Extending Monetary Values to Broader Performance and Impact Measures: Applications for Transportation and Lessons from Other Fields

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ABSTRACT

This paper examines recent progress at assigning monetary values to what are normally considered "hard to quantify" benefits of transportation projects, so that they can be considered in benefit-cost analysis. It focusing on three very different types of impacts -- environmental, health, safety and economic development – to examine how transportation project evaluation methods have evolved in recent years and how they compare to methods used for evaluation of non-transportation programs. The paper first uses examples of recent practice to show how transport agencies are continuing to refine their definitions of program performance measures to include broader impacts in project evaluation. It develops a classification system to distinguish fundamental direct effects from broader measures of indirect effects, a step that is important to minimize the double-counting of impacts in benefit-cost analysis. For each type of impact, the paper discusses the range of variation or apparent differences in impact valuation among agencies, and then shows that they are due less to imprecision in measurement than to fundamental issues about whether to use damage compensation, impact avoidance costs, stated preferences or behavioral valuation perspectives to define the impact values. Case studies as diverse as Australian roads, Wisconsin energy programs and Appalachian economic development programs are used to show how information and technology transfer are working between transport and non-transport agencies to improve impact measurement and its use in project benefit-cost evaluation for investment decision-making.

1. Introduction

"Performance measures" are indicators of the actual or expected outcomes of programs or projects, and are intended to measure their effectiveness. Performance measures are being used by transportation agencies today for a variety of purposes, from monitoring program performance to affecting budget allocations and selection among proposed projects. Yet while many transportation agencies in the United States are using performance indicators to monitor transportation system performance, few have applied monetary values to the full range of performance benefits.

For some types of performance measurement —such as pavement preservation, bridge inspection, safety, and congestion reduction — current practice often does include quantitative measures of facility condition or performance. Efforts have also been made, in some cases, to assign monetary values to project benefits aimed at improving this performance. Examples are the value of cost-saving benefits assigned to pavement and bridge preservation investments, and the valuation of travel time and vehicle operating cost savings associated with actions that reduce road congestion.

As a result, methods such as benefit-cost analysis (which require monetizing of all measured benefits and costs) can be applied in a fairly straightforward manner for many transportation projects with infrastructure preservation or congestion reduction objectives. However, for projects with other types of objectives -- such as improving environmental quality, health or economic development -- it is more difficult to know how much value is attained from the dollars invested. As a result, some categories of transportation system performance measurement are not commonly included in monetary benefit measures. The problem with this situation is that it limits the applicability of performance measures for assessing program tradeoffs, or for conducting "benefit-cost" or "return on investment" analyses.

This paper draws its content from a study conducted by the authors for the National Cooperative Highway Research Program (Weisbrod, Lynch and Meyer, 2007). That study examined the state of practice regarding estimation and application of monetary values for measuring the observed benefits or estimating the expected benefits of transportation programs and projects.

This article briefly reviews the different types of performance measurement as they pertain to transportation. It then it focuses on three types of performance measures that have traditionally been difficult to monetize, but which are now being monetized through a series of innovative efforts made by transportation agencies -- environmental impacts, safety/health impacts, and economic development impacts. For each type, it reviews recent research on the valuation of benefits and impacts, and presents examples of application of those measures by transportation agencies as well as "technology transfer" from non-transportation agencies. Finally, implications for transportation investment decision-making are noted.

2. Background: Classifying Benefits and Impacts

Many state transportation agencies have been using performance measures for internal management purposes and external accountability reasons for many years. Within the US, Minnesota and Florida were two of the first states to use performance measures in the management of their transportation agencies and in the development of performance-oriented statewide transportation plans and programs. Other state DOTs have also been early adopters of transportation performance measures, including those in Arizona, Kentucky, Maryland, Missouri, Oregon, Tennessee, Virginia and Washington.

Each of state DOTs cited above issues some form of annual report that includes indicators of agency or transportation system performance. Most focus on measuring achievement of agency goals relating to service delivery (e.g., levels of maintenance and snow plowing achieved) and transportation system performance (e.g., congestion levels and the state's safety record). A smaller number of states also include indicators of other environmental and economic factors that are affected as a consequence of their transportation-related programs and policies. NCHRP Report 446 surveyed state DOTs to determine how many were using a performance-based transportation planning process and the indicators used to measure performance and impacts (Cambridge Systematics, 2000). An inventory of performance measures used by various states is also available at the web site of Washington State DOT (2005).

Impact Classification. In the transportation literature, the oft-used concept of "performance measures" can actually encompass a wide range of impact and benefits, which can be classified into three primary groups:

- Direct Effects – Indicators of Transportation System Performance. These performance measures all relate to the physical condition of the system infrastructure and its ability to provide users with the kind of movement (or traffic flow) that are desired or that the system was designed to carry. Examples include measures of system operations efficiency (average travel times and distances), reliability, safety/security, physical system preservation, passenger mobility and freight movement.

- Indirect Effects – Indicators of Impact on People and their Environment. These performance measures also encompass impacts on non-users, which economists refer to as "externality impacts." They are labeled as "indirect" effects because they are all fundamentally broader impacts that result as a consequence of the direct effects. Examples include measures of impact on the economy, the environment and public health. In each case, the broader impacts occur are driven by a change in transportation system use (network configuration, use levels and patterns), interacting with aspects of the affected setting (such as location, climate and business or population demographics).

- Other Societal Considerations – Progress Toward Social Goals. These performance measures are expressed in terms of progress towards broad social goals rather than specific types of impact. Examples include energy efficiency and resource conservation, environmental justice (equity), and sustainability (financial and physical). In each case, a combination of direct and indirect impacts comes into pay to affect the social goal. For instance, sustainability can be defined as a based on a characterization of direct and indirect effects on resource use (relative to available sources), while equity can be defined as a characterization of direct and indirect effects on vulnerable population groups (relative to their impact on other population groups).

Table 1 shows twelve types of transportation-related performance or benefit that correspond to the above-cited three impact classes. This table focuses on impacts that can be quantified (i.e., represented by numeric measures), though not necessarily monetized (i.e., represented by money measures). There are other possible performance indicators not shown on this list, such as direct effects on "customer satisfaction" and indirect effects on "quality of life." Those are not shown because they are composite concepts that are driven largely by the other (already-listed) direct and indirect effects, as well as additional hard-to-quantify concepts such as "comfort."

Table 1: Types of Benefit and Indicators of Performance

Direct Effects on Transport System and Its Users	
Accessibility for Area Population	Travel times to key destinations; Size of customer or labor markets reachable within a given travel time
System Efficiency & Reliability for Users	Average Travel times (by mode), Volumes, Vehicle occupancy, Travel costs, Vehicle/ passenger miles traveled, Speeds, Delay
User Safety & Security	Number or Rate of Incidents (death, injury, property loss) or Insurance cost
Physical System Preservation	Condition ratings, Infrastructure age, Remaining service life
Passenger Mobility	Availability of modal options, Travel times, Delays and Costs to access key business and recreation destinations, associated Passengers, and Passenger-miles
Freight Movement	Modal options, Travel and Transfer Times, Delay, Costs, Ton-miles, Economic productivity of freight sectors
Indirect Effects on Broader Population	
Economic Development	Change in household costs and business costs of transport logistics, Recurring and non-recurring delays and traffic Incidences, Jobs created, Property tax revenues
Environmental Quality	Air quality (or emissions), Water quality (or emissions), Visual quality, Noise levels, Wetlands affected
Health	Days of Work Missed, Days in Hospital, Incidence and Severity of Illnesses (caused by environmental exposure or safety factors)
Other Societal Considerations (Composites Derived from Direct and Indirect Effects)	
Energy/Resource Conservation	Energy consumed, by resource
Environmental Justice (Equity)	Comparison Measures: Transport costs, travel times and accessibility to activity centers, by societal (income/age/race/ cultural) groups
Sustainability	Extent of *Energy* reliance on renewable vs. non-renewable resources; *Economic* reliance on declining vs continuing labor and material resources; economic affordability; *Environmental* damage impact on local reesources

Among the impact or benefit classes listed in the table, transportation agencies most commonly apply monetized performance measures for benefit/cost analysis that covers system operations efficiency, and passenger/ freight movement (using measures of system use and value of time savings) and system preservation (using measures of the economic cost of not replacing assets). Some software for highway benefit/cost analysis also allow for monetized valuation of traveler accidents and pollution emissions (based on rates per vehicle-mile of use). However, the broader impacts that encompass non-users are the least likely to be considered in monetary terms in performance measurement and benefit/cost assessment. They include indirect effects on environmental quality, health/safety and economic development. Accordingly, this paper focuses on those types of transportation impacts.

3. Monetization Techniques

It is particularly important to note that decision-making can be biased just by the tendency to focus on easy-to-measure user impacts (Litman, 2001). Accordingly, there has been a growth of efforts to also monetize societal impacts in order to facilitate broader benefit/cost assessment. These have been generated by needs to evaluate environmental policies, energy efficiency programs and economic development programs, as well as transportation projects and programs. The available measurement techniques have been laid out in a series of texts published during the last decade (Hanley and Spash, 1993; James, 1994; Gowdy and O'Hara, 1995). In general, they fall into two general categories: (1) those that express benefits in terms of avoiding losses, and (2) those that express benefits in terms improvements in value over what would otherwise take place. The range of available techniques for monetizing impacts is summarized below.

Techniques that express benefits in terms of avoiding losses

1) ***Damage Costs.*** This technique indicates the total estimated amount of economic losses produced or avoided by a project or program. For example, the damage costs of traffic crashes could include vehicle damages, costs of providing medical and emergency services, and lost productivity when people are disabled or killed. Valuation of traffic accident costs (to users) are often expressed in these terms. The valuation of programs to reduce traffic congestion are also expressed in terms of avoiding future economic damages that congestion would otherwise cause to businesses in a regional economy.

2) ***Compensation Rates.*** Legal judgments and other compensation rates for damages can also be used as a reference for assessing non-market costs. For example, wrongful injury victims are sometimes compensated by courts at a level that takes into consideration additional cost pain, discomfort and suffering. However, many traffic accidents lead to damages that are not compensated, and it would be poor policy to publicly compensate all such damages fully, since this may encourage some people (those who put a relatively low value on their injuries) to take excessive risks or even to cause a crash in order to receive compensation. As a result, compensation rates are seldom a good measure for evaluating public programs and policies.

3) ***Control or Prevention Costs***. A cost can be estimated based on what the expenditure that would be necessary to prevent, control or mitigate an incident after it occurred. For example, if a manufacturing or power plant is required to spend a given amount per ton to reduce the level of air pollution, we can infer that society considers the pollutant emission to impose costs at least that high if the levels were not lowered. (If both damage costs and control costs can be calculated, the lower of the two is generally used for analysis on the assumption that a rational economic actor would choose prevention if it is cheaper.) In this way, benefits of regional air pollution reduction programs have been valued by considering the opportunity cost of compliance with the Clean Air Act.

Techniques that express benefits in terms of improvement value

4) ***Direct Projected Income Growth.*** This technique uses an economic model to calculate the income benefit that would occur as a result of implementing various proposed projects or programs. This benefit may be expressed in terms of regional worker income (wage) growth, or in terms of total gross regional product (i.e., value added income) growth.

5) ***Shadow Prices (Revealed Preferences).*** This technique uses observations of variation in prices or spending for various goods or services as a way to infer the value of associated characteristics. For example, the value of reducing traffic noise can be estimated by observing the difference in house values on streets with low traffic noise levels, compared to similar houses on streets with higher traffic noise levels. This is a form of "hedonic price" analysis, which reflect "willingness to pay" for a wide variety of environmental and location access factors. The valuations are referred to as "shadow prices" in that are not actually any separate market prices for those factors. Another example of shadow prices would be the additional travel-related costs that are voluntarily incurred by visitors, which could provide a measure of the value associated with having improved access those destinations.

6) ***Contingent Valuation (Stated Preferences).*** This technique relies on surveys of individuals to deduce how much they value a particular factor that has no separate market price. For example, residents may be asked how much they would be willing to pay for a certain improvement in air quality or job access, or what would be an acceptable minimal compensation for the loss of a recreational site. While this technique can provide valuation for a very wide range of factors, there is evidence that survey respondents can over-estimate the extent to which they are willing to actually pay for and use new transportation services or improvements. For that reason, any such surveys need to be very carefully structured and interpreted to obtain accurate results**.**

Verhoef (1994) combines these various monetization methods into three general classes, each with its own advantages and disadvantages (cited in Bein, 2001):

- *Shortcut Approaches* – Techniques such as "Control or Prevention Costs" are considered shortcut approaches. They run the danger of underestimating the true benefits of an improvement because they adopt an available measure of cost impact to represent the full societal value of a broader benefit. For example, the benefit of air quality improvements resulting from transportation policies can be valued as the avoided cost of implementing pollution control measures that would otherwise be required by federal air quality regulations. The benefit of traffic congestion reduction can similarly be valued as the cost of additional infrastructure to avoid that congestion. However, the true societal "willingness to pay" for those benefits may be substantially greater or less than the avoided cost of compliance with regulations.

- *Non-Behavioral Valuation Approaches* - Techniques such as "Damage Costs" and "Compensation Rates" are considered non-behavioral because they aim at estimating the monetary value of unpriced impacts. The former develops a valuation based on cost of physical damage that is incurred or avoided, while the latter develops valuation based on jury judgments of real or perceived costs incurred. For example, air quality improvement can be valued as the reduction in building repair costs that would otherwise result from continuation of current air pollution impacts on outside walls. Similarly, safety benefits can be valued as the reduction in medical care costs that would otherwise occur from continuation of dangerous intersections and road curves. By themselves, these methods represent low-side measures of true value, particularly because they cannot infer any valuation of benefit for non-users of the transportation facilities. However, they are sometimes used in practice (even though they are acknowledged to be low-side estimates of benefit) because the results are more directly observable and easier to document than those obtained with other techniques.

- *Behavioral Valuation Approaches* – Techniques such as Projected Income Growth" and "Shadow Prices" (forms of revealed preference) and "Contingent Valuation" (a form of stated preference) are considered behavioral valuation approaches because they observe consumer behavior or choices made in response to a change in conditions. In each case, surrogate markets are sought in which observable environmental, social or business attributes accompany goods or factors being traded. "Hedonic prices" are inferred from statistical analysis of revealed preferences from observed situations. "Shadow prices" are inferred from the costs that households (or businesses) are willing to pay for particular outcomes. If markets do not exist to observe consumer prices or spending, then "contingent valuation" methods provide survey respondents with simulated markets where they can express their hypothetical valuations of improvements or degradation of environmental quality.

The rest of this article focuses on three types of indirect benefit – environmental, health/safety and economic development -- and examines how the various forms of behavioral, non-behavioral and shortcut methods are used for impact valuation.

4. Environmental Impacts

Types of Environmental Impacts. Impacts on the environment are most often measured in terms of tons of pollution emitted in a given study area. For transportation analysis, this usually means emissions of local air pollutants. However, that covers only part of the full environmental impacts of transportation, as there are many other aspects that could also be covered including greenhouse gases, water pollution and even "land pollution" (such as loss of wetlands or loss of usable land). When monetized, environmental impacts are usually calculated on the basis of a "dollars per ton" valuation of a given pollutant, though it can also be calculated from "dollars per acre" of land left unusable.

In the US, state and region-level transportation agencies usually most often focus their environmental performance measures on emissions of the four primary "mobile source pollutants" covered by the Clean Air Act (carbon monoxide, hydrocarbons, nitrogen oxides and particulates). The analysis may also be extended to the "criteria pollutants" covered by the National Ambient Air Quality Standards of the US Environmental Protection Agency (which adds lead, ozone, and sulfur oxides) (EPA, 2008).

Valuing Pollution Damage. The value of benefits associated with emissions reduction for transportation is sensitive to context, including existing levels of pollution in the affected areas;

density of population in an area; time of day (peak vs. non-peak); season, and other factors. This variation is indicated by Table 2, which shows values per ton of emissions as used by the Minnesota Public Utility Commission for environmental damage costs of different pollutants in different settings (from Rutgers, 2004).

Table 2. Air Pollution Environmental Values (per ton, 2002 Dollars)

Pollutant	Urban	Metropolitan Fringe	Rural
SO_2	0	0	0
PM_{10}	5 060 – 7 284	2 253 – 3 273	637 – 970
CO	1.20 – 2.57	0.86 – 1.52	0.24 – 0.46
NO_x	421 – 1,109	159 – 302	20 – 116
Pb (Lead)	3 551 – 4 394	1 873 – 2 262	456 - 508
CO_2	0.34 – 3.52	0.34 – 3.52	0.34 – 3.52

Source: Rutgers University (2004)

Since different types of vehicles also emit different mixes and levels of air pollution per mile of travel, total air pollution damage costs of transportation activity also vary by vehicle type and population density. This is illustrated by Table 3, which shows FHWA's national values for the marginal cost of air pollution per mile driven. Results of other studies show the wide range of estimates associated with air pollution damage costs. For instance, work by Eyre (1997) suggests that the damage costs of emissions from new diesel vehicles can be as high as 7.4 cents in urban areas, or low as 1.9 cents/per vehicle-mile in rural areas (all costs in 1996 dollars).

Table 3. Marginal Costs of Air Pollution by Type of Vehicle and Area
(Damage Cost in Cents per Vehicle-Mile, 1997 dollars)

Vehicle Class/ Highway Class	Urban Highway	Rural Highway
Urban Interstate Highway		
Car	1.33	1.14
Truck (40-80 kip, 4-5 axle)	4.49	3.85

Source: FHWA (2000).

Other studies assess air pollution costs of alternative truck and rail freight modes, expressed in terms of cost per ton-mile (Forkenbrock, 2001), rather than in terms of cost per vehicle-mile as shown in Table 2. A truck can be carrying from 0 to 10 tons, depending on the nature of the cargo, so these two estimating methods can yield different pollution impacts for areas with different economic and freight profiles.

The variation in valuation of environmental impacts among different studies and agencies can lead some analysts to question the validity of including them in benefit/cost analyses to be used for decision-making. Yet it is important to note that a similar wide variation exists in research concerning the value of traveler time, and that variation has not prevented time savings from being widely adopted for performance measures and benefit/cost studies. (For instance, the value of freight time can range from under $1/hour to over $200/hour, as found in a review by the European Conference of Ministers of Transport, 2003.) In addition, the case study shown below illustrates how some transportation agencies are already accepting monetization of a wide range of environmental impacts.

Case Study: Australian and New Zealand. Austroads is an association of Australian and New

Zealand road transportation agencies, including state and national transportation departments and public transit organizations. Its guidance on project selection, and the relationship between this decision and system performance, is one of the few examples in the world where monetized costs have been associated with a wide range of externalities. Beginning in the early 2000s, Austroads undertook several studies to monetize externality costs associated with a range of topics that were of interest to the heads of the transportation agencies (such as noise, air pollution, water pollution, greenhouse/climate change, nature and landscape, and "urban separation" – an indicator of sprawl). These studies related environmental externality costs to the respective country's gross domestic product, and then estimated impacts on a per vehicle-kilometer basis. Table 4 shows the unit values adopted by Austroads for passenger cars and freight vehicles.

Table 4: Summary of Environmental Externality Costs
(Australian cents per vehicle-kilometer)

Externality	Cents per vehicle-km		Thousand Dollars per tonne-km			
	Car (urban)	Car (rural)	Combination Truck (urban)	Combination Truck (rural)	Rigid Truck (urban)	Rigid Truck (rural)
Noise	$0.70	$0.07	$23.00	0	$2.30	0
Air Pollution	$2.10	$0.02	$100.00	$1.00	$22.00	$0.22
Water Pollution	$0.30	$0.03	$15.00	$0.15	$3.30	$0.03
Greenhouse/Climate	$1.40	$1.40	$42.00	$42.00	$4.00	$4.00
Nature & Landscape	$0.04	$0.40	$15.00	$0.15	$3.30	$0.03
Urban Separation	$0.50	0	$22.00	0	$2.00	0
Total	$5.50	$1.90	$217.00	$43.30	$36.90	$4.28

Source: Austroads (2003)

These externality unit costs are easily used in project benefit/cost analysis and can also be aggregated to a systems performance level. At the project analysis level the unit values are simply multiplied by the change in transportation consumed to obtain an estimated dollar value of impact. At the systems level or at the much broader system indicator level these unit costs can be multiplied by the total amount of transportation consumed (that is, vehicle- or ton-kilometers) to obtain some estimate of the externality cost associated with system performance.

The derivation of these measures and the degree of confidence of their values differs among the various classes of impact. Air pollution costs were estimated on the basis of medical studies clearly indicating a percent increase in daily death rates as the concentration of various pollutants increases. The valuation of noise impacts was based on European and Canadian hedonic price studies that also indicated the impact of higher noise levels on property values. On the other hand, the interpretation and valuation of "urban separation" is more uncertain. This is a unique measure that is intended to reflect the impact of transportation investment on land use patterns and thus on the livability of urban communities. What is not clear, though, is how well the surrogate measures used to measure this effect -- travel time and travel distance -- really measure the level of compactness or livability of an urban area.

The acceptability of the Austroads approach in the US and in other countries likely varies by both type of impact and type of application. At the project level, monetization of environmental impacts such as noise and air pollution appears straightforward and draws from can a significant base of prior research. The inclusion of these non-user impacts in project decision-making is conceptually appealing in that the same unit values would be applied in comparing one project to another. In other words, the relative difference among the alternatives is the most important issue at the project level and holding the unit cost values constant across all alternatives, even if there is some uncertainty with the values, would still provide a relative comparison. However, in using the unit values in a regional performance monitoring capacity, the values of the unit costs becomes very important because they would be interpreted in a very real sense of being a "cost to society." In this context, public perceptions and difficulty in understanding the underlying principles could be a cause of concern to state transportation officials.

Technology Transfer: Emissions Valuation in Energy Programs. Another approach to the valuation of air quality impacts is to rely on valuations set by emission trading markets in the US and abroad. Domestic trading markets exist for SOx and NOx, although markets for greenhouse gases (GHG) do not exist in the US but they do exist only abroad (under the Kyoto protocols, as adopted in Europe). Table 5 shows the monetized values of air pollution as adopted for Wisconsin's Focus on Energy Program. Those values were used by Wisconsin to estimate and monetize reductions in electric power plant emissions resulting from energy efficiency policies and programs (Sumi et al, 2005).

Table 5. Estimates of the Value of Pollution Reduction for Wisconsin Energy Program

Type of Emission	Spot Market Price (2003)	Projected Price (2012)
SO_X (tons)	$130/ton	$332-392/ton
NO_X (tons)	n/a	$1 767-1 847
GHG (tons CO_2)	$1-2/ton	$5-10/ton
Mercury (lbs)	n/a	$16 000-120 653

Source: Sumi, et al., 2005

Yet another case in which air pollution was valued via emissions trading is found in a California study (SBTF, 2003). That study monetized the benefits of using various "green building" technologies and the impacts on pollutant emissions. While noting the difficulty in monetizing CO_2 emissions due to the lack of an established national trading market in the United States, the authors also noted the danger of dismissing or otherwise ignoring these impacts. They adopted a benefit value of $5 per ton in CO_2 emissions reduced, which was above the then current CO_2 trade prices in states and countries which had established markets, but below most medium-term estimates for CO_2 reduction costs.

An important finding is that both the California and Wisconsin approaches yield significantly higher values of air quality factors than those found by the Rutgers (2004) study, shown previously in Table 2. This reflect the differences between the higher values generated by marginal market prices under regulatory controls (shown here), and the lower values generated by direct damage cost estimates (shown in the earlier tables).

5. Safety and Health Impacts

Types of Impacts. Safety and health impacts may be expressed in terms of the frequency and severity of various forms of injury, illness and death associated with the operation and use of transportation facilities and services. The monetary value of these impacts may be measured in terms of the direct costs of response and treatment for injured or ill workers, as well as the value of lost worker productivity and income as well as lost net income for businesses.

Value (Social Cost) of Crashes. Traffic safety impacts are typically measured in terms of crash rates by level of severity, with unit valuation based on both damage costs and survey-based valuation of "quality of life" factors. Unit costs per crash for moderate injury and fatality accidents, as determined by the US DOT, are shown in Table 6. The injury costs reflect the "human capital" method, which accounts only for market costs of medical treatment and lost worker productivity. The non-injury cost adds vehicle repair and travel time delay. The "comprehensive" cost adds non-market impacts such as pain, grief, and reduced quality of life.

Table 6. US and European Estimates of Crash Costs per Vehicle Accident

	US (2000) Injury Crash (moderate)	US (2000) Fatality Crash	Europe (2003) Injury Crash	Europe (2003) Fatality Crash
Injury Costs				
Medical	$15 625	$22 095	$2 711	$6 197
Police & Emergency Services	$212	$833	$70	$1 538
Lost Human Cost or Market Productivity	$25 017	$595 358	$26 923	$884 615
Lost Worker Output or HH Productivity	$7 322	$191 541	5 102	460 314
Insurance Admin.	$6 909	$37 120	100	242
Workplace Costs	$1 953	$8 702	NA	NA
Legal Costs	$4 981	$102 138	NA	NA
Non-Non-Injury Costs				
Travel Delay	$846	$9 148	3 846	11 538
Property Damage	$3 954	$10 273	2 650	8 594
Total Cost	**$66 820**	**$977 208**	**41 335**	**1 376 734**
Quality of Life -Nonmarket	$91 137	$2 389 179		
Comprehensive Valuation of Impact	**$157 958**	**$3 366 388**		

US Source: US Dept. of Transportation, National Highway Safety Administration (NHTSA) estimates, reported in Blincoe, Lawrence et al.(2000)

Europe Source: ICF Consulting (2005); values have been converted from 2003 Euros into 2003 Dollars, based on exchange rate of 1.3 US Dollars per Euro.

The last two columns of Table 8 shows a European valuation of crash impacts. The categories are roughly similar, except that the European valuation does not add valuation of quality of life factors. On a comparable basis, the European market valuation is lower than the American equivalent for injury accidents ($41 thousand vs. $66 thousand), but higher than the American equivalent for fatal accident costs ($1.0 million vs. $1.3 million). These differences reflect a combination of factors – higher medical, legal and insurance cost structures in the US, but higher valuation of human costs and worker productivity in Europe. They are likely to also reflect differences in analysis methods as well as variation in exchange rates.

Value of Life. Two approaches to estimating the value of a human life lead to different results. Researchers using the "Human Capital" method generally find the value of a human life between $0.5 and $1 million. The more common "Comprehensive" method leads to a greater valuation of the loss of life that is most commonly between $2 million and $7 million, with a "working value" of about $3.3 million (Victoria Transportation Policy Institute, 2005).

A workshop report on economic performance measures, organized by the US Government Accountability Office, noted that one of the problems with economic analysis was the lack of guidelines regarding monetary values of crash benefits. The prime example cited in the conference report was the "Value of a Statistical Life" (VSL). It further noted that "the US Army Corps of Engineers tends not to value statistical lives saved, while the Centers for Disease Control and Prevention (CDC) values statistical lives saved (based on a 35-year-old man, for example) at $0.94, DOT at $2.7 million, and EPA at $6.1 million. Such differences create difficulty in comparing economic performance measures across agencies." (Government Accountability Office, 2004, p.31).

Technology Transfer – Health Valuation. The South Coast Air Quality Management District (SCAQMD), the air quality agency for Southern California, has established its own values of health and mortality rates, which are used in establishing the cost of air pollution involving both stationary and mobile sources. These values can be compared to alternative US, Canadian and European measures of unit health costs associated with air pollution and greenhouse gas emissions, as shown in Table 7. Taken together, they indicate a growing consensus on the range of health impacts that extend beyond traffic accident costs.

Table 7. Comparison of Health Valuations Associated with Air Quality

Symptom	**(1) SCAQMD**	**(2) US EPA**	**(3) US TAF**	**(4) Canada AQVM**	**(5) Europe ExternE**
Mortality Average (All Age Groups)	$3.5 m	$4.8m	$3.1m	$2.87m	$3.03m
Adult Chronic Bronchitis	$240 000	$260 000	$260 000	$186 200	$102 700
Cardiac Hospital Admissions	$14 000	$9 500	$9 300	$5 880	$7 696
Respiratory Hospital Admissions	$14 000	$6 900	$6 647	$4 620	$7 696
Emergency Room Visits	$500*	$194	$188	$399	$218
Restricted Activity Days	$60	$38	$54	$51	$73
Acute Respiratory Symptom Days	$11	$15	$12	$11	$ 7
Asthma Symptom Days	$36	$32	$33	$32	$36

** also includes work loss*

Sources: (1) South Coast Air Quality Management District (2006)
(2) US Environmental Protection Agency (1999)
(3) Tracking and Analysis Framework, developed by a consortium of US institutions, as quoted in Davis, Krupnick and Thurston (2000)
(4) Stratus Consulting (1999), as quoted from Davis, Krupnick and Thurston (2000)
(5) ExternE (1999), as quoted in Davis, Krupnick and Thurston (2000)

Technology Transfer: Safety and Comfort Valuation in Wisconsin Energy Program. The Wisconsin "Focus on Energy" (FOCUS) program has provided incentives and subsidies for the installation of new energy-efficient appliances in homes, particularly for low income households. As part of the benefit-cost analysis, the program evaluation derived estimates of the monetary value of a range of "non-energy benefits" (NEBs) for that target population (Hall and Roth, 2003). These benefits included increased safety and health associated with better heating and ventilation systems, reduction of carbon monoxide leaks and elimination of mold problems, ultimately reducing the frequency and intensity of illnesses and their associated medical costs and sick days lost from work. Other NEBs included comfort factors, including temperature comfort, noise reduction, improved equipment reliability and appearance of home affecting its property value. Monetary values for these impacts were estimated on the basis of three different valuation methods that all involved surveys of participants, to elicit perceptions of the incidence and magnitude of the NEBs and tradeoffs or comparisons of their value relative to the measurable energy savings.

6. Economic Development Impacts

Types of Impacts. Economic development commonly refers to changes in business activity that expand (and improve) jobs and income for residents of an area. Transportation improvements generally create economic development through two mechanisms: (1) by reducing travel-related costs for existing transportation movements in the area, and (2) by expanding the market access and connectivity available from that area, making it possible for new kinds of activity to occur there. Both mechanisms can lead to expansion of existing businesses and attraction of new businesses, and they both do so by enhancing the productivity and profitability of operating in the affected area.

Use of Economic Development Measures. Economic development benefits are of particular interest to many state and regional agencies because economic development can be an important motivator or even the primary reason for some transportation investments. *NCHRP Synthesis 463* included a survey of state DOTs concerning the use of economic development impact measures in highway investment decisions. Two-thirds of the states surveyed reported that they conduct evaluations of economic impacts at least occasionally, although a much smaller portion routinely conduct evaluations of completed projects (Weisbrod, 2000).

Economic development impacts are similar to both environmental and health impacts in that they are also multi-faceted. For instance, economic development impacts can be quantified in terms of changes in jobs, income, value added or business output. However, unlike environmental impacts, they cannot rely on standard rules of thumb for monetization but instead require the use of economic models. The approaches that can be used for measurement and analysis of economic development performance impacts are described here.

Types of Economic Development Measures. The selection of appropriate economic impact measures depends on the fundamental economic goals of the transportation project. Economic goals may include promoting economic growth, diversifying away from traditional industries, or creating jobs in economically distressed or blighted areas. The performance measures include:

- *Intermediate Results.* These are shorter-term direct impact measures. They include such impacts as (a) increase in land investment, values and sales, (b) increases in construction of new buildings, (c) increases in time savings, scale of market or other cost efficiencies for businesses and residents.

- *Final Outcome Measures.* These are the ultimate results of what the program accomplished to achieve economic development objectives. They include:

(1) *Business Growth* -- the impact on economic opportunities in a region. This is most commonly measured in terms of jobs, income (wages), value added (GDP) or output

(business sales or revenue). Jobs is commonly used because it is easy to understand by policy makers and the public, and it is not affected by changes over time in inflation or exchange rates. However, since it is not a monetized value, it cannot be used in Benefit/Cost (B/C) analysis or Return on Investment (ROI) analysis. Among the monetary measures, the most common are income (wages) or the slightly broader measure of Value Added (which reflects worker wage income plus net corporate income).

(2) *Business Mix* – the impact on economic diversification, measured in terms of change in the composition of the area's economic base. This most commonly includes measures of the relative change in employment in high-paying (vs. low-paying) jobs, high-growth (vs. low-growth) industries or business growth targets (e.g., tourism, exporting and/or technology industries).

(3) *Economic Equity and Social Welfare* –the impact on ameliorating social inequities, measured by reduction in unemployment rates, poverty rates or incidence of benefit among selected vulnerable groups.

The intermediate and final outcomes tend to be highly correlated, and they unfold over time in a sequence, as discussed in a FHWA guide to highway impact measurement (Economic Development Research Group, 2001).

Drivers of Economic Development Change. The major elements of economic impact that are directly affected by transportation are:

a) *Changes in Spending* – on vehicles, buildings, facilities, or other materials as a result of either initial capital investment in facilities or else ongoing operations and maintenance;

b) *Changes in Traffic-Related Costs* – change in business cost of input materials, workforce and product deliveries, or consumer cost of commuting living associated with shifts in vehicle volumes, travel times and travel distances (affecting vehicle-miles of travel and vehicle-hours of travel);

c) *Changes in Access* – affecting labor market access and scale, customer/ delivery market access and scale, access to recreation opportunities, inter-modal connectivity to airports, ports, rail terminals and border crossings **.**

Monetization Models. The preceding three categories of direct transportation change can be input o economic models, which then calculate broader impacts on the regional economy. The range of economic impact models and the ways in which they can be used are described in *NCHRP Synthesis Report 290* (Economic Development Research Group, 2001*).* The primary tools are regional input-output models and regional economic simulation models; the evolution of these modeling tools and recent advances in their use are also described in Weisbrod (2008). Generally, these models calculate how regional economic growth occurs as a result of shifts in spending flow through the economy (item "a" in the preceding list), and shifts in travel costs (item "b" in the preceding list).

While many states have occasionally used regional economic simulation models for assessing benefits of travel time and travel cost savings, these techniques have not had broad use for statewide or region-wide performance metrics. One reason is that they have been expensive to use; another reason is that such models alone can significantly under-estimate the true value of transportation projects by missing the business productivity benefits of improving system connectivity and access to markets (item “c” in the preceding list).

Business productivity impacts include efficiencies in logistics systems, and scale economies in production and distribution systems. They are sometimes referred to as “externality effects” rather than “user benefits” because the beneficiaries are usually not the travelers. However, freight transportation proponents have argued that it is really shippers, rather than truck drivers, who are truly “users” of the freight transportation system. That line of logic parallels the issue often raised in energy efficiency programs, where energy cost-saving benefits can be measured from the viewpoint of electricity generators, participating consumers or other beneficiaries (Goldberg et al, 2007).

The measurement of logistics and market access impacts calls for appropriate modeling tools, and a range of analysis systems have been developed to capture those effects. They all use variants of a business attraction model that relates the growth and attraction of specific industries to changes in various forms of market access (labor, supplier and customer markets) and intermodal connectivity (including access to airports, seaports and intermodal rail terminals). Examples of integrated economic impact analysis tools bring these the access and connectivity impacts on business attraction include Indiana’s Major Corridor Investment-Benefit Analysis System (Kaliski and Weisbrod, 1999), Montana’s Highway Economic Analysis Tool (Cambridge Systematics et al, 2005) and the TREDIS system used in Oregon (Economic Development Research Group, 2007).

Accounting for Overall Economic Impacts. In practice, economic development impacts often reflect the net effect of many offsetting factors. An illustration is provided by the *Handbook for Integrating Impact Assessment in the Economic Analysis of Projects* (Asian Development Bank (2001). It identifies the economic value of a new bridge project as being driven by a variety of changes that span all three categories of direct effect, including:

- Savings in vehicle operating costs and driver time
- Value of freight and passenger time savings
- Benefits of access generated by the new traffic
- Losses to existing ferry operators
- Savings of not having to construct other facilities (such as a power-interconnector which would have needed to be built without the new bridge)
- Cost savings from erosion prevention and and income generated by increased agricultural production.

It is also important to recognize that regional or state boundaries can affect the measurement of economic impacts. For instance, a highway improvement in one region can enhance access and productivity for businesses in adjacent regions. A highway improvement can also cause business location shifts among regions. However, it is important to note that even a shift in business location among regions is not necessarily a zero net benefit to society as long as there is some productivity enhancement associated with the relocation. This is the case with transportation improvements, since no rational business would undergo the transaction costs of relocation unless there was some resulting profitability gain from doing so. (The misperception that business relocations induced by transportation improvements have no net societal benefit comes from literature on the impact of local tax incentives, which unlike transportation improvements can change business costs without affecting productivity.)

Case Study: Appalachia. The Appalachian Regional Commission (ARC) is a regional economic development agency set up as a partnership of federal and state governments. Its goals are to "(1) increase job opportunities and per capita income in Appalachia, (2) strengthen the capacity of the people of Appalachia to compete in the global economy, (3) develop and improve Appalachia's infrastructure to make the region economically competitive, and (4) reduce Appalachia's isolation." (Appalachian Regional Commission, 2005).

ARC has a long history of funding studies to predict the economic impacts of its investments and evaluating the performance of its programs and expenditures. ARC uses evaluative economic impact studies to validate its past investment expenditures, help target future expenditures to programs that prove most effective in supporting the Commission's mission, and revise programs to better accomplish its goals. The Commission conducts an annual in-house performance review of its program categories as required by the Government Performance and Results Act of 1993 (GPRA).

A major element of ARC's program is to reduce isolation by working with state DOTs to fund and implement a series of highway and road projects. This arrangement has led ARC to implement a series of economic development performance measures applied to its highway spending. The agency's economic development mission has further focused its economic impact analyses on three categories of impacts:

- Economic efficiencies, such as reduced business costs associated with decreases in travel times and operating costs, which make the region more attractive as a business location;
- The distribution of impacts within the region, with particular focus on how well the Commission's programs are helping improve economic conditions in the most distressed counties in the region, and
- Impacts attributable to improved access to markets within the region, in the broader United States, and globally.

As a result, ARC has funded a series of studies of the economic impacts of its transportation investment program. They include: a retrospective analysis of the economic impacts of investments to date in the Appalachian Development Highway System (Wilbur Smith Associates, 1998), a study of the potential role of intermodal transportation access in enhancing the region's future role in the global economy (Rahall Transportation Institute, 2004), evaluation of actual compared to expected impacts of access road and public works programs (Brandow Company and Economic Development Research Group, 2007), a statistical comparison of economic growth in Appalachian counties compared to their counterparts (Isserman and Rephann, 1995, and Lynch, 2008) and economic modeling of the likely future economic impact of completing the Appalachian Development Highway System (Cambridge Systematics et al, 2008). Table 8 lists the economic development impacts monetized in these various studies.

Table 8. Economic Development Impacts Monetized in ARC Studies

Measure	Units
Jobs	- Net new jobs created - Jobs retained - Jobs created and retained per dollar of public investment
Poverty	- Change in number of residents living under the poverty level - Change in poverty rate in region compared to other comparable regions and the nation as a whole
Leveraging of ARC investment	- Ratio of private dollars invested to ARC dollars invested - Ratio of private dollars invested to all public dollars invested
Income	- Dollar value of change in personal income or disposable income - Dollar value of change in per capita income - Dollar value of change in value added (gross regional product) - Ratio of personal income created to dollars of public investment
Transportation Efficiencies	- Dollar value of travel times savings - Dollar value of safety benefits - Dollar value of operating costs savings
Taxes	- Change in property taxes, sales taxes and income tax revenues

The ARC's mandate to improve socioeconomic conditions in the Appalachian region dictates the monetization of economic development measures for program evaluation and predictive impact analysis. These various monetary measures are used on an on-going basis to: (a) justify future federal earmarks for the Commission, (b) improve program delivery, (c) target future investments and (4) educate the public about the success of the Commission's work.

7. Applying Benefit-Cost Analysis

Finally, it is also important to distinguish economic development impacts from other benefit indicators used in benefit-cost (B/C) analysis. Table 9 shows the difference in definitions of economic development impact from various alternative benefit measures of travel efficiency benefit and societal benefit. The measure of "economic development impact" covers many of the same elements as those two benefit measures, but it is distinct from them because it is a measure of impact on a specific area. Economic development impact is usually measured in terms of changes in the flow of dollars (income and business sales) in the economy of an area and the associated jobs occurring there. As such, it can include the change in local income growth that comes just from attracting businesses to shift locations (which is not counted in most benefit/cost studies), and it can leave out other benefits that do not directly affect the flow of dollars and jobs in the economy (such as air quality and the value of personal time, which can be counted in benefit/cost studies).

Table 4-17. Difference between Economic Value of Benefits and Impacts on the Economy

	Travel Efficiency Benefit	Societal Benefit	Econ Development Impact
$ Travel Time Savings for personal travel	Yes	Yes	--
$ Travel Time Savings for business travel	Yes	Yes	Yes
$ Vehicle Operating Expense Savings	Yes	Yes	Yes
$ Business Productivity Gains	--	Yes	Yes
$ Value of Environmental Benefits	--	Yes	--
$ Income Growth from Business Attraction	--	--	Yes

Source: Weisbrod (2008)

Case Study: Benefit/Cost for Energy Program. "Focus on Energy" (FOCUS) is Wisconsin's statewide energy efficiency and renewable energy initiative. The program was created by the legislature in 1999 to meet six policy objectives via reduction in demand for fossil fuels: (1) improve energy efficiency and decrease usage, (2) improve the health of the state's economy, (3) reduce negative environmental impacts of energy consumption, (4) facilitate market transformation by reducing market barriers to increased energy efficiency, (5) increase electric system reliability and (6) stimulate the energy efficiency services industry. With this diverse set of goals, FOCUS included a program of ongoing program evaluation, utilizing benefit/cost analysis with monetized measures of social, environmental and economic impacts similar to those that are (or can be) used for transportation evaluation.

(1) *Energy Savings Impacts.* The FOCUS evaluations include monetized values for both the "direct energy savings" and "market effect energy savings," both of which represent efficiency benefits of the program.

- *Direct Energy Savings (Participants)* are defined as the "energy savings due to the energy-efficiency measures directly attributable to the programs and tracked by them. They are valued in terms of avoided cost to the customer of the avoided energy use over the expected life of the measure"(Goldberg et al, 2003).

- *Market Effects* are defined as energy savings from additional actions taken outside the program by either participants or non-participants that would not have occurred without the program. They are also valued in terms of avoided costs to the customer.

(2) Environmental Impacts -- The FOCUS evaluations include monetized values for both pollutants and greenhouse gases.

- *Pollutants* – The researchers first calculated reductions in emissions (in pounds) of SOx and NOx resulting from program implementation. They then multiplied these totals by the market value of emissions trading credits ($/ton) to arrive at a monetized value of reductions in emissions for these two pollutants.

- *Greenhouse Gases*-- Currently, there is not an active emissions trading market for carbon dioxide (CO_2) in the United States. To monetize the value of reduced CO_2 emissions, the researchers used a value of cents/kWh and cents/therm of CO_2 emission developed from a review of market values in Europe as well as research by the Wisconsin Public Service Commission that reviewed values used by eleven other states.

(3) Safety and Comfort Impacts – The FOCUS evaluation also derived a range of "non-energy benefits" (NEBs) associated with program effects from the installation of new energy-saving equipment in homes. The NEBs included health, safety, comfort and reliability effects. Monetary values for these impacts were estimated using customer surveys to elicit perceptions of the incidence and magnitude of the NEBs, and tradeoffs or comparisons of their value relative to the measurable energy savings.

(4) Economic Impacts and Benefits -- The FOCUS evaluation recognized program effects on the flow of dollars in the state economy and its growth, through use of an economic model. This allowed for calculation of economic impacts in terms of three different effects:

- *efficiency and productivity impacts* –i.e., household and business cost savings;
- *distributional impacts* – i.e., gains in manufacturing, distribution and service industries that directly benefitted from program operations spending, or indirectly from incentives for additional purchases of energy efficient products and services;
- *business growth and attraction impacts* – results of increased cost competitiveness leading to induced investment and business attraction to the state from outside areas.

The FOCUS evaluations included a series of alternative approaches for comparing the benefits and costs of the programs (Goldberg et al, 2007). The "simple" B/C includes valuation of benefits including avoided energy costs, program and participant costs and direct environmental impacts associated with natural gas use. The "expanded" B/C adds monetary measures of non-energy benefits, pollution and greenhouse gas externalities, and valuation of cost savings based on statewide income impact. In other words, it counts both the benefits to program participants and additional societal benefits due to mitigated externalities and reduced ratepayer costs. The FOCUS evaluation also includes an "economic development benefit" measure that reflects net effects on growth of statewide income or value added. These various measures parallel the difference between user benefits, societal benefits and economic development benefits that have been used in some transportation studies.

8. Implications for Transportation Practice

In practice, the application of benefit/cost analysis by transportation agencies can be classified into three categories:

1. *Traveler Benefit Analysis* – The most narrow form of B/C analysis recognizes benefits only in terms of traveler time, traveler expense and traveler safety factors (which are collectively referred to as "user benefits"). Proponents of these studies dismiss the need to include additional impacts on non-travelers, because they are deemed too difficult to measure, or too prone to double counting, or unnecessary if transportation agencies are to

focus on transportation flows. This form of benefit/cost analysis is most commonly conducted as part of engineering studies.

2. *Broader Analysis Studies* – Many major investment studies funded by transportation agencies are now also including air pollution reduction benefits as well as user benefits. This addition has been encouraged in the US by the fact that many urban areas are not in full attainment of EPA Air Quality standards. Commonly used highway analysis systems that have been expanded to allow for air pollution benefits include CalBC, BCA_Net and HERS.

3. *Economic Impact Studies* – An increasing number of transportation benefit/cost studies are also allowing for the inclusion of economic development benefits, particularly for projects where market access improvement, intermodal connectivity and economic growth are explicit motivations for the proposed investments. However, careful accounting and analysis is needed to distinguish efficiency or productivity gains from spatial transfers of activity. Systems that allow for this broader set of economic benefits, in addition environmental impacts, include HEAT and TREDIS.

While monetary values for environmental, health/safety and economic development impacts are often not included in transportation B/C studies, the examples provided in this article indicate that there is growing consensus on valuation methods available for evaluating both transportation and non-transportation projects and programs. Guidance on the application of benefit/cost analysis by transportation agencies is generally consistent in recognizing the legitimacy of external impacts associated with environmental, safety and economic development effects in addition to traveler time and cost benefits.

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