MAJOR INVESTMENT ANALYSIS FOR MULTIMODAL PROJECTS IN URBAN CORRIDORS:
PHASE I REPORT

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16. ABSTRACT

Recent legislative and regulatory actions require major investment analyses of transportation projects prior to construction. These analyses must respect the intermodal consequences of proposed actions. The most commonly applied transportation investment analysis methods apply to specific modes and funding circumstances. The lack of a comprehensive investment evaluation methodology impedes advancement of intermodal and multi-modal transportation system development. Benefit-cost analysis may offer the best opportunity for fairly assessing the investment worthiness of transportation projects with multi- and intermodal impacts. Initial investigation of the feasibility of the benefit-cost approach finds it superior to the two most popular current methods, the Federal Transit Administration's cost effectiveness index, and the American Association of State Highway and Transportation Officials' user benefit analysis. Major technical hurdles to implementation of benefit-cost analysis are modal limitations in travel forecasting and development of cost factors for environmental impacts. A subsequent phase of this study will compare the benefit-cost approach to other methods by applying the various techniques to five transportation alternatives in the Oklahoma City region.

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EXECUTIVE SUMMARY

Recent legislation and regulations require transportation planning agencies to undertake studies of investment worthiness prior to committing funds to major urban transportation infrastructure projects. Traditionally, investment studies have been specific to modes and funding circumstance. The lack of a standardized evaluation methodology applicable to all modes and sensitive to a wide range of costs and benefits has hampered multimodal planning. This report describes alternative techniques for conducting major investment studies of urban transportation projects involving different and/or competing modes.

The research project under which this report has been prepared consists of two phases. This report documents Phase I, which summarizes findings on four topics:

1. basis for making transportation investments;
2. methods of transportation investment analysis;
3. data required for multimodal transportation investment studies; and
4. methods for forecasting multimodal travel.

Phase II of the project applies the different forecasting methods to mixed mode projects in the Oklahoma City region. The purpose of Phase II is to determine:

or more performance measures.

Many factors influence government's view of the merits of a transportation investment. These factors include sources of financing, the level of the government, and the impacts of the project on the government's constituents. A municipal government would not consider travel time savings to the interstate trucker a benefit, since few if any of the benefits would accrue locally. Nor would the national government consider business closures due to construction of a by-pass highway a cost, since the losses would be offset by gains elsewhere. Local government views a competitively awarded grant as a benefit, since local construction jobs would be created. Nationally, a competitively awarded grants is a transfer payment, since the net change in jobs nationally is zero. Formula grants are not viewed locally in the same way as competitive grants. With formula grants, the investment issue is where to spend the money, not whether to spend it.

There are four widely applied evaluation techniques in the U.S. One is the user benefit analysis described in a American Association of State Highway and Transportation Official's 1977 manual. This method is a limited form of benefit-cost analysis. The second method is the Federal Transit Administration's major investment index, which seeks to minimize the average cost per new rider attracted to transit. The third method is cost effectiveness analysis, where the goal is to optimize some performance measure per unit of cost. Examples include maximizing person-hours of travel per dollar of expenditure, or minimizing delays. The fourth method is actually a process which varies by state. Each state prepares an annual program of capital improvements, termed the Section 105 program, and various levels and types of analyses may be applied to projects in the course of the program's preparation.

None of the evaluation methods is fair to all modes. The AASHTO and FTA methods are particularly unfair to projects whose benefits accrue principally to commercial traffic. Although the AASHTO method makes allowance for truck traffic, it does not address commercial travel in passenger cars. The FTA method considers only the direct beneficiaries of investments, ignoring indirect benefits such as reductions in congestion and accidents. Cost effectiveness analysis relies on a single performance measure, and no non-monetary performance measure has yet been devised which recognizes the differential economic impacts of the various modes. There has been experimentation with multicriteria and weighting techniques to make cost effectiveness studies more comprehensive, but in so doing the methods begin to take on the characteristics of the benefit-cost analyses they were designed to replace.

Although benefit-cost analysis is cumbersome and arcane, it is the only method currently capable of fair mixed mode evaluations. The challenge is to make benefit-cost analysis fairer and easier to apply. This report contains several recommended improvements. Some of these improvements could be implemented immediately, whereas others will require more time to develop, test, and implement. Short-term improvements include:

1. expanding the AASHTO user benefit analysis to include non-user impacts, such as air quality and noise benefits;
2. conducting benefit-cost studies from the perspective of each affected group, including in each analysis only those costs and benefits relevant to that group;
3. preparing travel forecasts for a minimum of two forecast years in addition to a good base year inventory; and
4. conducting sensitivity tests on evaluation results to determine the impacts of input parameters.

Longer term improvements involve:

1. developing better cost estimates of non-user benefits;

2. separately forecasting commercial and private travel;
3. better methods for forecasting local and non-local truck and commercial passenger travel;
4. forecasting induced and latent travel demand; and
5. better estimates of the value of travel time.

Many of the recommended improvements concern travel forecasting. Phase I demonstrates a number of methods which can be used to isolate commercial traffic from non-commercial travel. These techniques must be regarded as interim measures. Factors influencing commercial mode and route choice are significantly different than those affecting private passenger travel, but, for the most part, have been ignored in practice.

A comprehensive, financially based, benefit-cost analysis, along with the AASHTO and FTA techniques, will be applied to several investment alternatives in the Oklahoma City region in Phase II. The investment alternatives involve multiple modes, many intermodal impacts, and various funding scenarios. Phase II will use the principles, cost parameters, and travel forecasting results developed in Phase I. Investment worthiness using the different approaches will demonstrate the extent to which project selection is influenced by choice of evaluation technique.

CHAPTER 1

Theoretical Basis for Mixed Mode Project Evaluations

The federal, state, and local governments in the U.S. are all active partners in the planning, design, and construction of urban transportation projects. Typical of advanced economies, government forums rather than unregulated private markets guide the allocation of infrastructure investments. Two characteristics of urban transportation systems make this necessary:

1. Transportation systems have large economies of scale. Regulating competition among modes and carriers keeps unit costs low.
2. Transportation systems have large positive and negative externalities. Since the actions of one operator or jurisdiction have consequences for others, governments have created institutional mechanisms to assure a fair sharing of costs and benefits.

How these characteristics influence evaluators varies according to two additional factors: the source of money for the improvement, and the level of government conducting the evaluation.

LOCAL PERSPECTIVE ON THE BENEFITS OF URBAN TRANSPORTATION INVESTMENTS

State and local governments (hereinafter, local government) compete for economic and social development. This competition takes many forms, such as incentives to attract and retain export oriented employers, trade shows, raiding professional sports franchises, and pursuing federal urban transportation grants. By investing in transportation infrastructure, local government seeks to improve its competitive position.

In economic terms, local government seeks to increase local utility. Local utility might be measured by the total market value of all local real estate, on the premise that property values fully capitalize all the positive and negative features of a community. Since it is difficult to estimate property values, or predict their change in response to a transportation system improvement, an alternate measure is often used, regional disposable personal income (*RDPY*). Economists adjust *RDPY* for positive and negative local attributes such as air pollution, crime, quality of schools, climate, cultural amenities, noise, congestion. Regional utility increases with increases in local resident income and/or positive local attributes, as well as reductions in negative local attributes.

Eq. (1) is the regional macroeconomic accounting identity.

$$GRP \equiv C+I+G+X-M \tag{1}$$

where

GRP = gross regional product, the value of the final goods and services produced in a region

C = consumption, or regional retail purchases by residents of the region

I = private investment in plant, land, equipment, and infrastructure

G = government purchases from within the region

X = sales by regional businesses and residents to residents of other regions

M = purchases made by businesses and residents of the region of goods and services produced in other regions

GRP has a direct relationship with *RDPY* as shown in Eq. (2). Together, Eq.s (1) and (2) illustrate four views of the investment worthiness of urban transportation projects, depending on project financing.

$$RDPY = GRP-A-T \tag{2}$$

where

$RPDY$ = regional personal disposable income

A = business and personal taxes, undistributed corporate profits

T = government transfer payments and interest

Locally Financed from General Tax Revenues

Local government would use its own locally collected funds to make an investment in its transportation system, in order to increase local utility, if four tests are met:

1. the project is financially feasible;
2. the gain in local utility exceeds the project's real costs;
3. the accounting includes all relevant project effects; and
4. there are no other investments with an even greater positive impact on local utility.

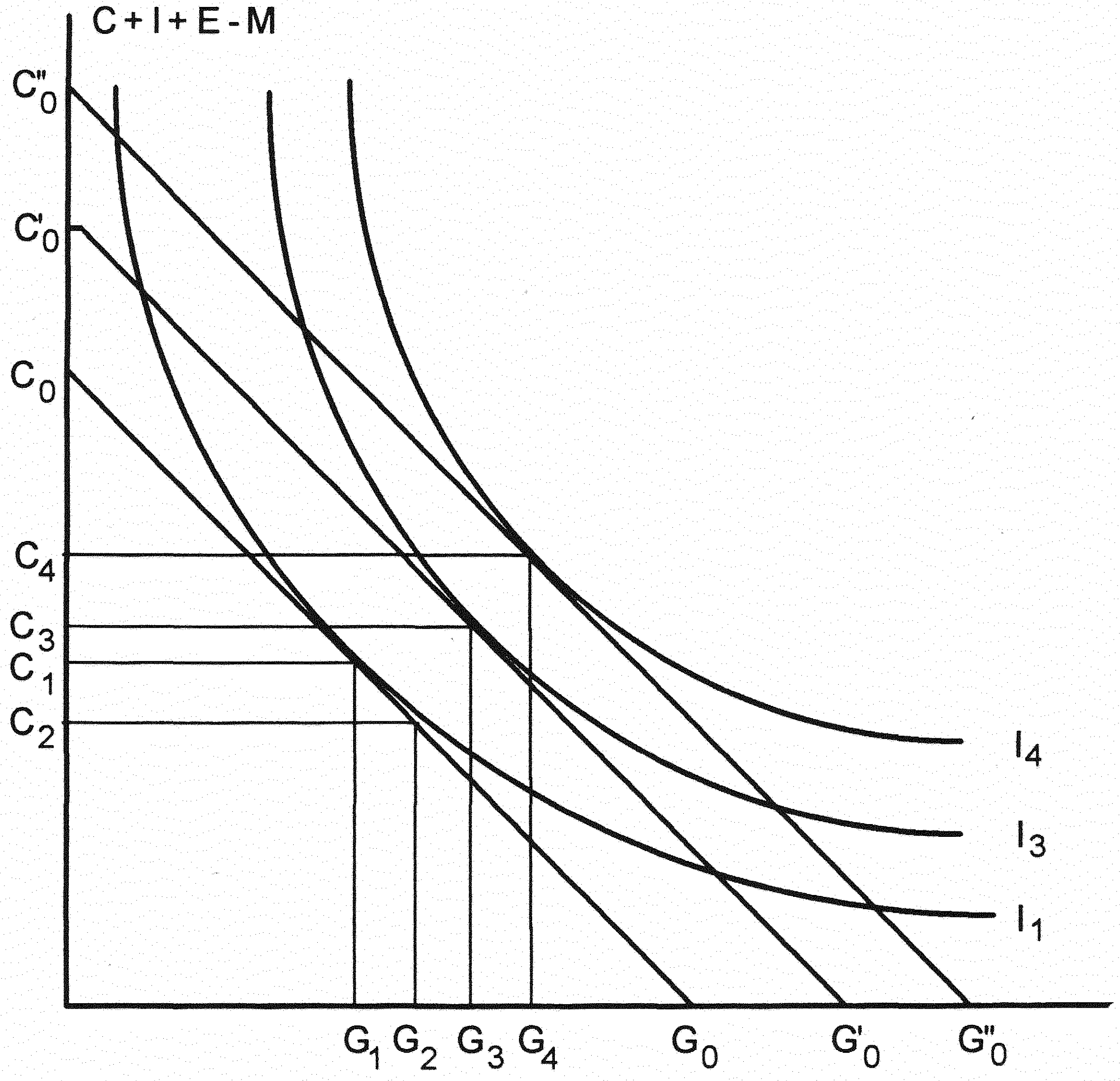
Projects financed through local mechanisms include those funded from general obligation bonds and property taxes. Condition one, financial feasibility, means the region has the resources to construct the improvement.

Condition two refers to the closed system presented in Eq. (1). A public improvement financed with locally collected money must be at the expense of other regional accounts, and as such are transfer payments. The only real project costs are those associated with arranging the transfer, termed *transaction costs*, which represent real efficiency losses.

Figure 1.1 illustrates the process of economic expansion resulting from a transportation improvement. The figure splits the regional economy into two components. The y-axis shows expenditures for consumption (C), investment (I), exports (E), and imports (M). The x-axis shows government expenditures (G). The budget lines, C_0G_0, show the possible allocations of GNP to each of the two sectors. Prior to the transportation investment, the economy is in equilibrium at C_1 and G_1, where the regional utility curve, I_1, is just tangent to the budget constraint. If no transportation investment is made, the economy grows over time to C_3 and G_3. The transportation investment requires a diversion of funds from the private sector to government, and in the short run results in a suboptimal allocation of *RDPY*, C_2 and G_2. However, in the long run the investment leads to C_4 and G_4, which yields higher levels of government and private spending and utility than the do nothing option at C_3 and G_3. The benefit of the improvement equals the higher levels of expenditure resulting from the transportation investment, the quantity $[(C_4 - C_3) + (G_4 - G_3)]$. The investment is warranted if the transaction costs are less than the benefit obtained from the improvement.

Figure 1.1

Budget Constraint and Utility



This simplified presentation masks two important details. First, GNP growth occurs over time rather than instantaneously as depicted in Figure 1.1. A more realistic representation would include a third axis, time. With the third axis, economic growth would be seen to occur at different rates with and without the impovement. While people's willingness to defer current consumption in order to realize a higher level of future consumption is implicit in the model, the actual mechanics of calculating this willingness are problematic. Second, the people who bear the transaction costs may be different from those who enjoy the benefits. Although irrelevant to the efficiency criterion, the winners and losers issue is often the most controversial element of a proposed improvement.

Investing in urban transportation projects can increase local utility by reducing the cost of doing business. A successful transportation investment can initiate a cycle whereby businesses in the city find themselves earning extraordinary profits. These excess profits allow export firms to lower their prices and expand their markets, which, in turn, leads to higher incomes and consumption and investment. In terms of Eq. (2), local government increases *RDPY* by increasing government transfer payments less than the increase in *GRP*.

Condition three requires that the determination of utility change recognize all relevant effects. Relevant effects are the direct and indirect benefits conveyed to and costs imposed on a region. While direct effects, such as travel time savings and accident reduction, are commonly considered in evaluation studies, there is less attention given to indirect effects. If a transportation investment lead to higher health care costs due to increases in automobile emissions, the incremental cost should be deducted from the gross change in local utility. Similarly, a state government decision to cease subsidizing a short-haul railroad may reduce expenditures less than anticipated if increased maintenance on highways is required due to additional truck traffic.

There are also many locally irrelevant effects. If construction of a new freeway saves interstate truckers ten minutes per trip through a town, the benefit conveyed to the trucker is irrelevant to local government since it does not affect local utility. However, the truck may impose disbenefits on the community which are not born by the trucker, such as higher levels of noise and vibration. This indirect effect would clearly be relevant to local government.

It is usually impractical to calculate project benefits from aggregate measures such as *RDPY*. Transportation projects are frequently too small to have a measurable impact on *RDPY*. Or, some impacts do not have market prices, as is the case with noise impacts. Or, forecasting capabilities are inadequate for the precision required, which might occur if there is a very long lag between effecting an improvement and realizing an increase in *RDPY*. Local government instead estimates the utility effect by determining the amount local residents would be willing to pay for the individual benefits of a project, net of additional disbenefits. If this summation is positive and exceeds transaction and opportunity costs, and the utility gain possible through alternate investments (condition 4), the project is worthy of construction. Table 1.1 lists the benefits of locally financed urban transportation projects.

Locally Financed By User Fees

Local government may rely on user fees to pay for new facilities. In urban transportation, user fees take the form of gasoline and excise taxes, registration fees, tolls, and transit fares. User fee financing imposes on local government an administrative and fiduciary responsibility, which includes collecting fees from users, and designing, constructing, and operating the improvement.

Table 1.1

Benefits to Local Government of Locally Financed Transportation Improvements

<u>User Benefits</u>

- Savings to Local Users of the Improved Mode
- Induced Travel

<u>Non-User Benefits</u>

- Savings to Local Users of Unimproved Mode(s)
- Changes in Local Deficits and Subsidies
- Reductions in Energy Use by Local Residents
- Air Quality Improvement
- Noise Reductions

Unlike projects financed with general revenues, local government will not ordinarily be concerned with the first test, financial feasibility, unless it is acting on behalf of users. Financial feasibility is of greatest concern to those who provide the funds for construction and operation. In some cases this group will consist of motor vehicle users paying for a project through fuel taxes. In other cases this group will comprise purchasers of revenue bonds, who provide the initial capital for toll roads and bridges. For either group, financial feasibility means the expected benefits exceed the costs of the project. For purchasers of revenue bonds, benefits would be limited to bond yields, and cost would equal the money raised by the issue. For a state transportation agency evaluating financial feasibility on behalf of users, costs would refer to the capital, operating, and maintenance cost of the project.

The fourth test requires that an improvement increase local utility more than any other investment. Since some group other than the entire community is paying for the project, any increase in local utility would be an improvement from the perspective of the local government, even if the increase is less than would be the case if the same amount of money were expended on another project. Local government may try to influence a project in such a way as to further increase local utility, but would not deny any project that adds to local utility at essentially no cost to local residents.

User costs and benefits may concern local government when acting in a fiduciary role. *Private benefits and costs*, those that affect users directly and indirectly, constitute the basis for the financial feasibility test. Private benefits include savings in travel time, accident costs, and out-of-pocket expenditures. The decision to include benefits to new users in the user evaluation depends on whether financing is on a *pay-as-you-go* or *pay-as-you-use* basis. Pay-as-you-go means that the revenue needed to construct an improvement is available prior to construction, as is common with state highways financed from motor fuel taxes. In this situation, benefits to new users, essentially induced travelers, would not be relevant to existing users, who must pay for the project.

Pay-as-you-use means that money for an improvement is generated after construction, as would be the case with a toll road financed by revenue bonds. Benefits to new users would be relevant since they will help pay for the project.

Mixed Funding

Transportation improvements may involve multiple funding sources, such as joint federal-state-local funding, and a mixture of general and user fee funding. Such projects present no special theoretical problems. Affected governments, financial contributors, and users independently assess the project for investment worthiness according to their particular costs and benefits.

Local government views federally funded projects in a manner similar to projects financed entirely from local general tax revenues. Transaction costs, which include expenditures required to obtain and administer federal funds, are the only real project cost. Benefits would be the same as those listed in Table 1.1 with one notable addition, the direct and indirect effects on local utility of the portion of the federal grant expended locally. Local governments regard federal grants as windfall gains. The portion of a federal grant expended locally has a multiplier effect on *RDPY* in much the same manner as an increase in local exports. Local governments regard income increases attributable to federally funded project expenditures as benefits.

Intergovernmental Grants

The effects of transportation system improvements usually extend beyond the borders of a single political jurisdiction. In order to stimulate spending on transportation, and account for non-local benefits, the federal government provides grants to local government. Transportation grants may be awarded through a competition (discretionary) or by formula. A pure discretionary grant program allows local government to choose whether to transfer money to the government sector from other regional accounts. This would be the case when the electorate votes on a general obligation bond issue to provide local matching funds to finance a particular improvement.

If money is available on a "spend it or lose it basis" (awarded by formula), local government will not refuse a grant as long as there is any increase in local utility to be had from its expenditure. Project viability tests numbers one and four, there cannot be any other financially feasible project which generates more local utility, must be modified to say there cannot be any other financially feasible <u>transportation</u> project which generates more local utility. Furthermore, it is no longer appropriate to count transaction costs as the only real project costs, since these costs must be born in any event, unless the local government refuses all formula grant funds.

Types of Evaluations

Local government will only proceed with a transportation improvement if the project satisfactorily passes two and possibly three types of evaluations: economic efficiency, financial efficiency, and user benefit. Economic efficiency involves summing the positive and negative impacts of a project and deducting transaction costs, if any. If the result is positive, the project is economically efficient. If local government is financing the project with locally collected general revenue, the proposed improvement must meet an additional economic efficiency test: there can be no other competing investment, transportation or otherwise, which would produce a greater increase in local utility.

Financial efficiency requires that project benefits exceed costs. Costs include transaction, capital, operating and maintenance costs. Benefits vary according to the means of financing. All the benefits listed in Table 1.1, measured on a willingness-to-pay basis, figure in an assessment of projects financed from locally collected general revenues. Projects financed on a pay-as-you-go basis from user fees include only the user benefits in Table 1.1. If the project is financed on a pay-as-you-use basis, with revenue bonds or private financing providing the initial capital, the assessment must satisfy bond rating agencies and, ultimately, bond purchasers. Furthermore, the assessment must address not only the willingness-to-pay, but also the ability-to-pay.

The final test, user benefit, is a type of financial efficiency assessment. Both the Federal Transit Administration (FTA) and the American Association of State Highway and Transportation Officials (AASHTO) evaluation methodologies are forms of user benefits assessments.[1] A user benefit assessment differs from a financial efficiency test for a pay-as-you-go project in only one respect; the former excludes transaction costs. User benefit evaluations had two advantages over more comprehensive evaluation methods. First, there is intuitive appeal in determining if the main beneficiaries of a project are willing to pay for it. Second, user benefit evaluations avoid having to assign values to non-user benefits.

NATIONAL PERSPECTIVE ON THE BENEFITS OF URBAN TRANSPORTATION INVESTMENTS

The federal government seeks urban transportation projects

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[1] Federal Transit Administration, *Methods and Technical Procedures for Transit Project Planning*, Washington, D.C., 1986, and American Association of State Highway and Transportation Officials, *A Manual on User Benefit Analysis for Highway and Bus Transit Projects*, Washington, D.C., 1977.

which increase national utility more than alternate investments. Increases in national utility are computed by summing increases in local utility, calculated as discussed in the section on the local perspective, and increases in non-local utility. Gains in national utility occur through an improvement in the allocation of resources which results in an increase in Gross Domestic Product (*GDP*), similar to the local government gains depicted in Figure 1.1. Transportation projects which increase national utility by generating more benefits than they incur in transaction costs are *economically efficient.*

Gains in national utility are not the only basis for federal interest in urban transportation. Another objective is income redistribution. There are many examples:

1. New rail start money targets the largest central business districts in the largest urban areas;
2. states receive a minimum allocation of federal highway money regardless of need or contribution;
3. projects funded by name in the various surface transportation acts redistribute income on the basis of political influence; and
4. transportation infrastructure investments stimulate employment during recessions.

The efficiency and redistribution objectives conflict, mostly because the redistribution objective is not clearly articulated but is instead revealed by legislative provisions. The efficiency objective is quite clear and is widely supported by the public and private sectors. Without specific policy guidance on the redistribution objective, it is not possible to develop measures of effectiveness. Consequently, project evaluation ordinarily rests on the efficiency criterion.

National utility can be represented by national income, Y. Assuming a zero balance of payments, Eq.s (3) and (4) describe the macroeconomic assumptions from which the efficiency criterion is derived.

$$Y = Consumption + Savings + Government \tag{3}$$

$$Y = No.\,of\ Workers * Output/Worker \tag{4}$$

For incomes to rise as a result of an urban transportation improvement, ceteris paribus, national income must rise more than the transaction costs associated with transferring funds from consumption and savings to government, in terms of Eq. (3). In terms of Eq. (4), holding the number of workers constant, output per worker must rise in order for Y to increase. Output per worker is also known as labor productivity.

Labor productivity can rise in one of three ways: (1) labor, through experience and training, can become more proficient; (2) investments in plant and equipment provide labor with better tools; and (3) technological innovation makes it possible to produce the same output using fewer raw materials. The federal government views urban transportation investments in the latter two contexts. For example, improvements in urban transportation make it possible for salespersons to visit more clients in the same amount of time. Also, transportation can substitute for inventory in just-in-time production processes.

There is evidence that transportation investment does lead to productivity improvement. In a recent series of articles, David Aschauer, of Bates College,[2] and Alice Munnel of the Federal Reserve Bank of Boston,[3] reported on their research which found a correlation between infrastructure investment, including transportation, and productivity. This research was based on aggregate, national data. The ideal evaluation procedure would rank transportation investments according to their impact on national productivity and, ultimately, gross domestic product. However, the

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[2] Aschauer, David. Is public expenditure productive?, *Journal of Monetary Economics*, Vol. 24, 1989, pp. 177 - 200.

[3] Munnel, Alice, ed. *Is There Shortfall in Public Capital Investment*, Federal Reserve Bank, Boston, Massachusetts, 1990.

effect of a single urban transportation project on national productivity has yet to be documented. Consequently, for the foreseeable future, summing individual urban transportation project benefits is the only practical approach to evaluation.

A list of the national benefits of urban transportation projects appears in Table 1.2. This list is similar to the list of local benefits in Table 1.1, except that it includes both local and non-local benefits. Project costs consist of transaction expenses incurred in transferring monies from the consumption and investment sectors to the government sector in Eq. (3). Both local and national transfer costs must be included in the calculation.

The federal government does not directly construct urban transportation improvements; it provides funds to local governments. These intergovernmental transfers are awarded competitively or by formula. The revenues for these grants may come from user fees or general tax receipts. The nature of the grant program and the source of funds jointly determine the appropriate type of evaluation.

grants reduce the "spend or lose it" pressure experienced by local government with grants distributed by formula.

Although justified on economic and financial grounds, there is little to be gained by conducting formal national evaluations of projects funded with formula allocated grants, since local government will spend the grant money on any project passing a local utility test, and the grant cannot ordinarily be repatriated by the federal government. When there is competition among projects for a limited amount of money under a discretionary grant program funded from user fees, the evaluation should only consider benefits accruing to those providing the money, and set cost equal to the amount of the grant. In such a situation, the federal evaluator applies two tests. First, the project must generate more national utility than competing projects. Second, the benefits of the project accruing to those providing the money should exceed the amount of the grant. For example, benefits to highway users should exceed the amount of a grant for a fixed guideway transit project funded from highway user fees (financial efficiency test). When there are two or more financially efficient projects, the federal government should select the project which generates the greatest amount of national utility.

Chapter Two

Evaluation Methods and Indices for High Occupancy Vehicle Projects

The two most common pre-investment evaluation methods employed in urban transportation studies are user benefit analysis, developed and endorsed by the American Association of State Highway and Transportation Officials (AASHTO),[1] and new rider analysis, required by the Federal Transit Administration (FTA) for major transit investments competing for section three grants.[2] Other suggested methods include benefit-cost analysis[3] and cost effectiveness measures.[4] All of these methods could be used to evaluate high occupancy vehicle (HOV) projects.

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[1] American Association of State Highway and Transportation Officials, *op. cit.*

[2] Federal Transit Administration, *op. cit.*

[3] See, for example, Schofield, J.A. (1987), *Cost-Benefit Analysis in Urban and Regional Planning*, Unwin-Hyman, London; Mishan, E. J. (1988), *Cost-Benefit Analysis*, Unwin-Hyman, London; Gramlich, Edward M. (1981), *Benefit-Cost Analysis of Government Programs*, Prentice-Hall, Englewood Cliffs, N.J.; Wohl, Martin, and Chris Hendrickson (1984), *Transportation Investment and Pricing Principles*, John Wiley & Sons, New York; and Johnston, Robert A., and Mark A. DeLuchi (1989), Evaluation methods for rail transit projects, *Transp. Res. A*, 23:4, pp. 317 - 325.

[4] Fielding, Gordon J., Roy E. Glauthier, and Charles A. Lave (1978), Performance measures for transit management, *Transportation*, Vol. 7, pp. 365 - 379.

federal money. The state money may come from gas tax revenues or special appropriations. Federal money may come from either the Federal Highway Administration (FHWA) through a formula grant program, or from the Federal Transit Administration (FTA) through a competitive grant.

AASHTO USER BENEFIT ANALYSIS

The Stanford Research Institute developed the AASHTO methodology, a form of cost-benefit analysis, in the early 1970s.[5] The method does not distinguish between local and national perspectives, nor vary by source of funds, as was suggested might be appropriate in Chapter 1. The AASHTO method defines costs to include capital, operating, and maintenance costs. Benefits are reductions in operating and travel costs to owners, passengers, and drivers of highway motor vehicles. The AASHTO method only considers highway user impacts: it excludes community impacts. AASHTO recommends that planners incorporate the results of the user benefit analysis into a "composite" evaluation process using non-economic methods such as cost-effectiveness or scoring techniques.[6]

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[5] AASHTO, *op. cit.*

[6] *ibid.*, p. 3.

The AASHTO method applies to virtually any type of highway improvement, including HOV projects. The method requires at least two forecasts of future patronage, generally five and fifteen years from the current year, with intermediate years interpolated. The traffic forecasts are converted into estimates of highway user costs with and without the project. The difference, calculated according to the principle of consumer surplus, is the project benefit.

Factors incorporated into the AASHTO method include the value of time, average vehicle occupancy, vehicle type, the time value of money, and salvage value. AASHTO recommends valuing travel time savings at different proportions of the local wage rate depending on the amount of travel time saved.[7]

Table 2.1 illustrates the general form of the evaluation process. The example shows two alternate projects with expected lives of 20 years, two patronage (volume) forecasts, and an inventory of existing conditions. Alternate zero is the "no build" benchmark, which represents the least expensive course of action. There are many possible definitions of the no build alternative, ranging from abandonment

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[7] *ibid.*, pp. 15 - 17.

of an existing facility to construction of committed and funded projects.[8] Project benefits are the user and operator cost savings obtained by building the project.

Figure 2.1 illustrates the calculation of benefits. The x-axis indicates the volume or patronage of the existing and proposed service. The y-axis shows the cost per trip, and includes out-of-pocket, travel time, and accident costs. For any given year, p_1 is the cost per trip at volume v_1, and p_2 is the cost per trip at volume v_2. If p_1 is the cost for a no build trip, and p_2 is the cost for the same trip after an improvement, then the *net change* in user benefit resulting from the improvement is the trapezoidal area p_1ABp_2. Pre-improvement travelers enjoy a windfall gain equal to p_1ACp_2, and new travelers benefit by the triangular area ABC. This calculation must be performed for each year over the life of the proposed improvement, discounted to present value, netted for capital cost, operator savings, and salvage values, and summed.

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[8] Lane, J. S., L. R. Grenseback, T. J. Martin, and S. C. Lockwood (1979), The no-action alternative, *National Cooperative Highway Research Program Reports 216* and *217*, Transportation Research Board, Washington, D.C. Also, see Wohl, *op. cit.*, pp. 154 - 155.

Table 2.1

AASHTO User Benefit Analysis Process

Year	No Build $B_{0,t} - C_{0,t}$	Build $B_{1,t} - C_{1,t}$	Build $B_{2,t} - C_{2,t}$	Patronage Estimate
1	$B_{0,1} - C_{0,1}$	$B_{1,1} - C_{1,1}$	$B_{2,1} - C_{2,1}$	Existing
2	$B_{0,2} - C_{0,2}$	$B_{1,2} - C_{1,2}$	$B_{2,2} - C_{2,2}$	Interpolate
.	.	.	.	.
.	.	.	.	.
5	$B_{0,5} - C_{0,5}$	$B_{1,5} - C_{1,5}$	$B_{2,5} - C_{2,5}$	Forecast
6	$B_{0,6} - C_{0,6}$	$B_{1,6} - C_{1,6}$	$B_{2,6} - C_{2,6}$	Interpolate
.	.	.	.	.
.	.	.	.	.
15	$B_{0,15} - C_{0,15}$	$B_{1,15} - C_{1,15}$	$B_{2,15} - C_{2,15}$	Forecast
.	.	.	.	.
20	$B_{0,20} - C_{0,20}$ + SV	$B_{1,20} - C_{1,20}$ + SV	$B_{2,20} - C_{2,20}$ + SV	Extrapolate

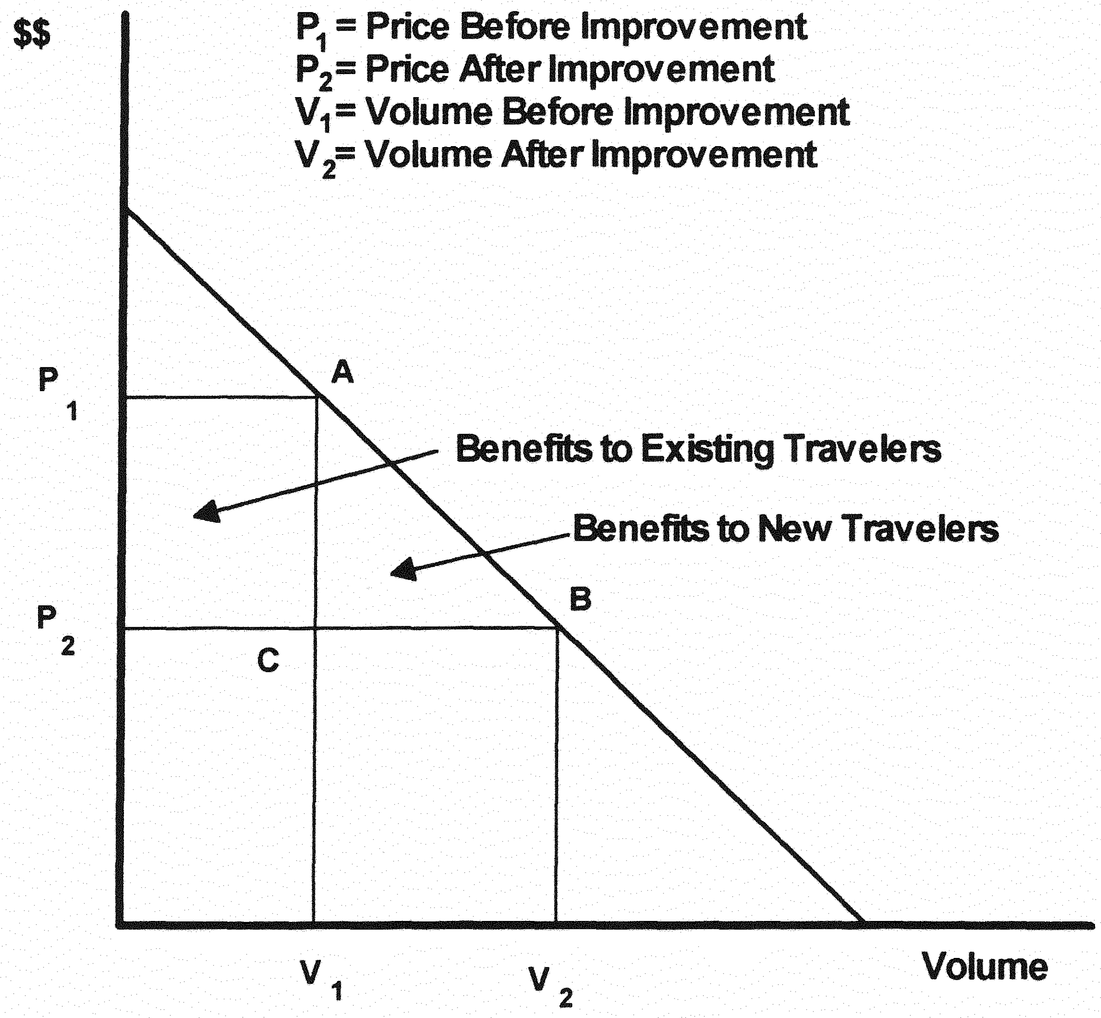
$B_{n,t}$ = Benefits of alternate "n" in year "t"

$C_{n,t}$ = Costs of alternate "n" in year "t"

S.V. = Salvage Value

Figure 2.1

Consumer surplus Model



AASHTO defines costs to include capital, maintenance, and operating expenses. Eq. (5) produces is *net present value* (NPV), which is the determinant of investment worthiness. If NPV is positive, the project produces user benefits in excess of financial costs. In the Table 2.1 example, where there are two alternatives to the no build option and no budget constraint, the project with the largest positive NPV would be most desirable.

$$NPV = \left[\sum_{i=1}^{t} (B_{n,i} - C_{n,i}) + SV_{n,t}\right] - \left[\sum_{i=1}^{t} (B_{0,i} - C_{0,i}) + SV_{0,t}\right] \qquad (5)$$

The AASHTO method has considerable appeal. It follows the principles of cost-benefit analysis, is rigorous, and avoids the most serious problems of double counting. For projects financed exclusively from user fees, evaluated from a national perspective, the AASHTO procedure meets the requirements of the financial feasibility test outlined in Chapter 1. The AASHTO method really only suffers two deficiencies. Its explicit exclusion of community impacts ignores what are often the most important factors to state and local decisionmakers. Second, the use of a single perspective for all evaluations fails to account for important transfer payments.

NEW RIDER ANALYSIS

The Federal Transit Administration (FTA) requires that urban areas competing for Section 3 grants for new system starts evaluate their projects by the average annualized cost per new rider.[9] HOV projects are eligible for these FTA funds.[10] While there are some similarities between the AASHTO user benefit analysis and FTA's new rider index (*NRI*), there are also many fundamental differences.

Where the AASHTO procedure judges investment worthiness over the life of a project, the FTA method employs a threshold of $6.00 per new rider to be achieved by the fifteenth year of operation, a figure derived from national averages and typical fixed guideway system configurations. Where several projects have *NRI*s below $6.00, the one with the lowest index would be most desirable.

Another difference in the two evaluation procedures is distinction FTA makes between local and national perspectives. Grant applicants must compute the *NRI* twice, once using total capital cost and again using only the federal

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[9] 23 *CFR* 450.316(6) and 49 *CFR* 613.316(6).

[10] Emerson, Donald J., ISTEA and HOV facilities in the United States, Proceedings, *Transportation Research Circular 409*, Transportation Research Board, Washington, D.C., June, 1993.

share of the cost.

The *NRI* recognizes two types of beneficiaries: existing transit patrons and travelers attracted to transit. Existing transit users benefit from a transit improvement in the form of travel time savings, whereas new rider benefits are measured by their number. Eq. (6) shows the manner in which benefits and costs combine to produce a single index.

$$NRI = \frac{C_{n,15} - C_{0,15} - \mathit{Benefits\ to\ Existing\ Riders}}{\mathit{Number\ of\ New\ Riders}} \tag{6}$$

The FTA evaluation procedure recognizes new rider benefits to include both new transit and new car and vanpool users. Eq.(2) favors new users over existing users, since the denominator is not normalized for trip length. Benefits not incorporated into the index include congestion, accident, noise, and user subsidy reductions as well as air quality improvements. These benefits are typically itemized in environmental impact statements but are not assigned economic value.

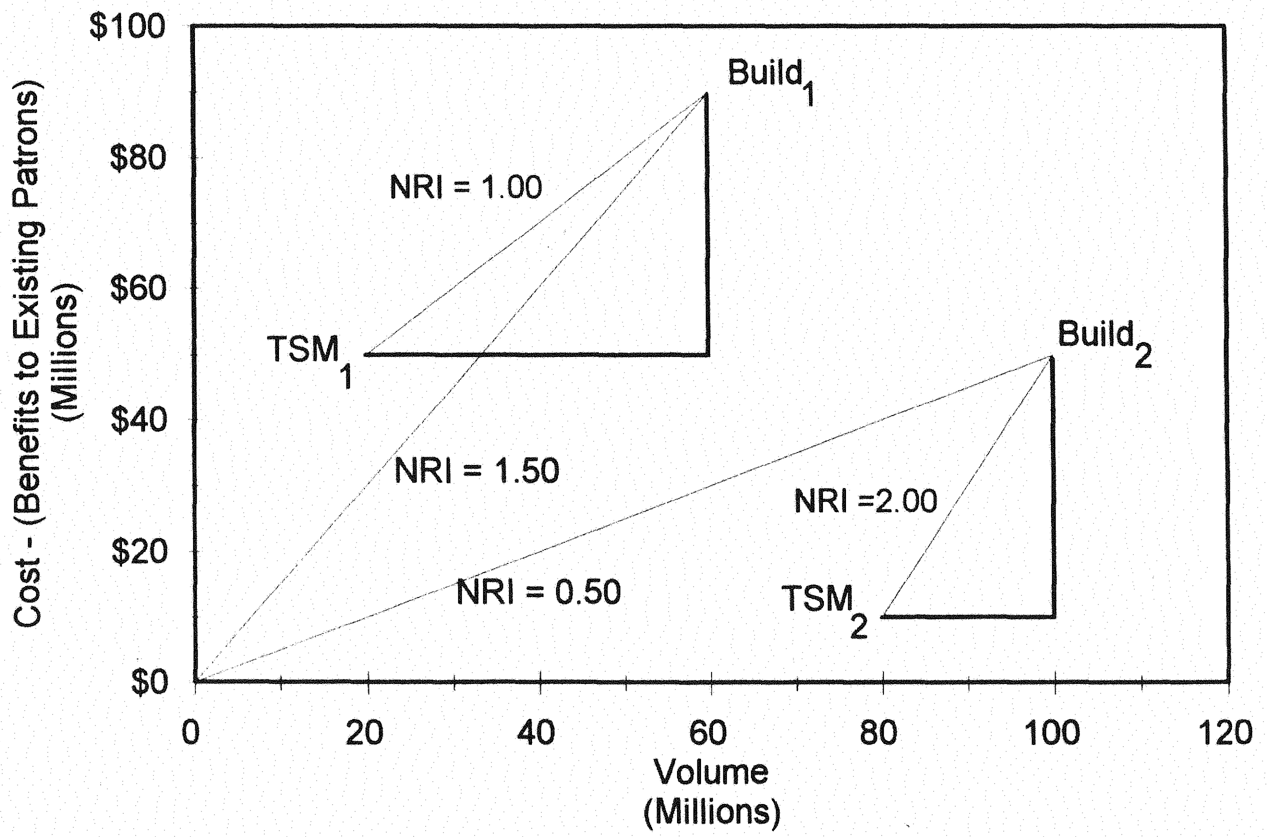
The FTA evaluation procedure uses a unique benchmark alternative for computing user benefits. Unlike the AASHTO procedure, which specifies a no build benchmark, the FTA allows for a significant improvement in transit service. The FTA benchmark, termed a transportation system management

(TSM) alternate, is the best all-bus, non-HOVway alternative. Figure 2.2 illustrates a consequence of this practice. The y-axis measures capital and operating costs minus benefits to existing patrons, and thus corresponds to the numerator in the NRI. The x-axis shows passenger volume, as in the denominator of the NRI. Projects in two cities are depicted.

The NRI is equivalent to the slope of a line from the benchmark alternative to the build alternative. With a TSM benchmark, project one has an NRI of 1.00, and project two has an NRI of 2.00. With a no build benchmark, project two is clearly superior to project one, with an NRI only one third of project one's. Current FTA practice would favor project one, though it costs more than project two and is less cost-effective according to FTA's own guidelines. Cities competing for FTA grants can portray their projects positively by developing a high cost TSM alternative.

Figure 2.2

Cost Effectiveness with TSM and No Build Benchmarks



CHARLES RIVERS ASSOCIATES REVISIONS

In a 1990 comprehensive review of FTA's major investment analysis procedures, the consulting firm of Charles Rivers Associates (CRA) suggested several revisions. CRA made several recommendations many of which concerned the value of diverting personal auto trips to public transportation. For example, the NRI does not acknowledge the air quality benefits of auto travelers who switch to transit. CRA estimated the cost of air pollution to be 3.2¢ per vehicle mile.[11] This estimate along with forecasts of vehicle-mile changes resulting from a proposed project makes incorporating air quality benefits in the calculation relatively easy.

CRA also recommended including accident reduction benefits accruing to travelers who divert from autos to transit. Transit travelers as a group experience fewer accidents per unit of exposure than auto travelers.[12] CRA estimated the benefit per diverted auto traveler at 18¢ to 20¢ per trip. The range reflects potential double counting, since some auto travelers know they derive an accident benefit from switching to transit. Patron fares pay in part for these benefits, and are therefore transfer payments not real

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[11] Charles Rivers Associates, Memorandum to Federal Transit Administration, Aug. 10, 1990.

[12] Charles Rivers Associates, Memorandum to Federal Transit Administration, Sept. 28, 1990.

efficiency gains. CRA recommends using 19¢ per diverted auto trip, and accepts the double counting as necessary to avoid excluding any potentially viable projects from the FTA grant competition.[13] Similar studies yielded an estimate of the lower limit of the noise benefit per diverted auto trip of 3¢.[14]

Subsidies

There are a variety of subsidies which affect modal choice. CRA recommends including three in the *NRI*: employer paid parking for employees, employer subsidized employee transit passes, and transit operating subsidies. CRA describes a method of accounting for changes in these subsidies.[15]

The FTA includes in the numerator of the *NRI* the change in operating costs between the TSM and build alternatives. CRA argues that this practice overstates the consequences of the build options. Fares paid by passengers purchase transit service, and are therefore transfer payments, not real social costs. Fares, however, appear twice in the FTA

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[13] Charles Rivers Associates, Memorandum to the Federal Transit Administration, Sept. 18, 1990.

[14] Charles Rivers Associates, Memoranda to the Federal Transit Administration, Sept. 13, 1990, and Sept. 18, 1990.

[15] Charles Rivers Associates, Memorandum to the Federal Transit Administration, July 6, 1990.

index, once in the form of operating costs, and again in the form of user benefits. To eliminate this double counting, CRA suggests including operating costs net of fares paid. This CRA recommendation is standard practice in the AASHTO procedure.[16]

It is common for employers to provide free parking to employees, or to partially offset the costs of parking. This is especially true at non-CBD worksites. When auto drivers divert to transit, savings accrue to employers in the form of additional parking capacity for customers and other uses. CRA recommends treating these savings as transit benefits. In the short term, savings in employer-paid parking subsidies might not readily convert into cash, but would instead take the form of unused real estate. Over time, however, employers will put the property into productive use.

Similarly, employers who encourage employees to use transit by subsidizing transit passes will incur additional costs as auto drivers switch to public transportation. These subsidies constitute real monetary costs to employers which should offset the benefits generated by the modal switch.

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[16] AASHTO, op. cit., p. 103.

Computational Revisions

CRA found several examples of computational practices which compromised the accuracy of the *NRI*. Prominent among these are the discounting conventions, which CRA believes overstate the attractiveness of transit projects by 10% to 20%.[17]

Current FTA practice is to compare the benefits of a transit project at some future point in time, typically fifteen years, to the capital costs expressed in current dollars. There are two problems with this procedure. First, it usually takes several years to construct a large scale transit project. The FTA procedure treats capital costs as if they were all expended in a single year. The correct procedure is to schedule capital expenditures over the likely construction period, discount them to present value, and then annualize the discounted present value of construction costs. CRA provides a table of capital recovery factors for construction periods of different durations.

Second, comparing the annualized capital costs to benefits in the fifteenth year presumes benefits are the same in each year over the life of the project. This too is

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[17] Charles Rivers Associates, Memorandum to the Federal Transit Administration, Sept. 24, 1990.

incorrect, since the benefit stream cannot begin until completion of project construction. CRA developed a chart which contains capital recovery factors for benefits depending on the duration of the construction period. For a project which takes five years to construct, CRA recommends reducing benefits in the fifteenth year by 32%, to account for a shorter period in which to recoup capital expenditures.

An important recommendation of CRA is to drop the practice of dividing benefits and costs by the number of new riders attracted by an investment.[18] CRA offered four justifications:

1. cost per new rider is too abstract a concept to be a useful measure of project merit, especially at the local level;
2. since the number of new riders is typically small compared to values in the numerator, the index is overly sensitive to small changes in forecasts;
3. the index violates the principle of keeping benefits and costs separate; and
4. the emphasis on new riders suggests that benefits to existing riders are unimportant.

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[18] Charles Rivers Associates, Memorandum to the Federal Transit Administration, Sept. 21, 1990.

The sum effect of the CRA revisions is to move the FTA evaluation procedure toward the AASHTO procedure and the financial efficiency test described in Chapter One. Major similarities between the CRA, financial efficiency test, and AASHTO techniques, which differ from FTA's *NRI*, include use of an unambiguous benefit-cost statistic (*net present value*), explicit recognition of transit deficits, valuing savings in vehicle operating costs (net of taxes), and credit for congestion and accident reduction. Common features of the CRA and financial efficiency test include accounting for air quality, noise, and parking benefits, and use of a no build benchmark. The CRA method differs from the AASHTO and financial efficiency test in two important respects. First, CRA relies on a single evaluation year whereas AASHTO and financial efficiency consider benefits and costs over the life of a project. Furthermore, AASHTO restricts the life of a project to 20 - 25 years, a limitation attributed to the inability to reliably forecast traffic beyond 20 years. CRA bases its capital recovery factors on a 45 year project life.

UNIVERSITY OF WISCONSIN - MILWAUKEE REVISIONS

A recent study by the University of Wisconsin - Milwaukee (UWM) examines techniques for measuring transit benefits, and procedures for evaluating proposed capital investments.[19] This study is noteworthy for its method of calculating benefits, the revisions proposed to the travel demand forecasting process, and its analysis of current practice.

Beimborn and Horowitz suggest calculating user benefits according to a concept they call "enhanced consumer surplus." Current practice measures the benefits of travel in terms of travel time savings multiplied by a value of time. Beimborn and Horowitz believe this only partially measures the value travelers attach to their trip. In Figure 2.1, the price of travel includes comfort and convenience as well as cash payments. Traditional practice, however, treats consumer surplus as the difference between the sum of travel times between each origin-destination pair with and without the project multiplied by a value of time. Beimborn and Horowitz argue that this method underestimates people's willingness-to-pay for the benefits obtained, since it ignores many factors which influence modal decisions. For example, a route improvement which eliminates a transfer generates real savings to travelers which should appear in the price of travel. To ameliorate this deficiency, Beimborn and Horowitz weight the components of price by factors

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[19] Beimborn, Edward and Alan Horowitz, *Measurement of Transit Benefits*, U.S. Dept. of Transp. Report WI-11-0013-1, Washington, D.C., June, 1993.

reflecting individual preferences. Table 2.2 lists the weights Beimborn and Horowitz recommend using in calculating user benefits.

Modeling capabilities will not permit determination of all the factors in Table 2.2. The fraction of time spent standing, for example, is not a normal model output. Similarly, there is no mechanism for incorporating weather conditions into a long range travel forecast for walk access patrons. However, some Table 2.2 user perception benefits can be weighted. For example, out-of-vehicle time can be aggregated and weighted by the average of out-of-vehicle weight, i.e., 1.6 times time spent out-of-vehicle.

Table 2.2

Typical Weights and Penalties For Travel Disutility

Factor	Weight
Transit Riding	1 + 2.0 (fraction of time standing)
Walking (good weather)	1.3
Waiting	1.9
Transfer (First)	1.6
Initial Wait	8.4 minutes
Transfer (2nd or 3rd)	23 minutes
Value of Time	0.167 to 0.333 of the average wage rate of choice riders

In addition to recommending the substitution of enhanced consumer surplus for the current, more limited definition, Beimborn and Horowitz make two additional suggestions. First, they take a strong stand in favor of aggregating all travel time savings, no matter how small, in order to determine consumer surplus. This position is in contrast to that of AASHTO, which recommends treating small per trip travel time savings (less than five minutes on a one-half hour trip) as either worth nothing or worth considerably less than larger travel time savings. The AASHTO position is based on surveys which indicate that travelers, especially those making work trips, allow for delays. Since small amounts of travel time savings fall within this allowance, travelers are unwilling to pay for the benefit. Beimborn and Horowitz base their argument on the notion that any time saved has economic value even if people are unwilling to pay for it. Current FTA practice calls for aggregating all time savings regardless of magnitude, but there are no technical impediments to treating different amounts of travel time savings differently. Beimborn and Horowitz's second recommendation echos the overwhelming sentiment of transportation economists that the benchmark for comparison should be the no build option rather than the TSM option currently used by FTA.

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION HOV LANE EVALUATION

Cy Ulberg, of the Washington State Transportation Center at the University of Washington, conducted an evaluation of existing HOV lanes in the Seattle area for the Washington State Department of Transportation.[20] The purposes of the study were to determine whether (1) the benefits of three HOV projects exceeded the costs of the construction and operation, and (2) alternative investments in either do nothing or adding a general purpose highway lane would produce even greater benefits per dollar of expenditure.

As with the University of Wisconsin project, Ulberg discusses at length the forecasting methodology required to predict conditions for the do nothing and add-a-mixed-lane alternatives. Ulberg reported this step to be the weakest element in the study principally due to the extent of network aggregation in the mode split analysis; Ulberg represented all the parallel arterial routes to the HOVways as single roads. An especially unique feature of Ulberg's forecasting methodology was the effort to estimate peak spreading.

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[20] Ulberg, Cy, *An Evaluation of the Cost Effectiveness of HOV Lanes*, Washington State Dept. of Transp. Report WA-RD 121.2, Olympia, WA, July 20, 1988.

Ulberg measured benefits as savings in the costs of travel time, vehicle operation, enforcement, highway maintenance, transit, accidents, and environmental impacts. Ulberg asserted that accident costs were higher in congested conditions, increasing by 13% with a drop in speed from 50 MPH to 45 MPH, a position which runs counter to CRA's finding that the relationship between congestion and accidents was unclear. Ulberg used environmental costs of 1.04¢ per mile, compared to the CRA value of 3.2¢ per mile.

The study's economic measure, marginal benefit-cost ratio, used data for the peak periods only, since the HOV lanes operated only during the peaks. The consequences of this partial analysis on the determination of project worthiness are unpredictable. Although benefits may be overstated, since off-peak travelers may experience longer travel times due to fewer travel lanes, the comparison is to total construction costs, not just those costs associated with peak period operation.

The two build options, add an HOV lane in each direction, and add a general purpose lanes in each direction, were compared to do nothing for three years, 1986, 1996, and 2006. Intermediate year costs and benefits were estimated by interpolation. The basic assumptions of the analysis are shown in Table 2.3.

Ulberg's study was important in several respects. The analysis was comprehensive in that it examined multiple modes operating in a single corridor. It also incorporated user as well as non-user costs and benefits. A sensitivity analysis conducted on the key input parameters showed that the economic efficiency finding reversed with relatively minor changes in the value of time, the discount rate, and freeway and arterial capacity.

The study does suffer from four problems. First, construction costs were not amortized over the construction period, but rather expressed as lump sum expenditures in 1986. CRA showed the consequences of this practice. Second, double counting probably occurred. For example, user payments in the form of bus fares are treated as costs even though they also appear in bus operating costs. Third, the study did not account for the effect of the projects on non-passenger traffic. Fourth, ignoring off-peak conditions makes an absolute finding of economic efficiency impossible. Any of these problems could be enough to reverse Ulberg's finding of HOV lane economic efficiency.

Table 2.3

Cost Assumptions in the Seattle Area HOV Study

Cost Parameter	Amount	Unit of Time
Parking		
Single Occupant	$ 3.71	Day
Carpool	3.00	Day
Vanpool	0	Day
Operating Cost		
Car	0.23	Mile
Van	0.42	Mile
Bus	0.31	Mile
Bus	24.83	Hour
Bus	82.17	Trip
Highway		
Maintenance	48,000	Year
Extra HOV	10,000	Year
HOV Enforcement	105,000	Year
Value of Time	7	Hour
Construction		
General	9,202,000	Year
Extra HOV	920,000	Year
Discount Rate	4.0%	Year

TEXAS TRANSPORTATION INSTITUTE HOV STUDIES

Two recent studies from the Texas Transportation Institute (TTI) concern the evaluation of HOV facilities. Turnbull, Henk, and Christiansen published a research report in 1991 titled *Suggested Procedures for Evaluating the Effectiveness of HOV Facilities.*[21] Although the guide specifically addresses the conduct of before and after studies, and does not examine issues of costs and benefits, it does provide several useful threshold values which can be used to judge whether a proposed project is likely to be economically efficient. These thresholds are listed in Table 2.4.

The National Cooperative Highway Research Program sponsored the second TTI study (NCHRP Project 7-12: Microcomputer Evaluation of Highway User Benefits). The project involved updating estimates of user, vehicle, maintenance, construction, and section costs. TTI also developed a microcomputer program to apply the 1977 AASHTO procedure using the updated cost data. The software does produce estimates of vehicle emission changes between alternatives, which was not included in the original AASHTO method. The

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[21] Turnbull, Katherine F., Russell H. Henk, and Dennis L. Christiansen, *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities*, Texas Transportation Institute Technical Report 925-2, College Station, TX, Feb. 1991.

procedure yields different indices of user benefit, including net present value, benefit-cost ratio, and the internal rate of return.

PERFORMANCE MEASURES

A final topic concerns the use of performance measures as alternatives to benefit-cost analysis. Performance measures can substitute for benefit-cost indices cost effectiveness studies. Absent a budget constraint, the most cost effective alternative is the one which can accomplish a goal at least cost. There are a large number of potential performance measures, and there is considerable disagreement on which one should drive investment decisions.

Various performance measures have been used over the years by transportation agencies to evaluate existing services and assess the potential for new service. Gordon Fielding of the University of California at Irvine has been especially active in attempting to link performance measures with decisionmaking in the transit industry. In a 1978 article, Fielding, Glauthier, and Lave[22] identified 21 possible performance measures, several of which could serve to guide investment decisions. In an expansion of this

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[22] Fielding, Gordon J., Roy E. Glauthier, and Charles A. Lave, *Transportation*, Vol. 7, 1978, pp. 365 - 379.

work,[23] Fielding refined the measures and provided computation methodologies. Table 2.5 lists some of his more general measures. Dividing Fielding's measures by cost would yield cost-effectiveness indicators, but such indices are clearly inappropriate for crossmodal comparisons, since they are all oriented toward transit service utilization.

In two other recent works, authors have explicitly attempted to develop performance measures appropriate for crossmodal comparisons. DeCorla-Souza[24] (1993) suggested a measure based on the cost of serving new trips. The method involves estimating the costs of serving trips in a region or corridor using alternative modal strategies. Costs include both social and private costs, as in benefit-cost analysis. Agencies would invest in the alternative which minimized the total cost per trip, or, the incremental cost per trip, where the increments in costs and trips are computed using a base year set of data.

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[23] Fielding, Gordon, *Managing Public Transit Strategically*, Josey-Bass, San Francisco, 1987.

[24] DeCorla-Souza, Patrick, Comparing cost effectiveness across modes, *Transportation Planning Applications*, Jerry Faris, Tallahassee, FL, Sept. 1993.

Table 2.4

Cost Effectiveness Thresholds for HOV Projects

Measure of Effectiveness	Threshold
Peak Hour/Direction Average Vehicle Occupancy	+10%
Carpoolers	+29%
Transit Patronage	+10% to +20%
Vehicle Operating Cost per Vehicle Mile	-5% to -20%
Transit On-Time Schedule Adherence	95%
HOV User Travel Time Savings	1 Min./Mile
HOV User Travel Time Savings	5 Min./Trip
Person Volume per Lane	+5% to +20%

Table 2.5

Transportation Performance Measures

Measure of Effectiveness	Source
(Revenue) Vehicle Hours per Vehicle	Fielding, 1978
(Revenue) Vehicle Miles per Vehicle	Fielding, 1978
Total Passengers per Vehicle	Fielding, 1978
Unlinked Trips per (Revenue) Vehicle Hour	Fielding, 1987
Average Cost per Additional (Work) Trip	DeCorla-Souza, 1993
Person-Miles per Minute	Wickstrom, 1993

DeCorla-Souza's index is similar to FTA's *NRI* except for its interpretation and extension to other modes. The index rests on a cost minimization objective, and contains no explicit measure of benefit. In the examples provided by DeCorla-Souza, there were two ways that an alternative might appear preferable to another; either by minimizing costs or minimizing trips. Were cost minimization the objective, policies discouraging motor vehicle use and encouraging high densities would produce desirable outcomes. The DeCorla-Souza index, by failing to identify a benefit measure, ignores the fact that people willingly trade-off travel time and cost to obtain other benefits. A better index would assess whether the exchange leads to an improvement in economic welfare.

Wickstrom[25] proposed a performance measure suitable for corridors where there are no access points. An ideal application would be a bridge. Wickstrom multiplies the volume crossing the bridge in a one minute interval (presumably peak flow) by average vehicle occupancy and the length of the section. The resulting statistic, person-miles of travel per minute, measures the efficiency of the transportation facility. Dividing Wickstrom's statistic by the cost

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[25] Wickstrom, George, Urban Transportation System Performance Measures, *Transportation Planning Methods Applications*, Jerry Faris, Tallahassee, FL, Sept. 1993.

of providing the facility would produce a measure similar to DeCorla-Souza's. The preferred alternative is the one which has the lowest cost per person. But the same criticism levied against DeCorla-Souza's index applies equally to Wickstom's; the object is not to minimize cost, but rather to maximize the difference between benefits and costs.

SUMMARY

Economists favor cost-benefit analysis as a basis for decisionmaking because it is comprehensive, unambiguous, and is based on an objective shared by all, economic efficiency. It suffers from a poor reputation among practitioners and decisionmakers due to past misuse and subtleties associated with double counting, transfer costs, and distributional impacts. However, of the indices examined, only B-C analysis has the potential to be other than partial analysis, a significant and compelling advantage. The challenge is to make the method understandable to decisionmakers, to train practitioners in its proper application, and to develop better methods of measuring the costs and benefits of alternatives.

Chapter 3

Methodology

Chapter 1 identified two potential goals for urban transportation projects: economic efficiency and income redistribution. Federal and state legislation does not clearly articulate the income redistribution goal, although spending priorities suggest redistribution influences policy. In practice project evaluation ordinarily rests on the efficiency criterion. This research project is intended to reveal the extent to which current evaluation methods accurately measure economic efficiency in a multimodal situation.

The methodology involves ranking the same set of transportation alternatives using different evaluation methods. The transportation alternatives consists of proposed highway and/or transit improvements in the Oklahoma City region. A comparison of project rankings according to the different evaluation methods will suggest the degree to which current procedures lead to different priorities even when decision-makers share the same investment objective, economic efficiency. Developing the investment indices involves measuring many different costs. This chapter, in addition to describing the important computational features of each index, provides estimates of those cost parameters.

OKLAHOMA CITY HOV PROJECT

The Oklahoma Department of Transportation conducted a systems level fixed guideway study in the Oklahoma City area in 1990 and 1991. A number of alternative corridors and technologies were considered through the Federal Transit Administration's major capital investment planning procedures.[1] Alternatives, in addition to no build and TSM, included light rail transit and HOVways. The study concluded that HOVways in two corridors (Norman and Northwest) were "cost effective" under FTA's criterion. Figure 3.1 show the Oklahoma City region and highlights the Norman and Northwest corridors.

The methodology described in this chapter will be used to suggest project priorities and investment decisions using three different evaluation indices: the FTA cost effectiveness criterion, the New Rider Index (*NRI*), AASHTO's user benefit index (*UBI*), and a comprehensive benefit-cost index, net present value (*NPV*), described in general terms in Chapter 1, and more fully detailed in this chapter. Analytically, the performance of the alternative evaluation techniques in resolving the two following questions establishes the basis for study's findings on the two central hypothe-

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[1] Federal Transit Administration, *op. cit.*, 1986.

ses:

1. Is either corridor (Norman or Northwest) economically efficient?
2. Is the choice of a priority corridor affected by the evaluation method used?

COST AND BENEFIT PARAMETERS

The FTA new rider index does not incorporate all the costs and benefits associated with proposed urban transportation projects; only transit and HOV user and operator benefits - count. Indeed, not all benefits to transit users figure into the index. For example, auto drivers and passengers who switch to transit benefit from reduced accident exposure, yet the *NRI* ignores these benefits.

The comprehensive assessment methodology described in Chapter 1 includes the cost factors and parameters listed in Table 3.1. The dollar figures reported reflect 1989 - 1990 values. These are the unit costs which will be used to compute the *UBI* and *NPV*. The *NRI* will continue to rely on FTA prescribed values.

Figure 3.1

Oklahoma City Fixed Guideway Study Corridors

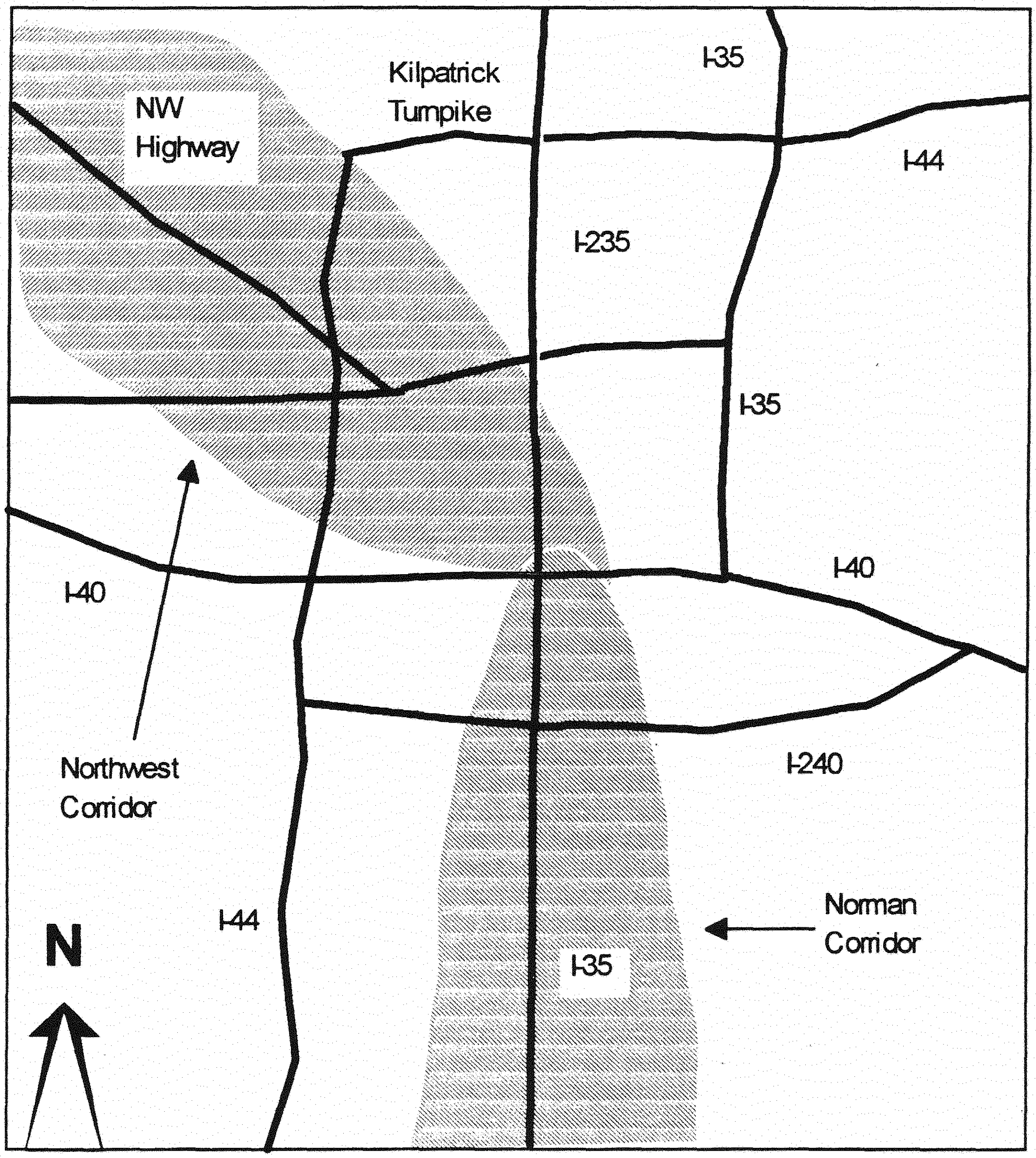

Table 3.1

Benefit and Cost Measures

Benefit/Cost Category	Benefit/Cost Measure	Cost Parameter	Source/Calculation
Existing User Benefits			
Transit	Travel Time Savings	$5.25/hr. for work trips; $2.63 for non-work trips	AASHTO Red Book and FTA Planning Guidelines; PUMS; NRI values = $4.00/hr. work trips, $2.00/hr. non-work trips
HOV	Travel Time Savings	Same as Transit	Same as Transit
	Veh. Operating Cost	$0.25/mile	Derived from FHWA's Costs of Owning and Operating Automobiles and Vans: 1984 (see Table 2)
Auto Drive Alone	Travel Time Savings	Same as Transit Users	Same as Transit Users
	Veh. Operating Cost	$0.25/mile	Same as HOV
Single Unit Trucks	Operator Cost/Hour	$16.38/hr.	MicroBENCOST Manual; includes depreciation
	Veh. Operating Cost	$0.415/mile	Derived from MicroBENCOST Manual and AASHTO Red Book; net of depreciation
Combination Trucks	Operator Cost/Hour	$22.53/hr.	MicroBENCOST Manual; includes depreciation
	Veh. Operating Cost	$0.743/mile	JFA Report; net of depreciation
Benefits of Auto Travel Diversion to Transit/HOV			
Transit	Travel Time Savings	Same as Transit Users	Same as Transit Users
	Accident Savings	$0.20 per Auto Trip Diverted to Transit	CRA 9/28/90 Memo
HOV	Travel Time Savings	Same as Transit Users	Same as Transit Users
Deficit/Subsidy Savings and Costs			
Transit Op. Costs	O&M for Transit Service	Will Vary by Alternative	O&M Cost in AA Report Less No. of Annual Patrons times $0.75/patron
HOV Operating Costs	O&M for HOV Facility	$31,883/mi./yr.	From WashDOT/Ulberg Study of I-5, I-90, and I-405 in Seattle, 1988 Dollars
Auto User	Subsidized Parking	$513/yr. in CBD; $443/yr. elsewhere	J. Gattis Survey, July 1993
Transit User	Subsidized Fares	$0.00; No Subsidized Fares in Corridors	COTPA (Metro Transit)
Air Quality	Public Health	$0.032/mi./VMT Reduction	CRA Memo (8/10/90)
Noise	Public Health	$0.03 per auto trip diverted to transit	CRA Memo (9/13/90); Assumes a truck free environment

Table 3.1 (cond.)

List of Acronyms

AA Report: Parsons, Brinckerhoff, Quade,& Douglas, *Oklahoma Fixed Guideway Transportation System Study: Oklahoma City Urban Area Phase II - Final Report*, Oklahoma City, 1992.

AASHTO Red Book: American Association of State Highway and Transportation Officials, *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements*, Washington, D.C., 1977.

Buffington & McFarland: Buffington, Jesse L., and William F. McFarland, *Benefit/Cost Analysis: Updated Unit Costs and Procedures*, Report 202-2, Texas Transportation Institute, 1975.

COTPA: Central Oklahoma Transportation and Parking Authority (now called Metro Transit), the transit operator for the Oklahoma City region.

CRA: Charles Rivers Associates, Cambridge, Massachusetts. Reference is to a series of unpublished memoranda produced for the Federal Transit Administration suggesting revisions to FTA's cost effectiveness index. Nine memoranda were prepared, dated 7/6/90, 8/10/90, 9/13/90, 9/21/90, 9/24/90 (2), 9/28/90 (2), and 11/15/90.

Table 3.1 (cond.)

List of Acronyms

FTA Planning Guidelines: Federal Transit Administration, *Procedures and Technical Methods for Transit Project Planning*, Washington, D.C., 1986.

HOV: High Occupancy Vehicle

JFA Report: *The Effect of Size and Weight Limits on Truck Costs*, Jack Faucett Associates, Report No. JACKFAU-91-352-1, Appendix A, Bethesda, MD., 1991.

J. Gattis Survey: A survey of parking costs in selected portions of the Oklahoma City metropolitan area, conducted by Dr. James Gattis, Department of Civil Engineering, University of Arkansas (formerly with the University of Oklahoma).

MicroBENCOST Manual: Unpublished Draft of a manual which updates and automates AASHTO's Red Book procedure. Prepared by W.F. McFarland, Texas Transportation Institute, 1993.

O&M: Operating and maintenance costs.

PUMS: Public Users Microdata Sample, 1990 Census, U.S. Census Bureau, Washington, D.C., 1994.

WashDOT/Ulberg Study: Ulberg, Cy, *An Evaluation of the Cost Effectiveness of HOV Lanes: Technical Report*, Report WA-RD 121.2, Washington State Department of Transportation, Olympia, 1988.

User Benefits

Benefits accrue to travelers in the form of savings in travel time and vehicle operating and accident costs. The rate at which these savings accrue depends on whether the traveler engages in personal or paid travel. Accident cost savings arise with a switch from auto travel to transit. Vehicle operating expenses, net of taxes, may include out-of-pocket and fixed ownership costs.

Travel Time Values

There has been extensive research on the value of travel time savings. Bradley and Gunn[2] provide a good summary of past work on personal travel time values. Historically, most studies of travel time values employed the revealed preference technique, in which researchers observed the choices made by travelers when confronted with two possible routes between an origin and destination, one free and one with a toll. This technique revealed that travelers choose higher out-of-pocket travel expenditures in order to save time as incomes increase. Subsequent elaborations on these studies conducted in association with AASHTO suggested that

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[2] Bradley, Mark A. and Hugh F. Gunn. Stated preference analysis of values of time in the Netherlands, *Transportation Research Record 1285*, 1990, pp. 78 - 88.

time values also vary with trip purpose and the amount of time saved.[3] For example, travelers appear to value home-to-work trips with time savings between five and 15 minutes five times higher than time savings less than five minutes. Non-work trips had lower across-the-board values than work trips. AASHTO recommended valuing travel time savings differently depending on the extent of the savings and trip purpose, arguing that people are unwilling to pay as much for small time savings.

As noted in Chapter 2, Beimborn and Horowitz take exception to valuing larger time savings at a higher rate than savings of less than five minutes.[4] TTI also abandoned AASHTO's practice in its recent project to automate the AASHTO evaluation procedure.[5] Valuing personal travel time at a fixed percentage of the average wage rate eliminates the need to categorize time savings for each origin-destination pair, a major computational simplification. FTA recommends valuing work trips twice the amount of non-work trips, but does not require stratification by the amount of

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[3] AASHTO, *op. cit.*, 1977, pp. 15 - 20.

[4] Beimborn, Edward, and Alan J. Horowitz, *op. cit.*, 1993, pp. 79 - 80.

[5] *MicroBENCOST User Manual: Draft*, Texas Transportation Institute, Oct. 1993, p. A-8. Confirmed with author Frank McFarland, January 1994.

time saved.[6]

As opposed to revealed preferences, Bradley and Gunn[7] use stated preference techniques to value time. Bradley and Gunn presented travelers with a series of hypothetical situations in which they had to choose between travel time savings and a variety of other goods. Although the researchers generally confirm earlier findings that values of time vary by trip purpose, amount of time saved, and the income of the traveler, they also conclude that people value time at consistently higher rates than indicated by the revealed preference methodology.

Thus, different research methods indicate different values of time, although the same factors appear influential regardless of technique. This project does not require an exact specification of time value since study objectives concern the relative effect of different evaluation methodologies and not a final determination of investment worthiness. However, in practice, an inexact measure can influence results, since travel time savings are often the largest benefit of a transportation investment.

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[6] Federal Transit Administration, *op. cit.*, p. II.6.14.

[7] Bradley, Mark A. and Hugh F. Gunn, op. cit., pp. 78 - 88.

Passenger Vehicle Operating Costs

Savings in passenger vehicle operating costs result from more direct routing. These savings are the product of a reduction in vehicle-miles-of-travel (VMT) and the cost per mile of vehicle operation. Vehicle operating costs consist of fixed and variable costs. To include fixed costs in vehicle operating costs in an investment analysis depends on whether the analysis is short or long range.

Fixed costs include license fees, insurance, and depreciation, all of which accrue whether the vehicle is in use or not. Variable costs are those expenses which arise only during vehicle operation, and include fuel, tires, and maintenance. In the short run, drivers consider only variable costs when making mode choices, causing travel by passenger vehicle to appear comparatively inexpensive.

In the long run, people can avoid fixed costs by not purchasing automobiles and traveling instead by transit or HOV. They can also make location choices which render auto use less necessary. Most major investment decisions constitute long run analysis; capacity is not fixed. Since the case study concerns major investment alternatives, which is inherently long run analysis, passenger vehicle operating costs should and do include fixed costs.

Several estimates of these vehicle operating costs are available. TTI provides estimates in its MicroBENCOST manual[8] of costs broken down by type of vehicle (small passenger car, medium/large passenger car, pickup and van). This is a useful structure but does require travel demand forecasts by vehicle type. Another source of similar data is the Federal Highway Administration's 1984 publication, *Costs of Owning and Operating Automobiles and Vans*.[9] As with the TTI values, FHWA reports costs by vehicle type, ranging from subcompact automobiles to passenger vans.

Drawing upon the FHWA report, and similar estimates produced by Hertz Corporation and the American Automobile Association, Ulberg developed a composite estimate of passenger vehicle operating costs under normal commuting conditions for his evaluation of HOV lanes in the Seattle region.[10] A composite estimate for Oklahoma City using Ulberg's methodology, field observations of vehicle types in the Norman Corridor, and FHWA's 1984 cost estimates, is $0.264 per mile. The vehicle classifications and unit costs which form the basis for this estimate appear in Table 2. Unit costs exclude taxes. The composite estimate in Table

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[8] *MicroBENCOST User Manual: Draft*, p. A-8.

[9] Federal Highway Administration, May 1984.

[10] Ulberg, Cy., *op. cit.*, July, 1988, pp. 49 - 50.

3.2 is the product of the total cost for each vehicle type, the row sums, and the percent of fleet. Inflating this unit cost by the consumer price index yields the cost per mile estimate for passenger vehicles which appears in Table 3.1.

Accident Savings

As noted in Chapter 2, there is scant evidence of a relationship between traffic volume and accident incidence.[11] Transit buses, however, do have a lower accident rate than privately operated vehicles. A shift from private passenger vehicles to transit would yield accident savings. Charles Rivers Associates (CRA) estimated these savings to be $0.20 per person-trip shifted to transit.[12] These savings arise from avoidance of property damage, personal injury, and fatalities.

Commercial Vehicle Operating Costs

Unlike travel for personal purposes, commercial travel directly affects the price level of goods and services. Transportation improvements which reduce travel time can make commerce more efficient thereby leading to lower prices

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[11] Charles Rivers Associates, Sept. 28, 1990, pp. 9 - 12.

[12] Charles Rivers Associates, _ibid_.

on goods and services. The *substitution effect* predicts that reductions in transportation costs lead to increased commercial travel.[13] Yet, capturing this basic relationship lies beyond the capabilities of the current generation of travel demand models. Current practice utilizes a trip table developed from a single land use plan to estimate total travel in a future horizon year[14] regardless of whether transportation costs differ between alternatives. Even when a study employs alternative land use plans, origins and destinations still reflect historic trip length distributions.

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[13] Heilbrun, James, *Urban Economics and Public Policy*, St. Martin's Press, 1987, pp. 99 - 100.

[14] See Beimborn and Horowitz (1993), pp. 71-76, for a good discussion of the paradox which results from use of the same trip table for assessment of multimodal projects.

Table 3.2

Vehicle Operating and Ownership Costs: Oklahoma City

		Unit Costs (1984 cents per mile)[a]					
Vehicle Type	Percent of Fleet[b]	Depreciation	Maintenance	Gas & Oil[c]	Parking/Tolls	Insurance	Total
Subcompact	11.5	5.9	5.1	4.4	0.9	5.0	21.3
Compact	22.4	7.3	4.6	4.6	0.9	4.3	21.7
Intermediate	33.7	8.6	5.2	5.7	0.9	5.6	26.0
Large	18.2	9.6	6.0	7.0	0.9	4.9	28.4
Vans/Pickups	14.2	10.7	6.9	9.1	0.9	8.9	36.5
Weighted Average						Weighted Average =	26.4

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[a] Unit costs are taken from the Federal Highway Administration Report: Cost of Owning and Operating Automobiles and Vans: 1984.

[b] Field observation, I-35 at the Robinson Street Interchange, April, 1994.

[c] Excludes state and federal taxes.

Existing travel simulation systems predict two counter-intuitive commercial traffic outcomes from a reduction in congestion: vehicle-hours-of-travel (VHT) and vehicle-miles-of-travel (VMT) will both decrease. Most likely VHT and VMT would increase with a reduction in congestion as business substitutes transportation for other factors of production. Nevertheless, given the limitations of current travel modeling systems, model predicted VMT and VHT reductions continue to serve as approximations of the benefits to commercial traffic resulting from transportation improvements. The value of these savings should equal the costs <u>not</u> incurred by commercial vehicle operations. Labor costs in particular should reflect actual wage rates. Benefit estimated in this manner are conservative, even when valuing VMT and VHT reductions at the full cost to the operator, since there is no allowance for induced travel or higher labor productivity.

Commercial traffic has two components: passenger travel and freight transport. Passenger travel includes taxis and persons traveling on business. Freight transport involves both labor and merchandise. Each must be valued differently. Passenger travel values equal the locally prevailing wage times the number of travelers plus vehicle operating costs times the number of vehicles. Freight transport typically employs trucks which have higher operating costs than passenger cars and have well known driver wage rates. Urban trip generation models comingle commercial traffic with four other trip purposes: non-home-based, truck, internal-external, and external-external. Non-home-based, internal-external, and external-external trip purposes all include commercial passenger car travel. Truck trips refer almost totally to local delivery vehicles, which are typically intermediate size trucks. Internal-external and external-external both contain large, interstate type trucks. An accurate assessment of the benefits of transportation improvements must address each vehicle type separately. Table 3.3 contains estimates of the proportion of each trip purpose by vehicle type in the Oklahoma City region. Source data for these estimates include the state's annual traffic survey, the 1964 Oklahoma City origin-destination home interview data, and interviews of travelers on Oklahoma turnpikes.

Converting the number of vehicles affected by a transportation improvement into estimates of changes in costs requires unit cost data broken down by vehicle type. Four sources provide estimates of these costs. Two of the sources have already been described: FHWA's *Costs of Owning and Operating Automobiles and Vans: 1984*, and TTI's *Micro-BENCOST Users Manual: Draft*. Jack Faucett Associates prepared the third source for the Federal Highway Administration, titled *The Effect of Size and Weight Limits on Truck Costs: Working Paper.*[15] This report describes variable and fixed costs for various types of combination trucks. A fourth source was the proprietary Truck Cost Analysis Model (*TCAM*), developed by Reebie Associates of Cambridge, Massachusetts. This model provides detailed data by type of truck, locality of operation, and includes driver wages. Since the *TCAM* model is proprietary, it is not used in this analysis.

Table 3.4 contains the unit cost estimates used in this study. These values also appear in Table 3.1 in essentially the same form. The values reported have been adjusted by the consumer price index to obtain equivalent 1990 costs. Since the TTI data on labor rates for different vehicle types also includes vehicle depreciation, the cost per mile excludes this factor to avoid double counting.

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[15] Report #JACKFAU-91-352-1, Bethesda, Maryland, October, 1991.

Table 3.3

Type of Vehicle by Trip Purpose

	Proportion (%)					
	Car, Van, Pickup		Single Unit Trucks		Combination Trucks	
Trip Purpose	Private	Comm.	Private	Comm.	Private	Comm.
Non-Home Based	75	25	0	0	0	0
Truck	0	0	0	85	0	15
Internal-External	50	15	0	25	0	10
External-External	50	10	0	10	0	30

Sources: Estimates prepared by author from: <u>Monthly Report to Bondholders</u>, Oklahoma Turnpike Authority, Oklahoma City, years 1988 through 1990; Oklahoma Turnpike Authority, <u>May 1988 Turnpike Driver Survey: Preliminary Data</u>; Oklahoma Department of Transportation, <u>Oklahoma 1991 Traffic Characteristics</u>.

Table 3.4

Commercial Driver and Vehicle Cost by Vehicle Type

Vehicle Type	Operating Cost (cents per mile)		Operating Cost (dollars per hour)	
	Labor	Vehicle[a]	Labor[a]	Vehicle
Passenger Car/Van	NA	17.92[b]	9.75[c]	NA
Single Unit Truck	NA	41.57[d]	15.01[c]	NA
Combination Truck	34.56[e]	74.27[e]	22.53[c]	NA

Notes: NA = not available. [a]Labor costs include vehicle depreciation and is excluded from the cost per mile data to avoid double counting.

Sources: [b]Federal Highway Administration, *Cost of Owning and Operating Automobiles and Vans: 1984*. [c]Texas Transportation Institute, *Draft MicroBENCOST Users Guide, 1993*. [d]Values obtained by combining data from TTI's *MicroBENCOST Users Guide*, and the American Association of State Highway and Transportation Official's *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements*, 1977. [e]Jack Faucett Associates, *The Effect of Size and Weight Limits on Truck Costs: Working Paper*, Report #JACKFAU-91-352-1, October, 1991.

Annualization Factors

Travel simulation models produce estimates of modal utilization on a typical weekday. A fair evaluation requires that costs and benefits appear in constant dollars. This study requires conversion of weekday traffic volumes and patronage to annual benefit and cost amounts prior to discounting to present value. If modal utilization was uniform for all days in a year, multiplying values for a typical day by 365 would yield annual equivalents. However, demand fluctuates from day to day and month to month. Furthermore, the extent of these fluctuations varies by trip purpose. Consequently, converting typical daily travel volumes into annual equivalents requires individual *annualization factors* for different trip purposes.

Table 3.5 shows the annualization factors used in this study. The number of weekdays in a year less six holidays yields the work trip annualization factor. Although there are more than six holidays during the year, businesses are open on many of them. The home-based-other trip purpose contains four subcategories: shopping, personal business, social-recreational, and school. For all purposes except school trips, weekend traffic volume and transit patronage are approximately half of the weekday volumes. Summing 255 workdays and half of the weekend and holiday trips (110/2) yields 310. The State regulates the number of school days, which on average amount to 172 days per year. Home interview data indicates that school trips constitute 14% of the home-based-other category.[16] A weighted average of the 310 days at 86% and 172 days at 14% yields 290. All other private travel is annualized at 310 days per year. These factors are considerably lower than generally permitted by FTA.[17]

Commercial traffic follows a different pattern. Although there is considerable business activity on weekends, much of it is retailing. The literature provides no basis for estimating the extent of weekend retail business related travel, but it is probably modest. Most commercial travel, that associated with government, finance, and manufacturing, occurs during the week with little weekend activity, and would thus have the same annualization factor as private work trips. This is the factor appearing in Table 3.5, and used in this project. This factor understates the total extent of commercial travel since retailing is not considered.

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[16] *Oklahoma City Area Regional Transportation Study: 2005 Plan*, Association of Central Oklahoma Governments, November, 1990, Table IV-5, p. 89.

[17] FTA, *op. cit.*, pp. II.5.28 - II.5.29.

Table 3.5

Annualization Factors

	Annualization Factors	
Trip Purpose	Private	Commercial
Home Based Work	255	NA
Home Based Other	290	NA
Non-Home Based	310	255
Truck	NA	255
Internal-External	310	255
External-External	310	255

NA = Not Applicable

Table 3.6

Benefit Parameters and Evaluation Methods

Cost/Benefit Parameter	Evaluation Method *NRI*	 *UBI*	 *NPV*
Existing Users			
Transit Passenger Travel Time	X	X	X
Auto Driver Travel Time		X	X
HOV Travel Time		X	X
Auto Operating Costs		X	X
Commercial Travel Time			X
Commercial Vehicle Op. Costs			X
Diverted Users			
Auto Passenger Travel Time		X	X
Transit Passenger Accident Costs		X	X
Transit Passenger Travel Time	X	X	X
Deficits/Subsidies			
Transit Operations	X		X
HOV Operations			X
Auto Parking			X
Transit Passes			X
Air Quality Improvement			X
Noise Reduction			X

Charles Rivers Associates (CRA) offered several suggestions for improving the *NRI*, as detailed in Chapter 2. The CRA revisions have considerable merit. A comparison of project rankings according to the *NRI* with and without the CRA revisions would reveal the effect of excluding such non-user benefits as congestion mitigation, air quality improvement, and noise reduction. To determine if the *NRI* can be improved by incorporating the CRA revisions, two versions will be computed in Phase II. In addition to the standard *NRI*, a variation which includes the following CRA recommendations will be computed:

1. counting as benefits and/or costs values for air quality improvement, noise reduction, congestion mitigation, and accident reductions;
2. discounting construction costs on a five year schedule (rather than assuming construction expenditures all occur in a single year); and
3. travel time savings based on local wage rates rather than nationally adopted values.

In addition, present value calculations will use a 10.0% discount rate in order to be consistent with results from the original fixed guideway study. The 10.0% rate is higher than currently prescribed by the federal government, but was the rate in use at the time of the fixed guideway study. The federal Office of Management and Budget has since mandated use of an 8.0% rate for all federal benefit-cost analyses to reflect the decline in inflation. Sensitivity tests, the results of which will be reported in a subsequent chapter, will reveal the effect of different interest rates on project priorities.

The *NRI* is a ratio obtained by dividing the costs and benefits by the number of new riders. If FTA abandoned the practice of dividing costs and benefits by the number of new riders, the *NRI* would appear quite similar to the comprehensive benefit-cost assessment described in Chapter 1.

User Benefit Index

As with the *NRI*, the AASHTO index considers a limited number of benefits. The AASHTO index focuses on users, ignoring all non-user benefits and costs. The following deviations from AASHTO recommended computational procedures arise from the need to control as many variables as possible in assessing the different evaluation indices:

1. benefits in the fifteenth year (2005) will be the basis for judging investment worthiness;
2. cost data from the Oklahoma City fixed guideway study will substitute for cost estimates prepared according

to AASHTO guidelines;

3. values of time will ignore the magnitude of the time saving;
4. the discounting procedure will use a 10.0% interest rate; and
5. project elements will have no salvage values.

Procedure one differs from the AASHTO recommended method of preparing travel forecasts for each and every year through a twenty year horizon. AASHTO suggests developing travel forecasts for two future time periods, typically five and fifteen year horizons, and interpolating intermediate year volumes. The entire stream of costs and benefits over the life of the project forms the basis for judging investment worthiness (see Chapter 2 for more detail). Current travel modeling practice in the Oklahoma City region relies on a single forecast year. Development of forecast data for additional years would add considerably to the project budget without meaningfully contributing to the study's objective, which is to determine the effect of different evaluation methods on project priorities.

There is also a need to remain consistent as much as possible with previous work, which is the basis for assumptions two through five. Under ideal conditions, an experiment holds all possible influences constant other than a single variable. Any variations in outcomes can thus be attributed to a specific variable. The Oklahoma City Fixed Guideway Study generated the data used to calculate the *NRI* for the Norman and Northwest corridors. To remain consistent with the original analysis requires use of the same data to calculate the *UBI*. The Phase II sensitivity tests will help determine the extent of influence certain factors exert over final outcomes.

Comprehensive Benefit-Cost Analysis

Deviations from the ideal AASHTO method apply equally to the comprehensive benefit-cost analysis procedure. In many ways the *NPV* technique combines the best features of the FTA and AASHTO indices, especially when the FTA index incorporates the CRA revisions. *NPV* includes non-user benefits, distinguishes between commercial and non-commercial travel, and makes use of local wage rates. While the AASHTO discounting procedure is the preferred means of arriving at present value, *NPV*, as with *UBI*, will use the FTA single horizon year convention.

Unlike the FTA and AASHTO methods, there will be separate *NPV* calculations for local, state, and federal perspectives. It is this practice, along with the extensive treatment of commercial travel, that distinguishes the *NPV* method from other evaluation techniques. In addition to economic efficiency, a preferred alternative must yield positive *NPV* for all financial participants. This is the financial efficiency test described in Chapter 2.

Chapter 4

Forecasting

A key step in major investment analysis is forecasting future travel volumes. As indicated in Fig. 2.2, the AASHTO method requires data for the current year and two forecast years. This is the minimum for both the AASHTO (*UBI*) and financial efficiency (*NPV*) tests. The data needed to conduct these two tests is organized in the manner illustrated in Fig. 4.1. One table is needed for each alternative. The drive-alone, shared ride, and transit data must be further subdivided into work and non-work related travel.

The FTA index, the *NRI*, can be computed from data developed for a single forecast year. The Oklahoma City fixed guideway systems study produced *NRI* values for four alternatives in two corridors, using a TSM benchmark. The alternatives consisted of light rail and high occupancy vehicle investments. A full *UBI* and *NPV* test would require forecasts for an additional year as well as establishing base year (1990) conditions, and developing a no build alternative. For purposes of this study, a ranking of the five alternatives (the four build options plus the TSM benchmark) compared to a no build scenario in a single year using each of the evaluation methodologies will be sufficient to demonstrate deficiencies in existing methodologies.

To assure comparability to the original Oklahoma City fixed guideway systems study, the additional data generated for the *UBI* and *NPV* index used as much of the original data files, mode split model, and networks, as possible. Unlike the original systems study, where highway forecasts were not prepared, the *UBI* and *NPV* measures require data on all affected modes. Crossmodal impacts are especially important for the HOVway alternatives, where congestion relief and commercial traffic benefits are most likely to be significant. From the description which follows, it will be clear that methodological correctness is difficult to achieve given current modeling systems and data collection priorities.

The Association of Central Oklahoma Governments (ACOG) provided original data files as follows:

1. Year 2005 Highway Network (adopted Plan);
2. Year 2005 Person-Trip Table;
3. Year 2010 Transit Trip Table (developed from the 2005 person-trip table using a growth factor technique);
4. Work Trip Multinomial Logit Mode Split Model; and
5. Year 2010 TSM and LRT Networks.

Figure 4.1

Data Required to Compute Investment Indices

	Drive-Alone	Shared-Ride	Commercial Car	Commercial Truck	Transit
Vehicle-Hours					
Vehicle-Miles					
Person-Hours					
Person-Miles					
No. of Trips					
No. of Transfers					
In-Vehicle Travel Time					
Out-of-Vehicle T. T.					
Trip Purpose					

Data for all of the alternatives either had to be constructed from this data or developed. The no-build alternative was defined as the year 2005 highway network plus the local bus element of the transit TSM alternative. Figure 4.2 illustrates how the remaining alternatives were developed from the no-build scenario. It was necessary to construct the HOV alternatives by adding links to the year 2005 highway network.

The most problematic element of the forecasting process concerned creation of numerically consistent but separate trip tables for the highway and transit modes. Figure 4.3 illustrates the general method of developing the trip tables. To assure comparability among the results, the total number of trips assigned to all modes had to be held constant for all forecasts, although this practice results in an understatement of total benefits since it ignores latent travel demand.[1] Although the original fixed guideway study used a 2005 trip table expanded to 2010 by a growth factor technique, the differences between the two trip tables were slight and could be ignored. Furthermore, only work trips were factored, which amount to about 20% of all person-trips.

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[1] Button, Kenneth J., *Transport Economics*, Edward Elgar Publishers, Brookfield, VT., 1993, p. 213.

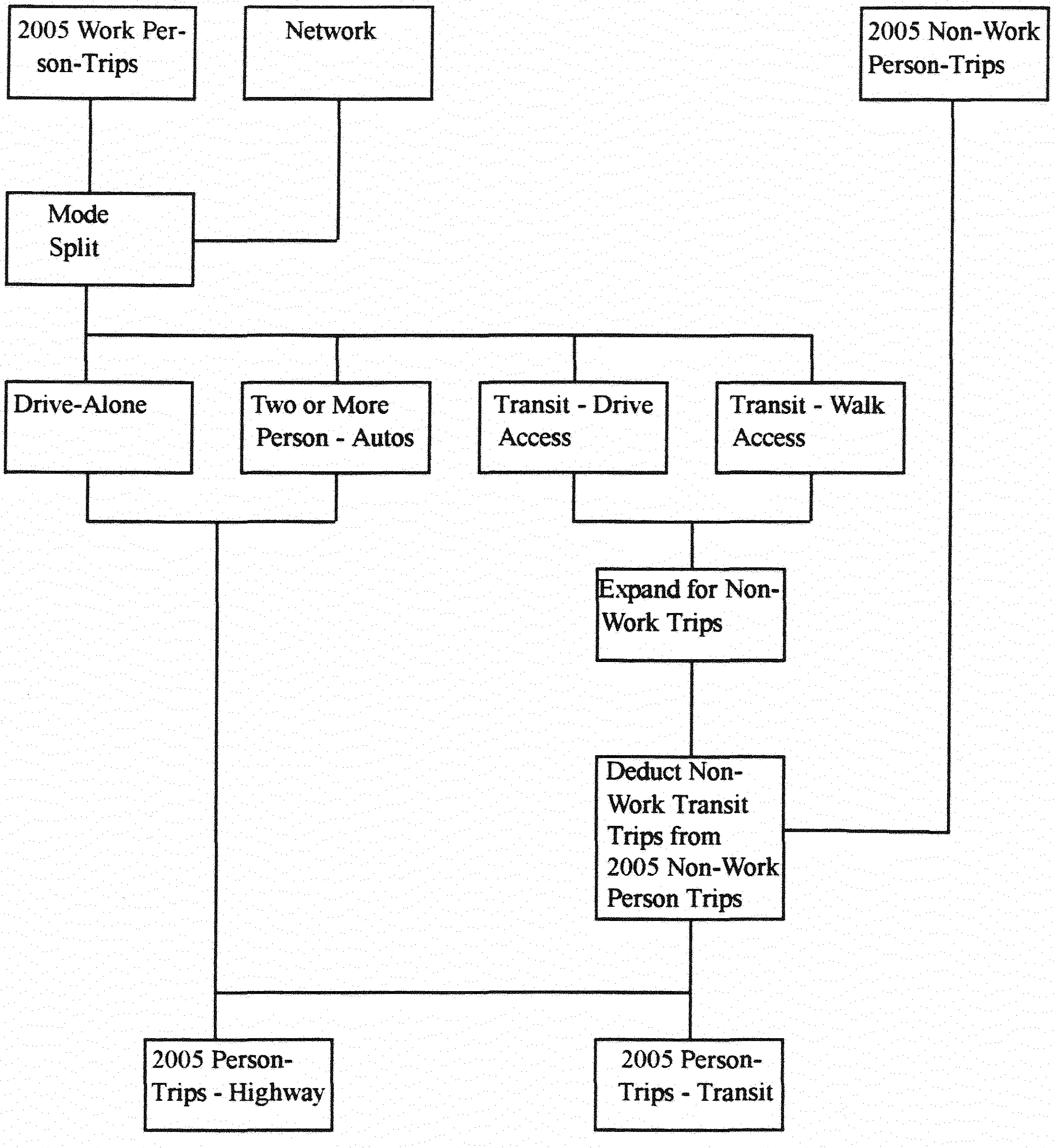
Figure 4.2

Relationships Among Alternative Networks

Alternative	Highway	Transit
Transp. System Management	No-Build Network	Local and Express Bus Network
Light Rail (Norman Corridor)	No-Build Network	Light Rail Transit in the U.S. 77/I-35 Corridor plus the TSM Network (express bus deleted where it duplicates the Light Rail Line
Light Rail (Northwest Corridor)	No-Build Network	Light Rail Transit along the Northwest Highway plus the TSM Network (express bus deleted where it duplicates the Light Rail Line)
High Occupancy Vehicle Lane (Norman Corridor)	No-Build Network Plus an Extra Lane on I-35 for Buses, Car- and Vanpools	TSM Transit Network with Express Buses Routed Onto the HOV Lane Where Possible
High Occupancy Vehicle Lane (Northwest Corridor)	No-Build Network Plus an Extra Lane along the Northwest Highway for Buses, Car- and Vanpools	TSM Transit Network with Express Buses Routed Onto the HOV Lane Where Possible

Figure 4.3

Construction of Trip Tables



The block labeled "2005 Work Person-Trips" in Figure 4.3 actually refers to the 2010 work person-trips obtained from ACOG. The mode split model was validated only for work trips. Non-work transit trips were estimated from the number of work trips per the method used in the Oklahoma City fixed guideway study.[2] Non-work transit trips were then deducted from total non-work person-trips to create separate trip tables for the highway and transit modes. All variations among the trip tables could be attributed to network differences as manifest through the mode split analysis. Additional detail on the travel forecasting process can be found in Putta.[3]

Highway and transit trips were separately assigned to their respective networks. Various summarizations and post-processing was required to produce the data necessary for the *UBI* and *NPV* indices. All of the required work-trip transit data was produced by the transportation software. For highway modes, the transportation modeling software produced summaries of the drive-alone, shared ride, and

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[2] Parsons, Brinckerhoff, Quade & Douglas, Inc., *Oklahoma Fixed Guideway Transportation System Study: Refinement of Travel Demand Model and Patronage Forecast for Tier I Corridors*, Jan. 1991, p. 32.

[3] Putta, Viplava K., *Assessing the Transferability of a Mode Split Model to the Oklahoma City Region Based on Direct and Cross Elasticities for Home Based Work Trips*, Masters Thesis, University of Oklahoma, Norman, 1994.

intra-regional truck modes. Except for truck trips, commercial traffic will have to be factored out of the drive-alone data. There were no commercial trips in shared-ride traffic since only commuter work trips were included in the modal split analysis. Much of the post-processing remains to be accomplished in Phase II, and will rely in part on the parameters reported in Chapter 3. The forecasting results are contained in Appendix A.

Appendix A

Travel Forecasting Results

Table: 1

No-Build Alternative: Auto User Statistics

Category	Vehicle trips	Person trips	Vehicle miles	Vehicle hours	Person miles	Person hours
Home Based Work Trips						
Auto trips	485942	563202	3430783	139907	4459077	178875
Car/Van pool trips	17337	38462	183605	8298	414867	18683
Truck	228003	228003	1212959	46475	1212959	46475
INT-EXT	249623	249623	5295221	222114	5295221	222114
EXT-EXT	26736	26736	924900	37947	924900	37947
All Other	1419213	2050280	8099533	314688	11663608	451538
Total	2426854	3156306	19147001	769429	23970632	955632

Table: 2

No-Build Alternative: Transit User Statistics for Home Based Work Trips

Category	Passenger trips	Passenger miles	Passenger hours(IVTT)	Passenger hours(OVTT)	Transfers	Passenger hours (WT)**
Auto access	3469	20437	1334	852	1247	563
Walk access	17463	85696	5844	4548	6547	2632
Total	20932	106133	7178	5400	7794	3195

** Wait Time (WT) is inclusive of Out of Vehicle Travel Time (OVTT).

April 14, 1994

Table: 3

Transportation System Management Alternative: Auto User Statistics

Category	Vehicle trips	Person trips	Vehicle miles	Vehicle hours	Person miles	Person hours
Home Based Work Trips						
Auto trips	480888	560800	3382559	137092	4427984	175603
Car/Van pool trips	16938	37556	178312	7798	402812	17550
Truck	228003	228003	1212959	45867	1212959	45867
INT-EXT	249623	249623	5295221	218676	5295221	218676
EXT-EXT	26736	26736	924900	37613	924900	37613
All Other	1418276	2048723	8088383	310434	11645360	445453
Total	2420464	3151441	19082334	757480	23909236	940763

Table: 4

Transportation System Management Alternative: Transit User Statistics for Home Based Work Trips

Category	Passenger trips	Passenger miles	Passenger hours(IVTT)	Passenger hours(OVTT)	Transfers	Passenger hours (WT)**
Auto access	5274	33802	1781	1322	1915	871
Walk access	21147	115067	6821	5665	8060	3331
Total	26421	148869	8602	6986	9975	4202

** Wait Time (WT) is inclusive of Out of Vehicle Travel Time (OVTT).

May 19, 1994

Table: 5

Light Rail Transit Alternative - Norman Corridor: Auto User Statistics

Category	Vehicle trips	Person trips	Vehicle miles	Vehicle hours	Person miles	Person hours
Home Based Work Trips						
Auto trips	482273	559590	3393065	136470	4420054	174637
Car/Van pool trips	16616	36832	174557	7594	394132	17090
Truck	228003	228003	1212959	45784	1212959	45784
INT-EXT	249623	249623	5295221	220145	5295221	220145
EXT-EXT	26736	26736	924900	37879	924900	37879
All Other	1417778	2047869	8084608	309824	11638012	444486
Total	2421029	3148653	19085310	757696	23885278	940021

Table: 6

Light Rail Transit Alternative - Norman Corridor: Transit User Statistics for Home Based Work Trips

Category	Passenger trips	Passenger miles	Passenger hours(IVTT)	Passenger hours(OVTT)	Transfers	Passenger hours (WT)**
Auto access	7887	41476	1749	1722	3640	1138
Walk access	24792	112840	10905	6607	10658	4083
Total	32679	154316	12654	8329	14298	5221

** Wait Time (WT) is inclusive of Out of Vehcle Time (OVTT).

April 20, 1994

Table: 7

Light Rail Transit Alternative - North-West Corridor: Auto User Statistics

Category	Vehicle trips	Person trips	Vehicle miles	Vehicle hours	Person miles	Person hours
Home Based Work Trips						
Auto trips	483728	561407	3419563	138826	4453619	177496
Car/Van pool trips	16879	37468	179552	7895	406617	17815
Truck	228003	228003	1212959	46189	1212959	46189
INT-EXT	249623	249623	5295221	221004	5295221	221004
EXT-EXT	26736	26736	924900	37759	924900	37759
All Other	1418437	2048948	8095975	312512	11649109	448090
Total	2423406	3152185	19128169	764185	23942425	948353

Table: 8

Light Rail Transit Alternative - North-West Corridor: Transit User Statistics for Home Based Work Trips

Category	Passenger trips	Passenger miles	Passenger hours(IVTT)	Passenger hours(OVTT)	Transfers	Passenger hours (WT)**
Auto access	5517	28398	1250	1425	2081	1171
Walk access	20185	81095	5022	6712	7686	4361
Total	25702	109493	6272	8137	9767	5531

** Wait Time (WT) is inclusive of Out of Vehcle Time (OVTT).

April 28, 1994

Table: 9

High Occpancy Vehicle Lane - Norman Corridor: Auto User Statistics

Category	Vehicle trips	Person trips	Vehicle miles	Vehicle hours	Person miles	Person hours
Home Based Work Trips						
Auto trips	485254	526582	3102140	116904	3949895	142197
Car/Van pool trips	31780	71800	434672	12765	1005447	29415
Truck	228003	228003	1234192	42374	1234192	42374
INT-EXT	249623	249623	5548574	203998	5548574	203998
EXT-EXT	26736	26736	1037101	34675	1037101	34675
All Other	1418278	2048729	8211116	287820	11822245	413157
Total	2439674	3151473	19567795	698536	24597454	865816

Table: 10

High Occupancy Vehicle Lane - Norman Corridor: Transit User Statistics for Home Based Work Trips

Category	Passenger trips	Passenger miles	Passenger hours(IVTT)	Passenger hours(OVTT)	Transfers	Passenger hours (WT)**
Auto access	5274	33609	3031	1961	1923	1371
Walk access	21101	114446	6792	5654	8022	3319
Total	26375	148055	9823	7615	9945	4691

** Wait Time (WT) is inclusive of Out of Vehcle Time (OVTT).

May 14, 1994

Table: 11

High Occpancy Vehicle Lane - North-West Corridor: Auto User Statistics

Category	Vehicle trips	Person trips	Vehicle miles	Vehicle hours	Person miles	Person hours
Home Based Work Trips						
Auto trips	481340	556116	3455198	128791	4479828	162929
Car/Van pool trips	19049	42258	206987	7368	467668	16608
Truck	228003	228003	1234850	42901	1234850	42901
INT-EXT	249623	249623	5538426	204807	5538426	204807
EXT-EXT	26736	26736	1051020	34505	1051020	34505
All Other	1418278	2048726	8215069	291410	11827740	413412
Total	2423029	3151462	19701550	709783	24599532	461751

Table: 12

High Occupancy Vehicle Lane - North-West Corridor: Transit User Statistics for Home Based Work Trips

Category	Passenger trips	Passenger miles	Passenger hours(IVTT)	Passenger hours(OVTT)	Transfers	Passenger hours (WT)**
Auto access	5288	33639	1773	1126	1937	874
Walk access	21147	114868	6811	5665	8070	3333
Total	26435	148507	8584	6791	10007	4207

** Wait Time (WT) is inclusive of Out of Vehcle Time (OVTT).

May 18, 1994