.2
7.0	8.3	—	2.4	2.4
8.0	7.7	—	1.8	1.8
9.0	7.1	—	1.2	1.2
10.0	6.7	—	0.8	0.8
11.0	6.3	—	0.4	0.4
12.0	5.9	—	—	—
13.0	5.6	—	—	—
14.0	5.3	—	—	—
15.0	5.0	—	—	—
16.0	4.8	—	—	—
				Total 30.3

methodologies. Modern techniques for measuring demand elasticities are very accurate but are information intensive (*12*).

The calculation of user benefits gets a bit more complicated if the effects of the project are so large that they appreciably affect the income of the user; in that case, the income effect shifts the demand curve, and the price effect of the project improvement is intertwined with the fact that the users now feel better off. Separating the income effect impacts of the project itself requires knowing how much the demand relationship shifts in response to changes in income (that is, it requires knowledge of the elasticity of demand with respect to income). But separating these two effects is relatively straightforward, and it can be implemented with the information from good transportation demand models.

Measuring the effect of the improvement on users' perception of travel cost is the other piece of information needed to measure traveler benefits. An unusual aspect of transportation activity (relative to many other goods and services in the economy) is that users commit their personal time to transportation activities. Consequently, the perceived cost of travel includes not only expenses such as gasoline or transit fares but also the value of the time spent traveling. This makes the value of time a crucial factor in cost-benefit analysis in transportation, in addition to the various cash or out-of-pocket costs. Deriving the appropriate value of time for users of various types, income classes, and trip purposes requires the same detailed information on the demography of actual travelers and the pattern of their travel behavior that is used to estimate demand relationships (*13,14*).

Measuring Transportation Benefits of Nonusers

There are a variety of parties who, though nonusers of the affected facility, nonetheless might experience benefits or costs as a consequence of a proposed project:

- Suppliers of transportation services (transit companies, road authorities or departments, etc.);
- Users of facilities elsewhere in the transportation network on the same, or other, transportation modes; and
- Other businesses and households.

Suppliers (producers) of transportation services are affected by changes in use of their facilities. Analogous to the consumer surplus enjoyed by users, there is a producer surplus that suppliers enjoy if they are able to charge more for a service than they actually would be willing to charge to provide it. When the cost of a service declines from a user's perspective (thereby increasing consumer surplus), this may cause the supplier to experience a reduction in producer surplus. From a cost-benefit accounting standpoint, declines in producer surplus offset gains in consumer surplus. Calculating changes in producer surplus requires knowing the effect of the proposed project on

- The producer's willingness-to-supply relationship (usually referred to simply as the supply relationship); and

- The revenues enjoyed by the supplier (typically, the projected toll or fare revenue).

In my experience, producer surplus effects seldom are calculated, even when they may be important, as in the case when the supply relationship slopes down with additional load (i.e., when there are economies of scale or scope, as with bus transit).

Users of facilities elsewhere in the transportation network usually are affected by transportation projects that affect a select portion of the network. It is very common for a positive benefit that is generated in one portion of the network to be at least partially offset by a disbenefit elsewhere on the network as traffic levels adjust to improvements. The principle of measuring the benefits on these indirectly affected portions of the network is the same as for the primary users' benefits. The challenge here is primarily in quantifying these network effects.

Unfortunately, although the state of transportation demand and network modeling has advanced significantly, the linkages between these modeling technologies and cost-benefit analysis virtually are nonexistent. Establishing and automating these links is an important research agenda item, in my view.

Businesses and households can be affected apart from their use of some portion of the network. In economics parlance, these effects are externalities that the transportation system engenders. Externalities can result in positive or negative benefits, and include such phenomena as

- *Environmental impacts.* A transportation improvement may either improve or degrade environmental conditions. Transportation activity has significant impacts on air, noise, and water resources. Some also argue that transportation activity contributes significantly to the apparent global warming trends.
- *Impacts on the health of the regional economy.* As Randall Eberts discusses in this conference, transportation improvements can affect the health of a regional economy by increasing the overall production possibilities of the economy.
- *Impacts on the cost of public services.* The use of transportation facilities affects the activity of courts, police departments, emergency service departments, and so forth.
- *Tax effects.* If a transportation improvement is financed with general tax revenues (as opposed to user charges), there are impacts on the consumer surplus of taxpayers.

In the externalities arena, the accounting of benefits and costs could be improved significantly if there were better information on the linkage between transportation activity and emissions, public service costs, and so forth. In addition, however, there is debate over the value to assign to some externalities, and there have been only a few meta-analyses of transportation externalities (*15*).

Decision Making When Benefits Cannot Be Quantified

The issue of quantification of benefits is not confined to the value of environmental externalities, though these are notoriously contentious. The lack of consensus values plagues transportation cost-benefit analysis. Such crucial parameters as the value of time, demand elasticity, the value of human life, and impacts on regional economic growth and the environment are either contested or only partially developed. Can decision making proceed without resolving these important informational issues?

Decision making can and does proceed, of course. It proceeds by using either implicit or explicit procedures to adopt values from decision makers. Implicit valuation often occurs unbeknownst to decision makers. For example, when decision makers choose not to do something (say, not spending $10 million on a road improvement that would save one life every year), they are adopting de facto a value of life (or at least an upper bound on the value) as surely as if they had asserted it directly. If enough decisions were observed from this perspective, it would be possible to infer decision-maker values.

The most rigorous explicit procedures to engage decision-maker values generally involve what are known as multicriterion decision processes (*1*). In these processes, the decision makers (who may either be officials or the public) are asked to rank alternative transportation projects on a number of dimensions or criteria, such as net economic benefits and environmental soundness. In so doing, the decision makers implicitly reveal the weight they apply to various performance attributes of the projects, which, in turn, implies something about the value of the underlying cost-benefit parameters.

Multicriterion analysis methodologies have been developed that attempt to measure and enforce consistent valuation behavior. In the Analytic Hierarchy Process (AHP), for example, decision makers report pairwise rankings of alternatives that then are used to develop implicit weights and consistency indicators (*16*). This technique has been used to explore the preference structures of transportation officials in the Seattle region.

In my view, multicriterion analysis methodologies are not a good substitute for better information about key cost-benefit parameters. In essence, such methodologies presume that, as a group, decision makers somehow harbor knowledge about the "true" value of these parameters and that, once extracted from an AHP or similar processes, they can be usefully and repeatedly applied. It is unlikely that decision-maker intuition is able inherently to solve complex scientific questions. In the worst case, if the decision makers happen to be completely wrong, consistent reliance on the results of multicriterion exercises results in a large number of wrong decisions. It might be better, in fact, to introduce some randomness in the decision-making process to diversify the risk of making multiple bad decisions.

Discounting and Present Value: The Time Value of Money

Most transportation projects involving capital improvements provide benefits over an extended period of time. For as long as the project is operational, it is providing transportation services. Therefore, some benefits (and disbenefits) will be associated with it throughout its life. The savings (or increases) in user travel time and expense relative to what they would have been without the project extend far into the future. If a life is saved or lost because of the operational characteristics of the facility, the value of what that life would have produced over each year of its expected duration also must be calculated.

Similarly, the development and operating costs associated with the improvements play out over an extended period of time. Though the bulk of the capital or development cost usually occurs at the front end of the implementation process, operating costs and maintenance costs occur over the life of the project.

The process of telescoping the stream of benefits and costs over time into an equivalent single figure in today's dollars is the process of present valuation. Present valuation is not simply a matter of adding up each year's benefits net of costs in a simple, arithmetic fashion. An adjustment needs to be made for society's perception of what a dollar is worth when it is received or spent in the future, as opposed to today.

Financial markets provide one source of insight about how to treat future benefits and costs. Financial markets are willing to give us positive interest rates on money that we set aside today. A dollar invested even in a riskless manner (through an insured bank savings account or a government security, for example) returns more than one dollar later. Consequently, a dollar received today is worth more now than it would be if received later because you always have the option of investing it and turning it into more than one dollar later.

The implication of this is that future benefits and costs should be discounted relative to benefits and costs experienced today. The rate, per year, that future benefits and costs should be discounted to present value is the discount rate. The discount rate should be selected so that it represents the forgone economic opportunities of the funds involved in the project. This leads to a few simple guiding principles for selecting discount rates when doing project evaluations:

- When there is no risk or uncertainty about the stream of future benefits and costs, and the social rate of time preference is the same as the private rate (explained below), transportation projects should be discounted using the riskless interest rates that prevail in private financial markets. The reason is that public projects are taking resources away from private projects, and they should be permitted to do so only if they offer a commensurate return. A good choice for the discount rate thus is the riskless rate of return that financial markets currently are offering over the same horizon as a cost or benefit element. One thousand dollars in pollution benefits received 10 years from now, for example, would be discounted using the current yield on the 10-year U.S. Treasury bond. If that yield is, say, 7 percent per annum, then the discounting calculation is

$$\text{Present value} = \frac{\$1{,}000}{\left(1+0.07\right)^{10}} = \$508$$

Thus, $1,000 in benefits received 10 years from now has a present value of only half that amount. The benefits and costs discounted in this manner in each year of the project's life from today (year zero) result in the net present value of the project:

$$\text{Net present value} = \frac{\left(B_0 - C_0\right)}{\left(1+r\right)^0} + \frac{\left(B_1 - C_1\right)}{\left(1+r\right)^1} + \dots + \frac{\left(B_T - C_T\right)}{\left(1+r\right)^T} = \sum_{t=1}^{T} \frac{\left(B_t - C_t\right)}{\left(1+r\right)^t}$$

where

B_t = the nominal value of benefits in year t,
C_t = the nominal value of costs in year t,
T = the life of the project in years, and
r = the discount rate.

- When there is some risk that benefits or costs will actually transpire as predicted, and the decision makers are risk-averse, then the net present value should be lower than that obtained when one is certain of the outcome. (Risk aversion means that decision makers value the possibility of gains less than they value the possibility of losses.) The best way to accommodate risk in cost-benefit analysis is to try to estimate benefits and costs on a certainty-equivalent basis by imagining inclusion of the costs of insurance policies and other protections against risk into the projections of the project costs. An alternative, rough-and-ready way to account for risk is to use a higher discount rate, $g > r$, obtained perhaps by looking at the rates of return required by investors in similarly risky enterprises. This method, however, is only useful when the pattern of risk affects all benefit and cost streams similarly.

- If private market considerations dominate financial markets, and private markets care only about the consumption prospects of the current generation of market participants, it may be the case that society is underinvesting. Specifically, the economist Kenneth Arrow and others argued that the social rate of time preference should be lower than the private-market rate of time preference (i.e., the private-market discount rate is higher than the one that should be used in public projects) (*17*). Many transportation projects involve high up-front costs, with benefits that play out only over long periods of time. If the social rate of time preference, s, is lower than the private rate, r, then projects discounted at s will have net present values that are higher than if they were discounted at r and thus be more likely to be undertaken.

Economists have debated whether very low discount rates should be used on public projects despite considerations such as the social underinvestment hypothesis (*18*). One reason for the debate is that through the operation of futures markets and by virtue of bequest behavior, the consumption prospects of future generations are adequately considered in present-day, private decision making. But these considerations, as well as the considerations of risk and uncertainty associated with individual projects, leave the matter of discount rate determination a field that still needs work.

Ranking Projects

Since we know that society has limited resources, it is obvious that we do not want to embark on transportation projects for which benefits are less than costs when properly converted to present value. Thus, the primary project selection rule is that the present discounted value of benefits, $\bar{B}$, should be greater than the present discounted value of costs, $\bar{C}$. Put differently, projects should be considered for implementation only if their net present value is positive:

$$\text{Net present value} = \left(\bar{B} - \bar{C}\right) > 0$$

Does this mean that society should pursue *all* projects with positive net present value? There are some obvious reasons why this simple prescription fails:

- *Projects are not necessarily mutually exclusive.* Candidate projects may overlap somewhat in the locus and type of some of the benefits they provide and may provide unique benefits in others. Similarly, there may be cost synergies (negative or positive) among subsets of candidate projects so that building a set of interrelated projects is more or less costly than building the projects individually.
- *Budgets are limited.* Decision makers may not have budget authority sufficient to build all of the projects that provide positive net benefits. In my view, this circumstance is rare; it is more likely that the list of transportation project "needs" includes many projects with negative net benefits. And, in any case, for projects with positive net benefits, the budget constraint could be resolved in many cases through user charges; indeed, if the projects are beneficial to users, properly structured user charges should be able to "capture" part of these benefits to provide the financing. Nonetheless, the perception of budget limitations is common, and there may in some cases be institutional rigidities that truly impose budget constraints arbitrarily.

As the nature of these issues suggests, the project selection process has the potential to get complex quickly. The nonmutual exclusivity of project benefits and costs means that the project selection process, rather than focusing on individual projects, should focus on alternative menus and configurations of projects in some cases. The issue of budget limitations means that a decision rule other than the simple $\bar{B} > \bar{C}$ rule must be evoked.

The solution to both of these issues can be found by remembering the purpose of cost-benefit analysis. Its purpose is to maximize social well-being from the available economic resources. What this implies, operationally, is that one needs to devise project configurations (the mutual-exclusivity issue) and affordable subsets of these configurations (the limited-budget issue) that maximize net present value. Hence, the project selection process can proceed using a dynamic screening process (*19*).

Although the process appears complex and time-consuming, it is guided by two relatively simple decision rules:

- *To deal with nonmutual exclusivity:* Projects should be included in project configurations if they maximize the sum of own-project and other-project net present value. By calculating beforehand the interactions of each project with all others (most of which will be zero), devising net present-value maximizing configurations is not arithmetically difficult (though seldom done).
- *To deal with limited budgets:* Projects and project configurations should be ranked in descending order of the ratios of $\bar{B}$ to $\bar{C}$. Candidate projects should be added to the implementation list until the budget is exhausted, starting with the project with the highest $\bar{B}/\bar{C}$ ratio.

The financial and arithmetic mechanics of project selection under constraints, therefore, are not a terribly important impediment to good transportation decision making. The procedures are well articulated in project planning manuals (*20*). The real impediments arise when the necessary data to evaluate net present value of individual projects fail to be developed. The most common reasons that this occurs are

- *Decision makers fail to consider all relevant alternatives.* It does no good to scrupulously develop accurate net present value calculations if the subset of project alternatives is arbitrarily truncated.
- *The underlying project impact analysis and modeling are poorly executed.* The calculation of benefits and costs *is* a complex exercise, particularly when the projects represent improvements to complex existing networks.
- *Net present value calculations are executed in a slipshod or intentionally distorted manner.* In the 1970s, the rapid expansion of state and federal requirements for environmental impact statements yielded many examples of inexpert application of cost-benefit analysis arithmetic, which, unfortunately, continues today.

The more readily good information for decision making is available, the more likely it is that project ranking exercises will be more robust and complete. It is hard to expect decision makers to scrutinize carefully a wide range of alternatives if it is impossible, or prohibitively costly, to assemble good information.

Dealing with Distributional Issues

The final aspect of project selection methodology that will be reviewed here is the issue of how to deal with the distributional or equity aspects of cost-benefit analysis, and the kind of measurement issues that thereby arise. As discussed earlier, distributional problems are not a conceptual fatal flaw in cost-benefit analysis from the Hicks-Kaldor perspective. If a project generates net economic benefits, it should be possible to use clever tax or pricing schemes to capture enough of the benefits from the winning group and redistribute them (in an effective way) to the losing group to nullify its loss. The only issue from the Hicks-Kaldor perspective, therefore, is whether it is possible to derive effective redistribution schemes. Even if it is not possible to implement a redistribution scheme within the context of the project itself, the adverse effects could be nullified through a tax scheme or other more general redistribution schemes. Hence, from a Hicks-Kaldor perspective, distributional issues are not a fatal flaw to implementation of efficient projects.

In the 1980s, economists raised the stakes on distributional issues in cost-benefit analysis by presenting ways that project selection processes could be modified to support the more general income redistributional aims of society, if so desired. They proposed that the selection of even inefficient projects (i.e., those with negative net present values) might be justified under some circumstances if those projects have the effect of improving the economic status of certain targeted or protected classes of individuals.

The logic of this argument is that when society decides to assist the less fortunate, it is implicitly saying that it is willing to trade off a certain amount of efficiency for improvement in societal equity. The only issue is selecting the method for effecting the income transfers; it should, of course, have the smallest possible adverse efficiency effects. By this reasoning, it may be worthwhile under some circumstances to "corrupt" the cost-benefit selection criteria if a project has sufficiently large, positive effects on the well-being of the targeted groups relative to the efficiency penalty.

Computationally, the conventional cost-benefit analysis procedures are accommodated to this goal by simply applying weights (greater than one) to the benefits that are received or costs that are paid, by the targeted class. As a result, a project is made to appear better or worse than it otherwise would in the normal course of net present valuation, thereby affecting its ranking and chances of selection for implementation.

The weights to use in this recalculation can, arguably, be derived by observing the relative treatment of various income groups in other aspects of policy (e.g., the tax or welfare systems) or by calculating the marginal value of additional income from other income and consumption data (*21,22*).

This extension of distribution considerations has the potential to cause great mischief in the evaluation of transportation project alternatives without additional research:

- To what extent does a project actually benefit or harm the targeted class? Existing transportation travel data and demand models are not particularly good at identifying the income class of beneficiaries of transportation projects. We know very little, from Census or other data, about precisely who travels where in our regions or interregionally. In addition to this (and partly because of it), travel demand parameters (such as demand elasticities) are not typically differentiated by income class. Hence, the measurement of the likely effects of a transportation project on any particular identified class of beneficiaries is highly speculative. Clearly, this is an area that would benefit from further research.
- Who is keeping track of the aggregate effect of such concessions to income distribution? If efficiency concessions are made, over time, to select projects that provide services to certain classes of travelers, how do we know when enough such projects have been adopted? Measured income statistics, of course, might well remain unchanged even if many transportation projects friendly to the targeted class have been built.

- Is the development of inefficient transportation services the best way to raise incomes? This is the central question that, to date, has been begged in decision makers' acceptance or rejection of transportation projects or policies because of equity considerations. Transit policy, policy toward older polluting vehicles, toward uninsured motorists, and congestion pricing have all been influenced, in my view, by the implicit grossing up of the benefits or costs of alternative actions on the poor.

Clearly, the subject of distributional impacts also is one that deserves considerable additional research.

Summary and Proposed Research Statements

The informational requirements of transportation decision processes are, in some sense, overarching; data on all aspects of travel behavior, travel cost, and network characteristics are needed, in one form or another, by the evaluation process. These are needed to set policy direction, to formulate and implement models of travel behavior and network conditions, and to measure the desirability of individual projects.

In addition, as the earlier discussion has hopefully made clear, transportation decisions also are influenced by conditions outside the transportation sector altogether: financial market conditions influence discount rates; information on income distributions and the cost of improving poor households' incomes affects the desirability of some transportation project alternatives; and the health consequences of air pollution influence the desirability of projects that change the quantity of emissions, to name but a few examples.

Finally, transportation decisions also are influenced by the quality of the available analytic tools and models. Some modeling tools are needed to measure the response of the transportation system to improvements. Others are needed to perform the proper cost-benefit accounting for individual projects or programs. Still others are needed to guide decision makers through the process of ranking and scheduling projects for implementation.

The following are some areas in which information initiatives would be particularly productive, in my view.

Expanded Information on Travel Behavior and Demographic Characteristics of Households

Description of Research Problem

The available Census of Transportation and Public Use MicroData Sample (PUMS) household census data provide only the most rudimentary basis for understanding how travel behavior varies with the demographic characteristics of households. The PUMS data, for example, do not provide trip length or place-of-work information. Neither source provides substantive nonwork tripmaking information or information about whether drivers have the option of free or fee parking. Consequently, it is difficult to build models that can be used to predict the differential response (and, thereby, the benefits enjoyed) by households of various incomes or other important demographic characteristics. Assembly of such information has been left to individual metropolitan planning organizations (MPOs) whose purposes and resources for assembling these kinds of data are limited. Even MPOs in large, complex regions such as the San Francisco Bay Area continue to rely on old and incomplete travel behavior surveys.

Work To Be Performed

This initiative would involve conducting a comprehensive survey of households, either through a large national sample or through a series of regionally focused samples. Data on trip information (trip origin, destination, mode, time, length, etc.) would be linked to detailed information on household characteristics (income, family structure, car ownership, out-of-pocket operating expenditures, workplace types, parking options, etc.). Modern transportation demand modeling argues that the surveys should utilize a tour orientation rather than a trip orientation. This way, the linking of trip purposes (such as the after-work shopping that is done on the commute trip home) can be better examined. A national sample would permit some comparisons of behavior across regions, but regional surveys can be used to develop demand models for the surveyed regions.

Cost Estimate: \$4 million to \$8 million for a national sample; \$350,000 to \$1 million for each regional sample

Improved Information on Transit Supply Conditions

Description of Research Problem

In the evaluation of highway and transit improvements, there is little attention paid to the nature of the transit system supply response. For example, when demand density rises in a particular corridor or between a particular origin-destination pair, transportation demand and network assignment models must make certain assumptions about how the road network performance will change and how transit service characteristics (headways, travel times, etc.) will change. Although reasonably thorough characterizations of how road networks will respond are available (namely, volume-delay relationships) and embedded in network assignment models, the characterization of how transit services will respond is usually highly stylized or ignored altogether. Transportation economists, on the other hand, believe that transit (bus transit, in particular) is characterized by significant economies of scope and scale as demand increases. Failure to accurately characterize the transit supply response can distort cost-benefit analysis since it mischaracterizes the size (and direction) of changes in producer surpluses.

Work To Be Performed

This initiative would involve two tasks: a meta-analysis of the theory of optimal transit service dispatch, and an empirical review of actual transit district dispatch behavior. The meta-analysis would survey and synthesize the literature on how to optimize route, vehicle, and headway choices. The empirical review would compare the actual behavior of a selected set of transit districts to see if those districts are behaving in a manner consistent with the prescription of the literature. To the extent the districts are behaving optimally, the theoretical characterization of transit supply can be used in long-term transportation modeling. To the extent that the districts appear to use rules other than optimal dispatch rules, the research would provide a critique of this behavior and provide recommendations of how to characterize transit supply responses in transportation models.

Cost Estimate: $550,000

Expanded Monetization of Transportation Externalities

Description of Research Problem

Environmental and other external effects of transportation are looming increasingly large in transportation planning decisions. However, such information is rarely included, in a monetized form, in cost-benefit analyses, even though much of this information is available. In addition, the available meta-analyses of transportation externalities have not tended to report relationships between transportation activity and externalities but rather have been oriented toward simple average or aggregate measures. In the evaluation of transportation projects in a cost-benefit framework, the failure to include monetizable information often causes the project selection process to be handed over to a multicriterion analysis. This introduces more subjectivity in project evaluation than is probably warranted.

Work To Be Performed

This initiative would involve a meta-analysis of the available literature on the economic value of public service costs, environmental externalities, and other transportation externalities. The literature review would be used to develop characterizations of the relationship (linear or nonlinear) between transportation activity and externalities. The research would yield ways to better incorporate analysis of externalities in transportation network modeling and planning.

Cost Estimate: $300,000

Improved Integration of Transportation System Modeling and Evaluation Models

Description of Research Problem

Very capable multistep transportation planning models have been developed in the past 5 years. Both trip- and tour-based travel demand models are tightly integrated with trip distribution and network assignment models such as EMME/2. The tools for using the information from such models for project or policy evaluation purposes, however, are rudimentary. The elements of such evaluation models exist in such decision support models as STE M and SP SM. But the integration between the typical four-step model operated by regional transportation planning and the evaluation models is weak, with the result that few transportation-planning processes produce economic impact measurements.

Work To Be Performed

This initiative would analyze the interface characteristics of the prominent transportation planning model suites and the available evaluation models. The interface characteristics include the form, dimension, content, and format of the output of transportation planning models and the analogous input requirements of the available evaluation models. The research would identify the compatible and incompatible aspects of various pairs of planning and evaluation models and discuss the best modeling suites for analyzing particular types of transportation improvements. It also would recommend enhancements to the existing models and develop intermediate models to better link the planning and evaluation models.

Cost Estimate: $500,000

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