MAJOR INVESTMENT ANALYSIS FOR MULTIMODAL PROJECTS IN URBAN CORRIDORS: FINAL REPORT

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16 . ABSTRACT

Urban areas considering major transportation investments evaluate alternatives using various techniques such as benefit-cost analysis and cost effectiveness measures. A comprehensive benefit-cost analysis is the least biased method of judging project merit when crossmodal impacts are significant. Using Oklahoma City data, five build alternatives in two corridors were examined using three different evaluation methodologies: (1) user benefit analysis, described in a 1977 American Association of State Highway and Transportation Officials manual; (2) cost effectiveness, which employs the Federal Transit Administration's average cost per new transit rider index; and (3) benefit-cost analysis, developed specifically for this study. The alternatives included light rail transit and high occupancy vehicle lanes. The study illustrates how benefit-cost analysis can incorporate important crossmodal interactions by distinguishing between passenger and commercial traffic, and trip purposes and vehicle types. The study demonstrates several innovative methodologies including procedures for calculating user benefits when the travel forecasting model uses a fixed trip table, estimating congestion relief to highway modes resulting from transit investments, and incorporating non-user costs such as air quality, noise, and parking subsidies. When properly applied, benefit-cost analysis reveals important transfer payments which are not apparent from other, more aggregate, evaluation techniques. A major finding is that the overall quality of an investment study is heavily dependent on the travel modeling procedures.

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EXECUTIVE SUMMARY

Recent legislative and regulatory actions require transportation planning agencies to undertake studies of investment worthiness prior to committing funds to major metropolitan 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 hampers multimodal planning. This report describes alternative techniques for conducting major investment studies of metropolitan transportation projects involving different and/or competing modes, and recommends certain practices.

Transportation investments should increase economic efficiency and/or redistribute income. Although transportation legislation mostly speaks to the first objective, there are ample examples of the redistribution objective in actual practice. Since the goals of redistribution are not clearly articulated, major investment studies ordinarily rely on the economic efficiency criterion.

Improving economic efficiency leads governments to invest in transportation when public returns on investment exceed those possible in the private sector. Such investments contribute to higher national welfare through increased income and lower relative prices. One approach to conducting major investment studies benefit-cost analysis. Other approaches include partial benefit-cost analysis, where the number of modes and perspectives consider are limited, and cost-effectiveness analysis, which is based on one or more performance measures.

Sources of financing, the level of the government, and the distribution of impacts all influence public attitudes toward transportation investments. An investment which conveys travel time savings to the interstate trucker might not be relevant to local decisionmakers. 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.

Intergovernmental grants profoundly affect local government perspective. Local government counts a competitively awarded grant as a benefit, since a larger improvement occurs than would have otherwise been possible. The national government views the same grant as a transfer payment; the money must be spent somewhere in the country. The "spend it or lose it" pressure exerted by formula grants leads local governments to rank projects rather than investigate their efficiency.

There are four different methods of conducting major metropolitan transportation investment analyses in use in the U.S. One is user benefit analysis, introduced in a 1977 manual published by the American Association of State Highway and Transportation Officials (AASHTO). The second method is the Federal Transit Administration's (FTA) new rider index, which measures the average cost per new rider attracted to transit. A third method is cost effectiveness analysis, where the goal is to optimize some performance measure per unit of cost. The fourth method is actually a process which varies by state according to how each prepares its annual Section 105/Statewide Transportation Improvement Program. Various levels and types of analyses may be applied to projects in the course of developing the program.

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 improved air quality. Most cost effectiveness indices measure flows or volumes which do not capture the differential economic impacts of alternative modes.

Although benefit-cost analysis is cumbersome and arcane, it is the only method currently capable of fair mixed mode evaluations. This report recommends a method of benefit-cost analysis appropriate for projects where multimodal consequences are likely to be significant. Implementing the method will require short term and long term changes in the conduct of major investment studies. In the short-term,

1. the AASHTO user benefit procedure can be expanded to incorporate non-user

impacts such as air quality and noise benefits;

2. the accounting of benefits and costs should be done separately for each group of payers and beneficiaries, including in each accounting only those costs and benefits relevant to that group (stakeholder analysis);
3. short and long term travel forecasts should be prepared;
4. transportation agencies need to expand their surveillance of the existing transportation system such that a good base year inventory of modal use and traffic volumes is always available;
5. major investment studies should report the results of sensitivity tests concerning the influence exerted by key input (policy) parameters; and
6. conversion factors will be needed to divide travel forecasts into private and commercial categories classified by type of vehicle.

Longer term improvements involve:

1. developing better unit costs, especially for non-user and social impacts;
2. directly forecasting commercial and private travel;
3. better methods for forecasting local and non-local truck and commercial passenger travel;
4. forecasting latent travel demand (relaxing the fixed trip table assumption); and
5. better estimates of the value of travel time.

Many of the recommendations concern the importance of addressing commercial and non-commercial traffic separately given the different value associated with travel time savings for the two groups. This report describes a short-term method which can be used to isolate commercial and non-commercial travel.

The study finds that different investment analysis techniques can produce different priorities. Applying three different evaluation methods -- benefit-cost analysis, AASHTO user benefit analysis, and the FTA cost-effectiveness technique -- to investment alternatives in the Oklahoma City region produced conflicting results. The AASHTO and benefit-cost techniques resulted in the same set of project rankings with slightly different findings on investment worthiness. FTA's cost effectiveness technique yielded a different set of priorities and indicated none of the alternatives warranted investment. The Oklahoma City alternatives involve multiple modes, many intermodal impacts, and various funding scenarios.

Sensitivity tests on the results showed the value of time to have the greatest influence on the benefit-cost and AASHTO analyses. Procedures used to schedule capital cost most influenced the FTA procedure.

The evidence leads to the conclusion that FTA's cost effectiveness analysis suffers from too many structural flaws to be a reliable indicator of project merit. The FTA should probably abandon its cost-effectiveness index in favor of a benefit-cost type analysis. The AASHTO user benefit analysis procedure still provides valuable guidance in assessing the user component of the benefit stream, particularly with respect to: discounting travel time savings according to the magnitude of the savings; analyzing costs and benefits over a twenty year period; comparing to a no-build benchmark; and estimating vehicle operating costs.

Benefit-cost analysis combines the best AASHTO procedures with estimates of non-user costs into an analytic framework which distinguishes benefits and costs from each stakeholder perspective, including modal perspectives. In benefit-cost analysis, the investment decision can vary according to perspective and the type of financing.

The most critical variables in benefit-cost analysis are the values assigned to commercial and private travel. For auto travel, available data and theory suggest that private travel time savings are worth one-fourth to two-thirds those of the commercial sector. Where commercial traffic is heavy, this value of time scale will favor highway projects which is where the bulk of commercial travel occurs. Commuter oriented systems such as rail transit may have difficulty competing for investment dollars when alternate highway projects exist. One advantage of FTA's cost effectiveness index is that it yields a list of projects in which to invest. AASHTO's user benefit and benefit-cost analyses carry no such guarantee.

The study also demonstrates how to test the validity of project rankings and investment decisions by varying key parameters one at a time over a reasonable range. If the same project would be selected even with changes in critical variables, the decision is probably sound. For input variables which affect mode and route choice, new trip tables must be constructed each time a parameter value changes.

Although benefit-cost analysis offers the best opportunity for conducting multi-modal major investment studies, there are significant data and modeling problems to overcome. Ultimately, new travel modeling capabilities are needed which better link travel forecasting systems with investment analysis.

CHAPTER ONE

EVALUATING TRANSPORTATION INVESTMENTS

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, regional disposable personal income (*RDPY*) serves as an approximate measure. Comprehensive measurement of local utility requires an adjustment in *RDPY* for positive and negative local attributes such as air pollution, crime, quality of schools, climate, cultural amenities, noise, and congestion. Regional utility increases with increases in local resident income and/or positive local attributes, as well as reductions in negative local attributes.

Eq. (1.1) is the regional macroeconomic accounting identity.

$$GRP \equiv C + I + G + X - M \tag{1.1}$$

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 from regional output
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. (1.2). Together, Eq.s (1.1) and (1.2) illustrate the four requirements for investment worthy urban transportation projects

$$RDPY = GRP - A - T \tag{1.2}$$

where

RDPY =	regional personal disposable income
A =	business and personal taxes, undistributed corporate profits
T =	non-local 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:

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. (1.1). 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 condition two. Line P_0G_0 represents all potential allocations of regional product, and as such is the budget constraint faced by a region. If a region currently allocates P_1 to consumption, investment, imports, and exports, and G_1 to government, utility U_1 is realized. It should be clear that an even higher level of utility, U_2, could be attained by allocating additional resources to government (G_2 - G_1), which must occur at the expense of the other sectors (P_1 - P_2). The cost of realizing this gain in utility are (1) the opportunity cost of foregoing P_1 - P_2 in activity in the non-governmental regional accounts, and (2) the expenses associated with effecting the transfer. Condition two is met if the gain in utility exceeds the sum of the opportunity and transaction costs.

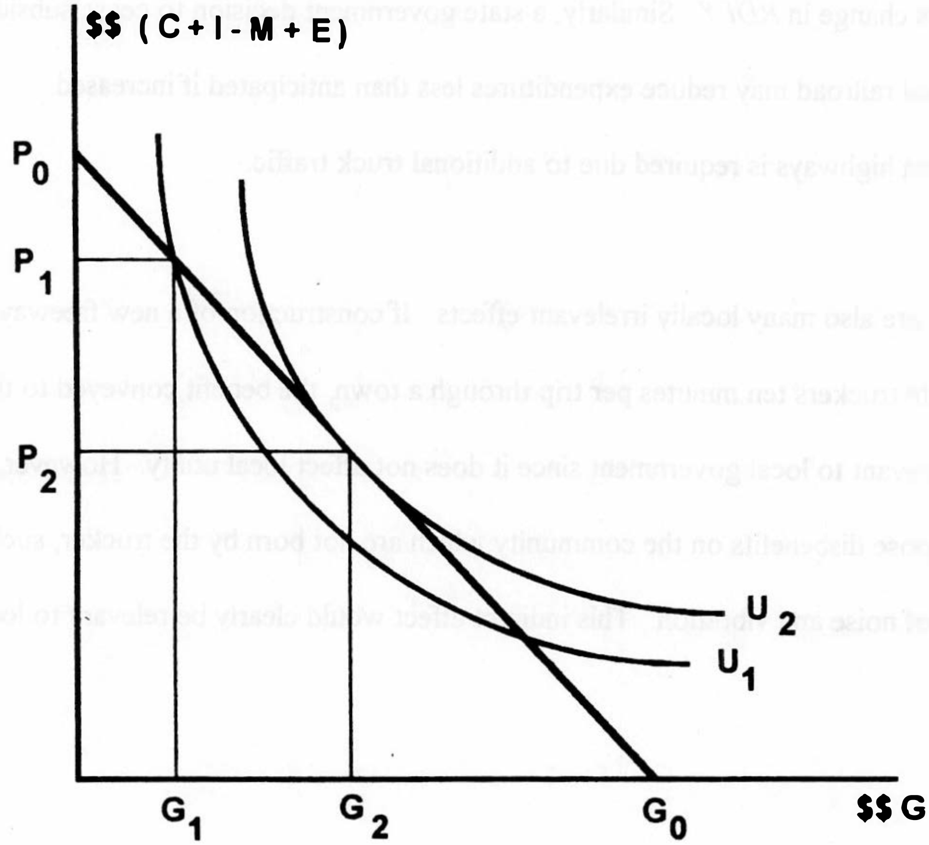
Urban transportation investments increase local utility by reducing the cost of doing business. A successful transportation investment can initiate a cycle whereby businesses in the city find themselves earning extraordinary profits. These excess profits allow export firms to lower their prices and expand their markets, which, in turn, leads to higher incomes and consumption and investment. In terms of Eq. (1.2), local government increases *RDPY* by increasing government transfer payments *T* 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 and costs conveyed to and 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 leads to higher health care costs due to increases in automobile emissions, the incremental increase in cost should be deducted from the gross change in *RDPY*. 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.

FIGURE 1.1

BUDGET CONSTRAINT AND UTILITY



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 four), the project is worthy of construction. Table 1.1 lists the benefits of locally financed urban transportation projects.

TABLE 1.1

BENEFITS TO LOCAL GOVERNMENT OF LOCALLY FINANCED TRANSPORTATION IMPROVEMENTS

User Benefits

Savings to Local Users of the Improved Mode or Facility

Savings to Local Users of Unimproved Modes or Facilities

Non-User Benefits

Operator Savings

Reductions in Local Deficits and Subsidies

Local Energy Conservation

Air Quality Improvement

Noise Reductions

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. With user fee financing, local government acts on behalf of users, assuring that investments serve the interests of the group paying for the improvement. 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.

Local government officials will view any user financed gain in local utility as desirable since the government risks little own-source money, This is true even if the investment produces less increase in local utility 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 maximize local utility, but will not deny approval to any project that adds to local utility and for which users are willing to pay.

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 relevance of new user benefits 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 major highways financed from motor fuel taxes. In this situation, benefits to new users, essentially realized latent demand, 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.

Intergovernmental Grants

Transportation improvements may involve 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 merit according to their particular costs and benefits.

The effects of transportation system improvements often 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. From the local perspective, a discretionary grant program permits the locality to choose whether to participate in a project. 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.

Projects financed with discretionary grants impose transaction costs on the recipient government. These are the expenditures required to obtain and administer federal funds. 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 government judges the merits of undertaking an investment by comparing its benefits to these transaction costs.

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 conditions 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 transportation 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 and capital expenses; operating and maintenance cost savings are treated as benefits. All the benefits listed in Table 1.1, measured on a willingness to pay basis, figure in a financial efficiency test 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 type of evaluation, user benefit, is a type of financial efficiency assessment. Both the FTA and the 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 have 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

If national policy is to increase national utility, then the national government will seek to invest in those regions which can generate the greatest welfare gain for the money. Gains

[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.

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. 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 through legislative actions and appropriations. 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 (1.3) and (1.4) describe the macroeconomic assumptions from which the efficiency criterion is derived.

$$Y = Consumption + Savings + Government \tag{1.3}$$

$$Y = No.\,of\ Workers * Output/Worker \tag{1.4}$$

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. (1.3). In terms of Eq. (1.4), 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. Aschauer[2] and Munnel[3] independently reported 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 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 sums benefits in all regions of the country. Project costs consist of transaction expenses incurred in transferring monies from the consumption and investment sectors to the government sector in Eq. (1.3). Both local and national transfer costs must be included in the calculation.

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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.s *Is there a shortfall in Public Capital Investment*, Federal Reserve Bank, Boston, Massachusetts, 1990.

TABLE 1.2

NATIONAL BENEFITS OF URBAN TRANSPORTATION INVESTMENTS

User Benefits

Savings to Users of the Improved Mode or Facility

Savings to Users of Unimproved Modes or Facilities

Non-User Benefits

Operator Savings

Reductions in Deficits and Subsidies

Energy Conservation

Air Quality Improvement

Noise Reductions

Types of Evaluations

Economically efficient projects will produce benefits exceeding transaction costs. This is an appropriate type of evaluation for financing schemes involving new taxes, but in practice is seldom required. Typically the decision to shift resources to the government sector for urban transportation projects occurs prior to project development. Ordinarily, the federal evaluator must select projects in which to invest, not judge the merits of urban transportation investments in general. Consequently, transaction expenses are properly classified as *a prior* expenditures, and not viewed as costs.

Depending on the circumstances, projects competing for federal grants may have to meet both economic and financial efficiency tests. Since transaction costs are usually ignored, the determination of economic efficiency rests on the sum of the benefits listed in Table 1.2. If the sum is positive, the project is economically efficient. If the benefits of a project exceed the costs born by the payers, the project is financially efficient.

Grants allocated by formula complicate the evaluation process. Even if a project fails both the economic and financial efficiency tests at the national level, it may be desirable locally. Local governments will make every effort to spend grants allocated by formula as long as there are projects which increase local utility regardless of the effect on national utility.

Projects competing for federal discretionary grants may also be subject to federal economic and financial efficiency tests. This assures that only the best projects are funded. A project which increases national utility without incurring transaction costs is economically efficient. A determination of financial efficiency depends on the source of money for the grant. For example, a financial efficiency evaluation for a fixed guideway project partially funded from highway user fees will consider only local and non-local highway user benefits, and costs will equal the amount of the grant. Conversely, projects funded from general tax receipts will account for both local and non-local user and non-user benefits, with costs again equal to the amount of the grant. A project can be economically efficient and still fail a financial efficiency test.

Evaluations of projects employing discretionary and formula grants, and local and non-local money, should involve independent efficiency tests for each funding source. For example, a project funded in part with federal highway user fees distributed by formula and in part with a local general obligation bond issue requires one economic efficiency test and two financial efficiency tests. First, the locality must demonstrate to voters, whose approval of the general obligation bond issue is necessary, that the project will produce a net gain in local utility. That is, the sum of the benefits in Table 1.1 is positive. This is the local economic efficiency test. Second, the project's benefits summed from Table 1.1 must exceed the money derived from the general obligation bond issue. This is the local financial efficiency test. In this case, if the project passes the second test, it also passes the less stringent first. As a practical matter, the first test is subsumed into the second. Third, highway user benefits (both local and non-local) should exceed the amount of the federal grant.

Project Selection Criteria

Despite the added evaluation complexity, discretionary grants have three advantages over grants based on formulas. First, competition among local governments increases the chances of funding only nationally efficient projects. Second, concentrating money makes it possible to fund very large projects, which may not be possible if many eligible recipients share limited resources. Third, discretionary grants reduce the spend it or lose it pressure experienced by local government with grants distributed by formula.

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.

SUMMARY

Figure 1.2 provides a guide to the types of investment analyses appropriate for a variety of funding sources and levels of government. Fuel taxes are assumed earmarked for transportation. Strict application of the chart requires analyzing benefits and costs separately for each stakeholder. When there are no transaction costs the financial efficiency test subsumes the economic efficiency test.

FIGURE 1.2

INVESTMENT TESTS

Stakeholder	Fuel Tax	Bonds	Formula Grant	Discretionary Grant	General Reveue
Federal	U	NA	NA	E,F	NA
State	U	E	E,F	E,F	E,F
Local	U	E	E,F	E,F	E,F
Bondholder	NA	F	NA	NA	NA
User	F	U	U	U	U
Non-User	E	E	E	E	E

CODES:
E = Economic Efficiency
F = Financial Feasibility
U = User Benefit
NA = not applicable

CHAPTER TWO

STATE OF THE PRACTICE

The two most common investment evaluation methods in U.S. urban transportation studies are user benefit analysis, developed AASHTO,[1] and new rider analysis, required by the FTA for major transit investments competing for section three grants.[2] Other suggested methods include benefit-cost analysis[3] and cost effectiveness measures.[4] Current application of these methods is usually to investment alternatives with few multimodal elements.

USER BENEFIT ANALYSIS

The Stanford Research Institute developed the AASHTO methodology, a form of cost-benefit analysis, in the early 1970s.[5] The AASHTO method defines costs to include capital, operating, and maintenance costs. Benefits are reductions in operating and travel

[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.

[5]AASHTO, *op. cit.*

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] 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 applies to virtually any type of highway improvement. The method requires at least two travel forecasts, 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.

Analyst supplied parameters include values of time, vehicle occupancies, vehicle types, and salvage values. 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)

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

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

forecasts, and an inventory of existing conditions. Alternate zero is the *no build* benchmark, which represents the least expensive course of action.[8] Project benefits are the user and operator cost savings obtained by building the project.

Figure 2.1 illustrates the calculation of user benefits in a one-mode environment. 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 and operator costs, and salvage values, and summed for each category of user: existing, users of competing and complementary modes, and new users.

[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

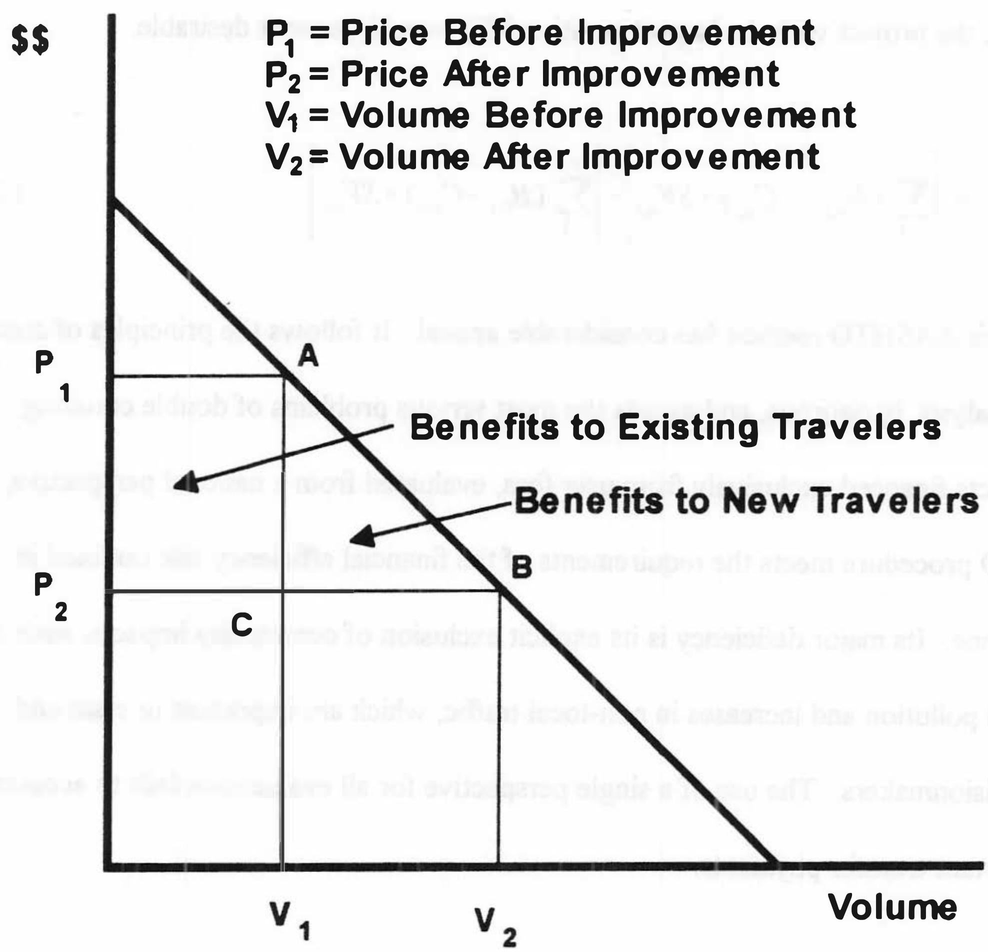
$B_{n,t}$ = Benefits of alternate "n" in year "t"

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

S.V. = Salvage Value

FIGURE 2.1

CONSUMER SURPLUS MODEL



Eq. (2.1) produces *net present value* (*NPV*), the index 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.

$$NPV = \left[\sum_{t=1}^{t} (B_{n,t} - C_{n,t}) + SV_{n,t}\right] - \left[\sum_{t=1}^{t} (B_{0,t} - C_{0,t}) + SV_{0,t}\right] \tag{2.1}$$

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 efficiency test outlined in Chapter one. Its major deficiency is its explicit exclusion of community impacts, such as noise and pollution and increases in non-local traffic, which are important to state and local decisionmakers. 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 three grants for major transit investments evaluate their projects by the average annualized cost per new rider.[9] 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 the distinction FTA makes between local and national perspectives. Grant applicants must compute the *NRI* twice, once using total capital cost and again using only federal cost.

The *NRI* recognizes two types of beneficiaries: existing transit patrons and new 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. (2.2) shows the manner in which benefits and costs combine to produce a single index.

$$NRI = \frac{C_{n,15} - C_{0,15} - \textit{Benefits to Existing Riders}}{\textit{Number of New Riders}} \tag{2.2}$$

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

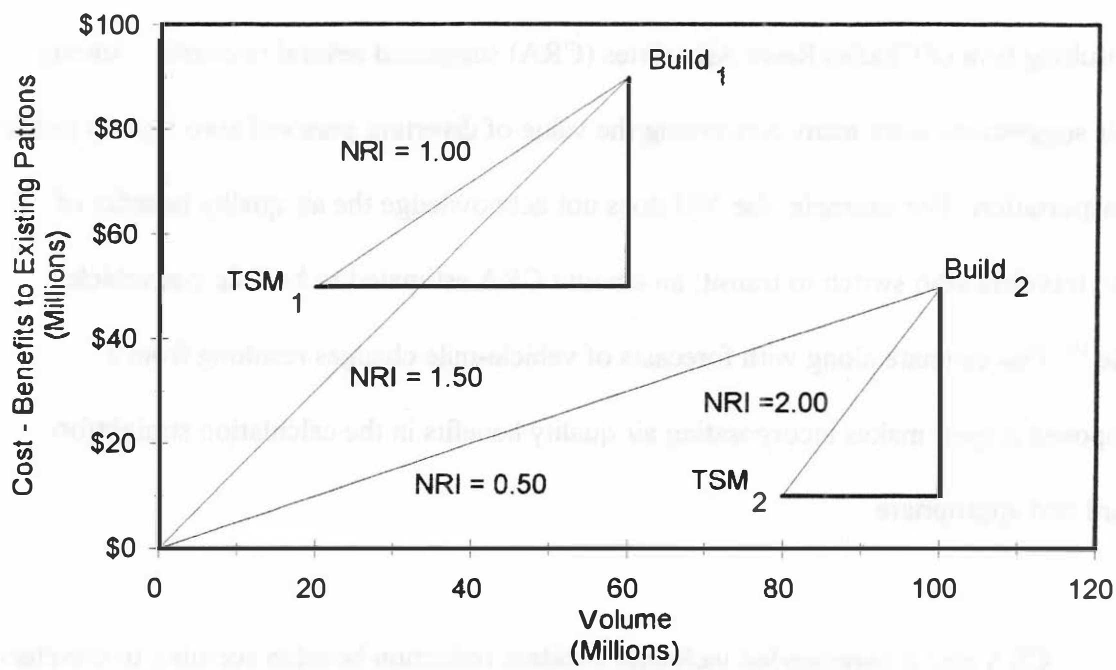
The FTA evaluation procedure recognizes new rider benefits to include both new transit and new car and vanpool users. Benefits not incorporated into the index include congestion, accident, noise, and user subsidy reductions as well as air quality improvements. These benefits are typically itemized in 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 significant improvement in transit service. The FTA benchmark, termed a transportation system management (TSM) alternate, is the best all-bus, non-guideway 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 has a *NRI* of 0.5 while project one is 1.5. 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. Projects can appear more attractive than they really are if there is a high cost TSM alternative.

FIGURE 2.2

COST EFFECTIVENESS WITH TSM AND NO BUILD BENCHMARKS



CHARLES RIVER ASSOCIATES REVISIONS

In a 1990 comprehensive review of FTA's major investment analysis procedures, the consulting firm of Charles River Associates (CRA) suggested several revisions. Among their suggestions were many concerning 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, an amount CRA estimated to be 3.2¢ per vehicle mile.[10] This estimate along with forecasts of vehicle-mile changes resulting from a proposed project makes incorporating air quality benefits in the calculation straightforward and appropriate.

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.[11] 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, and pay for these benefits through their fares. CRA recommends using 19¢ per diverted auto trip, and accepts the double counting as necessary to avoid excluding any potentially viable projects

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

[11]Charles River Associates, Memorandum to Federal Transit Administration, Sept. 28, 1990.

from the FTA grant competition.[12] As will be seen, specifying accident savings on a per trip basis poses serious methodological problems in a multimodal assessment. CRA also recommends a value of 3¢ per diverted auto trip as a conservative estimate of the lower limit of the noise benefit.[13]

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.[14]

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

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[12]Charles River Associates, Memorandum to the Federal Transit Administration, Sept. 18, 1990.

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

[14]Charles River Associates, Memorandum to the Federal Transit Administration, July 6, 1990.

FTA 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.[15]

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 to 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.

Computational Revisions

CRA contended FTA's discounting conventions overstated the attractiveness of transit

[15]AASHTO, *op. cit.*, p. 103.

projects by 10% to 20%.[16] CRA recommended abandoning the current FTA practice of comparing 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. A more correct procedure would schedule capital expenditures over the likely construction period, discount them to present value, and then annualize the discounted present value. CRA provides a table of capital recovery factors for construction periods of different durations.

Second, comparing annualized capital costs to benefits in the fifteenth year presumes benefits are the same each year over the life of the project, even though 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

[16]Charles River Associates, Memorandum to the Federal Transit Administration, Sept. 24, 1990.

and costs by the number of new riders attracted by an investment.[17] 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.

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. CRA's recommendations call for use of an unambiguous benefit-cost statistic such as *NPV*, explicit recognition of transit deficits, valuing savings in private motor vehicle operating costs, and credit for congestion and accident reduction. The CRA recommendations go beyond current AASHTO procedure by accounting for air quality, noise, and parking benefits. 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

[17]Charles River Associates, Memorandum to the Federal Transit Administration, Sept. 21, 1990.

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.[18] 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, and travel distance savings multiplied by a unit cost of travel. 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, defines the price change as the difference between the sum of travel time and vehicle operating

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

cost savings between each origin-destination pair with and without the project. 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 reflecting individual preferences. Table 2.2 lists the weights Beimborn and Horowitz recommend using in calculating user benefits.

The current generation of travel forecasting models do not permit use 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 the out-of-vehicle weights, i.e., 1.6.

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

Source: Beimborn, Edward, and Alan Horowitz. *Measurement of Transit Benefits*, U.S. Dept. of Transportation Report WI-11-0013-1, Washington, D.C., June, 1993.

Beimborn and Horowitz believe all travel time savings, no matter how small, should be included in 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 counter 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 valuing different amounts of travel time savings differently.

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION HOV LANE EVALUATION

Ulberg examines multimodal impacts in an evaluation of existing HOV lanes in the Seattle area.[19] The purposes of the study were to determine whether (1) the benefits of three HOV projects exceeded the costs of construction and operation, and (2) alternative investments in either do nothing or adding a general purpose highway lane would produce even

[19]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.

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[19]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.

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

Category		Amount	Units
Parking:	Single Occupant	$ 3.71	Day
	Carpool	3.00	Day
	Vanpool	-0-	Day
Operating Cost:	Car	0.23	Mile
	Van	0.42	Mile
	Bus	0.30	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:	All Users	7.00	Hour
Construction:	General	9,202,000	Year
	Extra HOV	920,000	Year
Discount Rate:		4.0%	Year

PERFORMANCE MEASURES

A final topic concerns the use of performance measures as alternatives to benefit-cost analysis. 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. In a 1978 article, Fielding, Glauthier, and Lave[20] identified 21 possible performance measures, several of which could serve to guide investment decisions. In a 1987 update of this work,[21] Fielding refined the measures and provided computation methodologies. Table 2.4 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 cross-modal comparisons, since they are all oriented toward transit service utilization.

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

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

DeCorla-Souza[22] suggested minimizing the cost of serving new 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 either the total cost or the incremental cost per trip, where the increments in costs and trips are computed using a base year set of data.

DeCorla-Souza's index is similar to FTA's *NRI* except for its interpretation. 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. In fact minimizing financial cost and/or reducing trips are not the goals of transportation investment. People willingly trade-off travel time and cost to obtain other benefits.

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

TABLE 2.4

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

Another problem with the DeCorla-Souza approach is the lack of distinction between commercial and non-commercial traffic. Trips, even when categorized by type of vehicle, are not an adequate measure of the value of trip-making. Neither the number of trips nor the cost per trip would be useful information in multimodal major investment studies. A better index would assess whether the additional cost is less than the improvement in economic welfare.

Wickstrom[23] proposed a performance measure for analyzing highway segments. 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 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-mile. But the same criticisms levied against DeCorla-Souza's index apply equally to Wickstom's; the object is not to minimize cost, but rather to increase welfare by spending money on transportation infrastructure.

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

SUMMARY

Economists favor benefit-cost analysis as a basis for decisionmaking because it is comprehensive, unambiguous, and advances popular efficiency and financial goals. Benefit-cost analysis 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 benefit-cost analysis has the potential to fairly incorporate crossmodal impacts, a significant and compelling advantage over other methods. 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 THREE

METHODOLOGY

Chapter one 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 selection according to the different evaluation methods will suggest the degree to which current procedures lead to different priorities even when decisionmakers share the same investment objectives, economic and financial 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 included TSM, light rail transit, and high occupancy vehicle (HOV) lanes. 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.

A major investment study for long-range multimodal planning must be capable of providing comparable data for all affected modes and governments. The light rail transit mode operates on a fixed guideway and carries passengers. High occupancy vehicles (HOVs) are rubber-tire, motorized vehicles carrying two or more people and guided by an on-board operator. HOVs are highway modes, and include buses, carpools, and vanpools. HOVs share the highway with single occupant private vehicles and commercial traffic.

HOV projects are eligible for FTA funds,[2] which is why the *NRI* was used in the initial study. Benefits and costs included only those related to transit passengers and the operator. To see how different major investment study methodologies might influence project selection, the original fixed guideway results will be compared with those prepared

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

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

according to the CRA revisions, AASHTO's user benefit index (*UBI*), and a comprehensive benefit-cost index, net present value (*NPV*). The performance of the alternative evaluation techniques in resolving two questions establishes the basis for study's findings:

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

COST AND BENEFIT PARAMETERS

Appendix A lists the unit costs used to compute the *NRI*, *UBI*, and *NPV* investment indices. The Appendix A data used in any specific situation varies with the methodology. The *NRI* recognizes transit and HOV user and transit operator benefits. The *UBI* adds other traveler benefits such as accident and congestion reduction. The *NPV* incorporates user and non-user benefits.

User Benefits

Benefits accrue to travelers in the form of savings in travel time and vehicle operating and accident costs. The same amount of travel time savings will have different value to users depending on the type of vehicle and trip purpose. Accident cost savings arise with a switch from auto travel to transit. Vehicle operating expenses are net of taxes and include out-of-pocket and fixed ownership costs.

Travel Time Values

Bradley and Gunn[3] provide a 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. Measured in this manner, travelers choose higher out-of-pocket travel expenditures in order to save time, and this inclination rises as incomes increase. Subsequent elaborations on these studies suggested that time values also vary with trip purpose and the amount of time saved.[4] 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.

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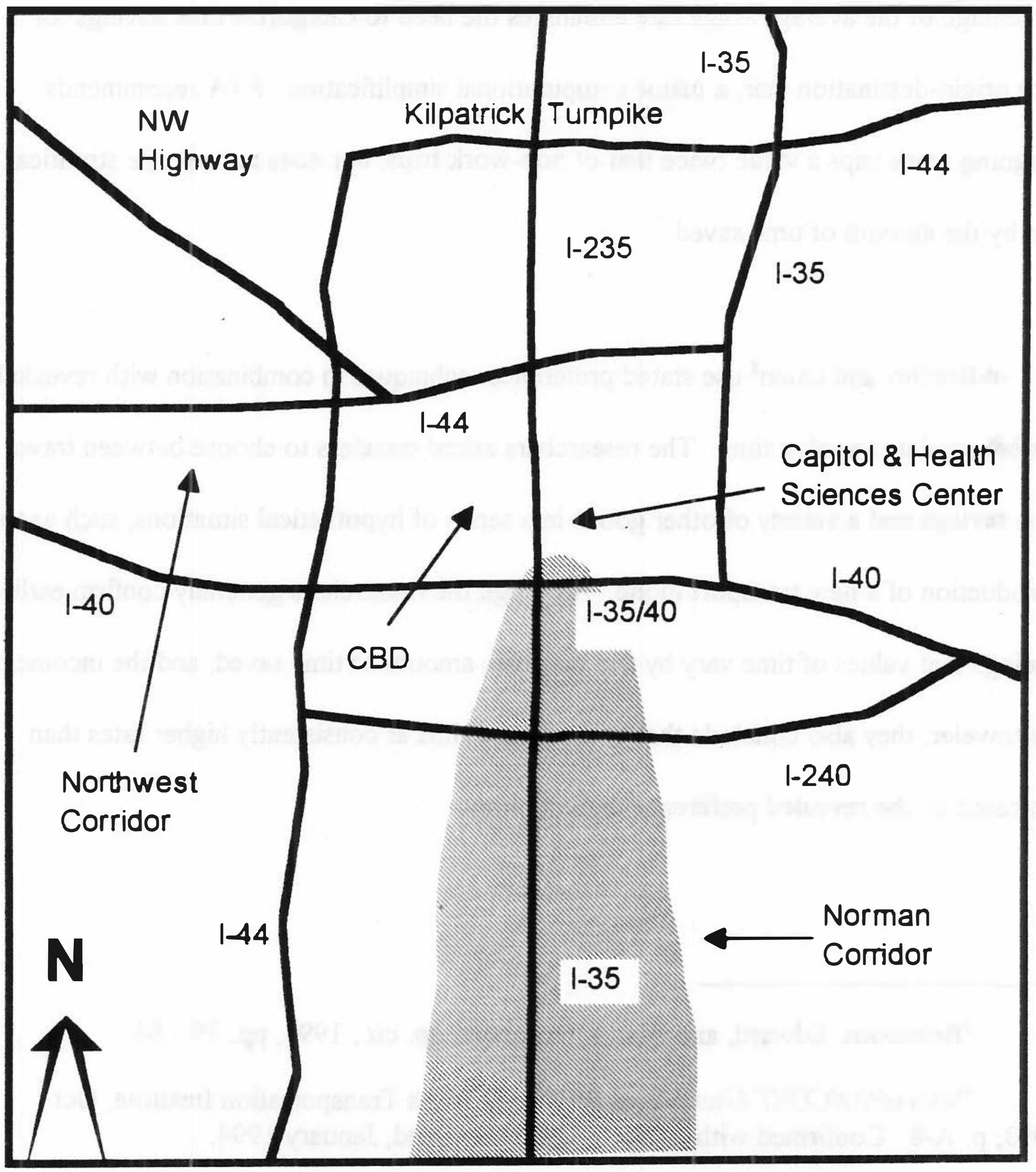
[3]Bradley, Mark A. and Hugh F. Gunn. Stated preference analysis of values of time in the Netherlands, *Transportation Research Record 1285*, 1990, pp. 78 - 88.

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

FIGURE 3.1

OKLAHOMA CITY FIXED GUIDEWAY STUDY CORRIDORS



As noted in Chapter two, Beimborn and Horowitz take exception to larger time savings at differential rates.[5] TTI also abandoned AASHTO's practice in its recent project to automate the AASHTO evaluation procedure.[6] 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 assigning work trips a value twice that of non-work trips, but does not require stratification by the amount of time saved.[7]

Bradley and Gunn[8] use stated preference techniques in combination with revealed preference data to value time. The researchers asked travelers to choose between travel time savings and a variety of other goods in a series of hypothetical situations, such as the introduction of a new transport mode. 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.

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

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

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

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

Different research methods indicate different values of time, although the same factors consistently appear influential. The value assigned to time can have major consequences; user travel time savings typically constitute the principal justification for urban transportation investment. To address uncertainty over parameter values, sensitivity tests should be performed to determine the consequences on project rankings from a range of parameter values. Chapter 6 demonstrates this approach. To obtain an initial value for the investment indices, the 1990 prevailing wage in the Oklahoma City region, $10.50 per hour, is used.

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. Whether 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[9] 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*.[10] 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

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

[10]Federal Highway Administration, May 1984.

estimate of passenger vehicle operating costs under normal commuting conditions for his evaluation of HOV lanes in the Seattle region.[11] 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 3.1. Unit costs exclude taxes. The composite estimate in Table 3.1 is the product of the total cost for each vehicle type, the row sums, and the percent of fleet. Adjusting this unit cost by the consumer price index (gasoline prices fell between 1984 and 1990) yields the cost per mile estimate for private passenger vehicles which appears in Appendix A. Operating costs for commercial automobiles excludes depreciation for reasons which are explained later in this chapter.

Accident Savings

As noted in Chapter two, there is scant evidence of a relationship between traffic volume and accident incidence.[12] 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. CRA estimated these savings to be $0.19 per person-trip shifted to transit.[13]

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

[12]CRA, Sept. 28, 1990, pp. 9 - 12.

[13]CRA, ibid.

Specifying accident savings benefits as a function of the number of trips on a particular mode complicates multimodal investment studies. Travel demand theory holds that travelers weigh certain factors such as travel time, cost, safety, and convenience in arriving at a choice of mode, destination, path, and departure and arrival times. To model these choices, analysts combine different modal qualities into an expression of *generalized cost* from which trip distribution and mode split impedances are developed. With the accident benefit specified on a per trip basis, it becomes a consequence of mode choice rather than a factor in the traveler's decision. If the accident benefit of choosing transit cannot be included in the generalized cost expression, travel models may produce irrational results, e.g. mode share may decrease with a decrease in trip cost.

Another procedure for incorporating accident benefits is the one employed in the MicroBENCOST program. Accident rates, which include vehicle-miles in the expression, decline with improvement of the transportation system. *MicroBENCOST* multiplies the change in the accident rate (accidents per vehicle-mile) by the change in vehicle-miles by the cost-per-accident to obtain accident benefits. Accident cost-per-vehicle-mile can be included in generalized cost as a component of vehicle operating costs. Since lower accident costs presumably translate into lower auto insurance rates, insurance expenses in Table 3.1 should be removed before estimating vehicle operating costs. If insurance expenses remain in vehicle operating costs, and continue to be expressed on a vehicle-mile basis, transportation improvements which increase vehicle-miles of travel might show negative accident benefits even if the improvement results in a lower accident rate.

Multimodal major investment studies require a strict accounting of modal cost differences. By assumption travelers are fully informed about the costs of the different modes, including the accident benefit obtained with a shift from auto travel to public transportation. Payment for this benefit occurs through fares and subsidies. To obtain rational results, the generalized costs confronting travelers must reflect as closely as possible all the consequences of the alternatives available. In the financial efficiency test, benefits calculated from generalized costs are compared to construction costs. A separate calculation of accident benefits violates the rules of that test by double-counting, since travelers pay accident costs either through transit subsidies or vehicle operating costs (insurance included). Multimodal studies where safety improvement is not part of the justification can ignore accident costs altogether as long as there is no change in the accident rate.

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 on goods and services. The *substitution effect* predicts that reductions in transportation costs lead to increased commercial travel.[14] Yet, capturing this basic relationship lies beyond the capabilities of the current generation of travel demand models. Most studies utilize a trip table developed from a single land use plan to estimate total travel in a future horizon year[15] 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.

Urban travel simulation models predict two counterintuitive commercial traffic outcomes from a reduction in congestion: vehicle-hours-of-travel (VHT) and vehicle-miles-of-travel (VMT) will both decrease. This outcome arises from the way trips and vehicles are currently defined. Most likely VHT and VMT would increase with a reduction in congestion as business substitutes transportation for other factors of production. The benefit of increasing travel should equal the income increases which accompany larger service areas. Since models will not allow measurement of the income effect, the cost savings should be estimated by valuing VMT and VHT reductions at the full cost to the operator. Benefits estimated in this manner are conservative since there is no allowance for induced travel or higher labor productivity. Labor costs in particular should reflect actual wage rates.

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

[15]Beimborn and Horowitz, *op. cit.*, pp. 71-76.

TABLE 3.1

VEHICLE OPERATING AND OWNERSHIP COSTS: OKLAHOMA CITY

Vehicle Type	Percent of Fleet[b]	Unit Costs (1984 cents per mile)[a]					
		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 With Depreciation							= 26.4
Weighted Average Without Depreciation							= 17.9

[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.

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 prevailing wage (or some fraction of it) 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 well known driver wage rates. Urban trip generation models commingle 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, typically intermediate size trucks. Internal-external and external-external both contain tractor-trailer combination trucks. An accurate assessment of the benefits of transportation improvements must address each vehicle type separately. Table 3.2 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 cited:

FHWA's *Costs of Owning and Operating Automobiles and Vans: 1984*, and TTI's *MicroBENCOST 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*.[16] 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 3.3 contains the unit cost estimates used in this study. These values also appear in Appendix A in the same form, with the exception of passenger car expenses which had to be adjusted to 1990 dollars. Since the TTI data on labor rates for different vehicle types includes vehicle depreciation, the cost per mile excludes this factor to avoid double counting.

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

TABLE 3.2

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: *Monthly Report to Bondholders*, Oklahoma Turnpike Authority, Oklahoma City, years 1988 through 1990; Oklahoma Turnpike Authority, *May 1988 Turnpike Driver Survey: Preliminary Data*; Oklahoma Department of Transportation, *Oklahoma 1991 Traffic Characteristics*.

Annualization Factors

Travel simulation models produce estimates of modal utilization on a typical weekday. Most investment studies require 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, varying by trip purpose. Consequently, converting typical daily travel volumes into annual equivalents requires individual ***annualization factors*** for different trip purposes.

TABLE 3.3

COMMERCIAL DRIVER AND VEHICLE COST BY VEHICLE TYPE

	Operating Cost (cents per mile)		Operating Cost (dollars per hour)	
Vehicle Type	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.

Table 3.4 shows the annualization factors used in this study. The work trip annualization factor equals the number of weekdays in a year less six holidays. 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 averages 172 days per year. Home interview data indicates that school trips constitute 14% of the home-based-other category.[17] 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.[18]

Different factors apply to commercial traffic. Although there is business activity on weekends, most of it is retailing. The literature provides no basis for estimating the extent of weekend retail business related travel (which excludes private trips made to retail establishments), but it is probably modest. With the exception of retail, commercial travel occurs during the work week and has the same annualization factor as private work trips.

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

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

This factor understates the total extent of commercial travel since retailing is not considered.

EVALUATION METHODS

The three evaluation methods examined in this study -- the FTA's new rider index (*NRI*), AASHTO's user benefit index (*UBI*), and comprehensive benefit-cost analysis (*NPV*) -- require different cost and benefit factors in arriving at a final index. Table 3.5 lists each benefit category and shows which figure into the calculation of the three different indices. All the indices include the capital cost of project construction.

New Rider Index

The *NRI* has been in use for many years. The FTA continues to rank competing projects in part on the basis of the *NRI*, which gives it considerable stature as an evaluation measure. On this basis alone the *NRI* warrants detailed examination.

TABLE 3.4

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

The CRA revisions detailed in Chapter two 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. In addition to the standard *NRI*, versions which include the following CRA recommendations will be computed:

1. discounting construction costs on a five year schedule (rather than assuming construction expenditures all occur in a single year); and
2. travel time savings based on local wage rates rather than nationally adopted values.

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 Chapter 6, will reveal the effect of different interest rates on project priorities.

TABLE 3.5

BENEFIT PARAMETERS AND EVALUATION METHODS

Cost/Benefit Parameter	*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
Number of Transit Passengers	X		
Deficits/Subsidies			
Transit Operations	X		X
HOV Operations			X
Auto Parking			X
Transit Passes			X
Air Quality Improvement			X
Noise Reduction			X

User Benefit Index

As with the *NRI*, the AASHTO index focuses on users, ignoring all non-user benefits and costs. Despite this similarity, five assumptions arise from the need to control as many variables as possible when comparing the *NRI* and the *UBI*:

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 summing user benefits for each and every year through a twenty year horizon. The entire stream of costs and benefits over the life of the project forms the basis for judging investment worthiness. Current travel modeling practice in the Oklahoma City region relies on a single forecast year. Development of forecast data for additional years would involve substantial additional effort without contributing significantly 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 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*. Sensitivity tests can be used to indicate the influence certain factors exert over final outcomes.

Comprehensive Benefit-Cost Analysis

The five assumptions 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 two.

CHAPTER FOUR

FORECASTING

A key step in major investment analysis is forecasting future travel volumes. As indicated in Table 2.1, the AASHTO method requires data for the current year and two forecast years. This is the minimum for both the *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. Travel time savings can be stratified into groups according to the amount of the per trip savings.

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. The *UBI* and *NPV* tests require forecasts for two future years as well as establishing base year (1990) conditions, and developing a no build alternative. Ideally all the requisite data for all of the forecast years should be developed. For purposes of this study, travel forecasts for a single year (2005) will be sufficient to identify differences among the evaluation methods.

To assure comparability to the original Oklahoma City Fixed Guideway Systems Study, the additional data generated for the *UBI* and *NPV* indices relied on the original data files, mode split model, and networks. 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.

The Association of Central Oklahoma Governments (ACOG) provided original fixed guideway system study 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.

Proper conduct of the evaluation methods required that new data for all of the alternatives be constructed. 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.

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-Veh. Travel Time					
Out-of-Veh. Travel Time					
Trip Purpose					

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

An unbiased multi-modal analysis requires numerically consistent but separate trip tables for the highway and transit modes. Figure 4.3 illustrates the general method of developing the trip tables. The total number of trips assigned to all modes was held constant for all forecasts, resulting in an understatement of total benefits since latent travel demand is not addressed.[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.

The block labeled "2005 Work Person-Trips" in Figure 4.3 actually refers to the 2010 home-based-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 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. Al variations among the trip tables result from network differences as manifest through the mode split analysis. Additional detail on the travel forecasting process can be found in Putta.[3]

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

[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*

GENERALIZED COST

The trip tables for each alternative differed according to network characteristics and travel impedances. Travel impedances derive from a generalized cost function and network characteristics. Generalized cost incorporates the expenses, monetary and non-monetary, associated with making a trip over a particular network by a particular mode.

Economic theory holds that a decrease in the cost of travel by a mode should result in increased utilization of that mode. Actual modeling practice does not guarantee this outcome, a particularly vexing problem in multimodal studies. Given a fixed trip table, increases in the use of one mode occur at the expense of other modes. Furthermore, decreases in the use of a mode reduce its generalized cost which should through successive adjustments result in a new equilibrium in which all modes experience somewhat higher utilization. In practice this does not occur since there is no provision for latent travel demand and the transit and highway trip tables, once separated, do not again change in a single model run. Close examination of the modeling results in this study provide an example of the problem. The introduction of improved transit service results in higher transit utilization and lower auto drive-alone use even though the shift in traffic

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Trips, Masters Thesis, University of Oklahoma, Norman, 1994.

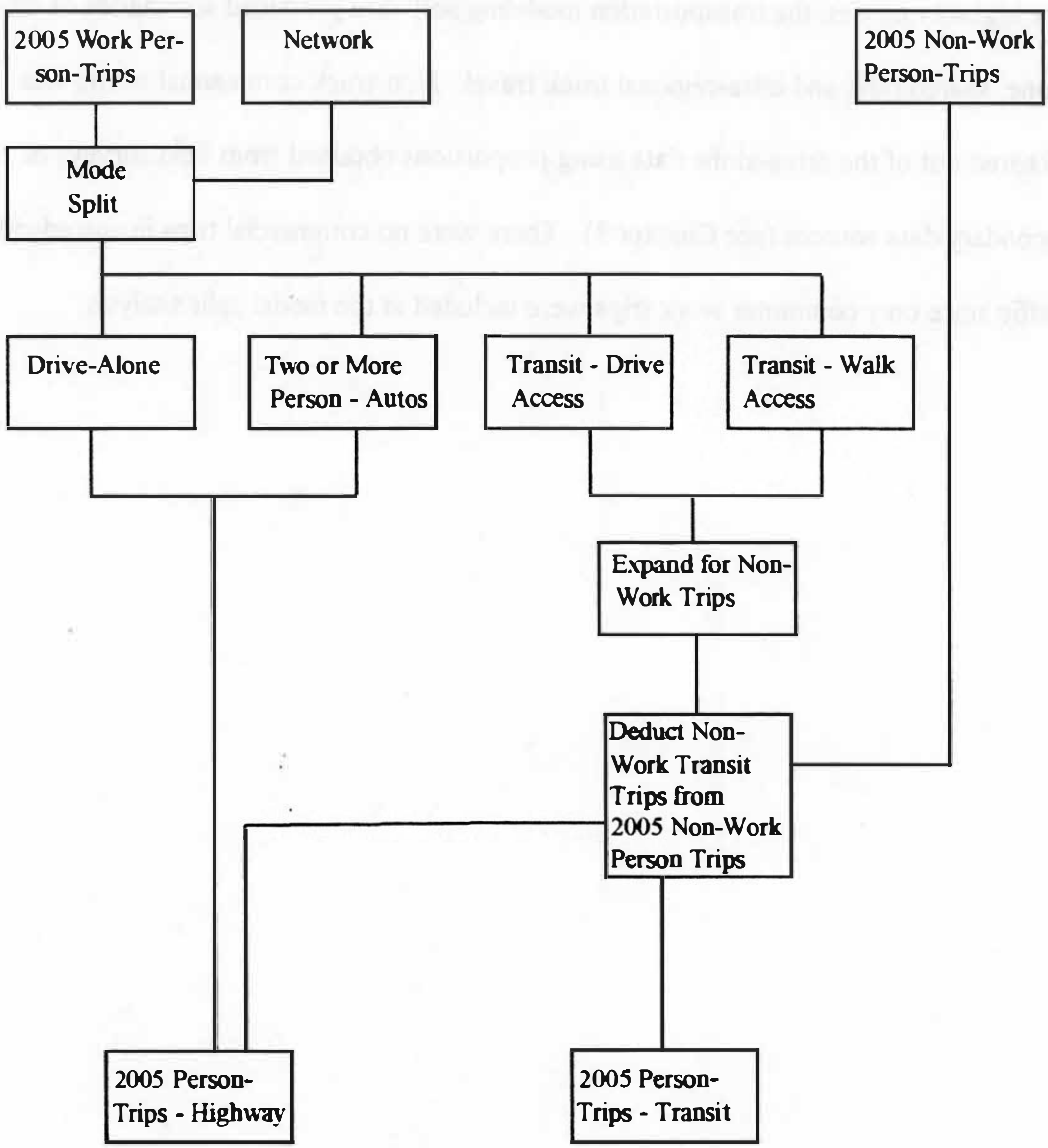
from highways to transit reduces the cost of driving alone.[4]

Highway and transit trips were separately assigned to their respective networks. For highway modes, the transportation modeling software produced summaries of drive-alone, shared ride, and intra-regional truck travel. Non-truck commercial traffic was factored out of the drive-alone data using proportions obtained from field surveys or secondary data sources (see Chapter 3). There were no commercial trips in shared-ride traffic since only commuter work trips were included in the modal split analysis.

[4]Beimborn, Edward, and Alan Horowitz, *Measuring Transit Benefits*, University of Wisconsin - Milwaukee, 1993.

FIGURE 4.3

CONSTRUCTION OF TRIP TABLES



CHAPTER FIVE

COMPUTING THE INDICES

The average daily demand forecasts listed in Appendix B represent the most likely travel volumes and mode splits in the year 2005 based on standard FTA generalized costs for path building. Appendix C contains the year 2005 travel forecasts after annualizing and transforming the data using the procedures and factors described in Chapter 3. Multiplying the Appendix B data by the cost factors in Appendix A according to certain methodological rules yields the different investment indices under study. The *NRI* requires only data on transit use, whereas the AASHTO index (*UBI*) uses data for both highway and transit modes. The benefit-cost index (*NPV*) also uses the AASHTO database plus additional data on non-user costs such as noise and air pollution.

NEW RIDER INDEX

The *NRI*s calculated in the original Oklahoma City Fixed Guideway System Study differ from the indices in this analysis in three ways. First, the original study did not have a no-build option which this study does. Second, the *NRI*s reported in this study incorporate some CRA recommendations, such as those related to discounting capital costs. Finally, the original study used slightly different path building criteria and network configurations.

Two different sets of travel time values were examined: (1) according to FTA specifications ($4.00 per hour for work trips, $2.00 per hour for non-work), and (2) at a fraction of the prevailing wages. In either case the relationship between the values was the same: non-work travel was one-half the value of work travel. Consequently, changing the value of time does not affect the ranking of the alternatives but does affect the absolute magnitude of the cost effectiveness index.

The original Oklahoma City Fixed Guideway Systems Study provided estimates of annual operating and maintenance (O&M) costs for all build options. To synthesize no build O&M costs, the unit cost per transit service-mile for the TSM option was multiplied by service-miles for no build. The CRA analysis determined that O&M costs of the sort utilized in the Oklahoma City study overstate the actual social costs of the options, and recommends using instead changes in subsidies. Chapter 6 examines the effect of this alternative procedure.

CRA also recommends spreading project capital costs over five years to more accurately reflect actual construction times and cash flows.[1] Appendix D shows the capital costs scheduled in the manner recommended by CRA, and converted to annual equivalent amounts using a 10% discount rate.

Table 5.1 shows two sets of *NRI* values for the alternatives: one with a TSM

[1]CRA, *How the timing and proper discounting of costs and benefits affects the value of and application of the UMTA cost-per-new-rider threshold*, (unpublished memorandum to UMTA), September 24, 1990.

benchmark (original plus types 1 and 2), and a second with a no-build benchmark (types 3, 4, and 5). None of the alternatives, including the TSM option, approach FTA's $6.00 per new rider threshold regardless of the type of *NRI* version used, although there is precedent for FTA funding of projects with cost effectiveness values substantially in excess of $6.00.[2] Table 5.1 also illustrates the importance of using the no build option as a benchmark, since it reveals that the TSM option is inferior to all other alternatives except LRT-NW, an outcome which would not be apparent with a TSM benchmark.

USER BENEFIT INDEX

Table 5.2 contains the *UBIs* developed according to AASHTO specifications except for the few specific features already noted. In contrast to the FTA regulated cost effectiveness analysis, which showed none of the projects to be worthy of investment (although LRT-NOR had the lowest index value), the user benefit analysis reveals two financially attractive options: HOV-NOR and HOV-NW, with the former clearly superior. Crossmodal impacts and the no build benchmark account for the difference in the *NRI* and user benefit results. Whereas the FTA index incorporates only transit benefits and costs, the user benefit index considers impacts on highway users as well as transit users.

[2]Zimmerman, Samuel L., UMTA and major investments: Evaluation process and results, *Transportation Research Record 1209*, 1989, pp. 32-36.

TABLE 5.1

COST EFFECTIVENESS INDICES

	Average Cost per New Rider Attracted to Transit (dollars)					
Alternative	**Original**	**Type #1[a]**	**Type #2[b]**	**Type #3[c]**	**Type #4[d]**	**Type #5[e]**
TSM				**23.86**	**22.78**	**22.03**
LRT-NOR	**120.32**	**12.49**	**12.45**	**15.80**	**14.75**	**14.00**
LRT-NW	**86.67**	**57.35**	**56.85**	**33.78**	**32.60**	**31.86**
HOV-NOR	**4.14**	**13.63**	**13.63**	**19.95**	**18.91**	**18.16**
HOV-NW	**7.94**	**19.09**	**19.02**	**22.00**	**20.95**	**20.20**

[a]TSM benchmark. Based on $4.00 per hour work trip travel time, and $2.00 per hour for non-work travel time.

[b]TSM benchmark. Based on prevailing wage (see Appendix A).

[c]No build benchmark. Based on $4.00 per hour for work trip travel time, and $2.00 per hour for non-work travel time.

[d]No build benchmark. Based on prevailing wage (see Appendix A).

[e]No build benchmark. Based on prevailing wage (see Appendix A) and change in O&M subsidy rather than total O&M cost.

TABLE 5.2

USER BENEFIT INDICES

	Millions of 1990 dollars				
Alternative	**Benefits to Non-Switchers**	**Benefits to Switchers**	**O&M Cost Savings**	**Capital Costs**	**Net User Benefit**
TSM	**$25.2**	**$0.1**	**($2.7)**	**$4.9**	**$17.7**
LRT-NOR	**$22.5**	**$0.3**	**($4.7)**	**$40.8**	**($22.7)**
LRT-NW	**$10.5**	**$0.2**	**($8.9)**	**$30.4**	**($28.6)**
HOV-NOR	**$159.3**	**$3.5**	**($7.4)**	**$11.4**	**$143.9**
HOV-NW	**$92.9**	**$0.9**	**($8.2)**	**$15.3**	**$70.3**

The values in Table 5.2 come from a cross-classification structure which distinguishes auto from truck traffic, and commercial from private travel. This disaggregation allows use of actual costs for commercial travel, regardless of mode used, instead of the fraction of the wage rate used for non-commercial travel. User cost savings derive from the generalized cost function in Eq. (5.1).

$$GC = \frac{(IVTT)(VOT) + (OVTT)(VOT) + (VMT)(VOC)}{Person\ Trips} \tag{5.1}$$

where

GC = generalized cost

IVTT = in-vehicle travel time

OVTT = out-of-vehicle travel time

VOT = value of time

VOC = vehicle operating cost

VMT = vehicle miles of travel

As is evident in Table 5.3, highway user impacts overwhelm transit user benefits even when the improvement is to the transit system.

With any transportation improvement, benefits accrue to three separate groups: (1) travelers who continue to use the mode they did before the improvement, (2) travelers who travel on a mode when they did not travel at all before the improvement (latent demand), and (3) travelers who switch from one mode to another as a result of the improvement. Unimodal studies treat travelers as existing or new and calculate consumer surplus as in Fig. 2.1. In multimodal studies using fixed trip tables, all new users of a mode come from other modes. Figure 5.1 illustrates how to estimate these benefits in a two mode environment with a fixed trip table when one mode (transit) is improved. Prior to the transit improvement, the travel market is in equilibrium; highway travelers perceive price equal to p_1 which results in a volume of H_1, and the transit price is c_1 with volume equal to T_1. No one can switch modes without incurring a higher cost. A transit improvement has the effect of increasing transit capacity resulting in a new supply curve, S_T'. The new supply curve leads to a lower transit price c_2 and higher volume T_2. Since the new transit travelers diverted from highway modes, such that $(T_2\text{-}T_1)=(H_1\text{-}H_2)$, the new, lower demand curve, D_H', for highway use results in less congestion and consequently a lower perceived price, p_2. Ordinarily, the lower highway price would bring new travelers into the market, for example $H_3\text{-}H_2$ with benefit equal to $0.5(H_3\text{-}H_2)(p_1\text{-}p_2)$. However, the fixed trip table assumption prevents this outcome. The lightly shaded area in the highway mode diagram indicates the benefit of the transit improvement to highway users who do not switch to transit, algebraically equal to $(p_1\text{-}p_2)H_2$. In the case of transit, benefits to travelers who do not switch are $(c_1\text{-}c_2)T_1$, shown as the lightly shaded area in the transit portion of the diagram.

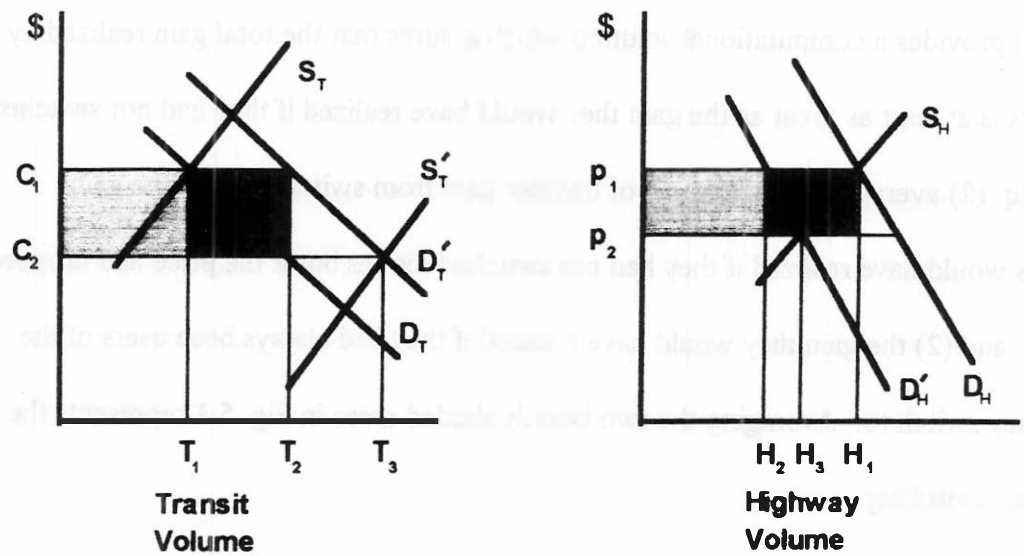
TABLE 5.3

USER BENEFITS BY TYPE

	Millions of dollars				
Beneficiary	**TSM**	**LRT-NOR**	**LRT-NW**	**HOV-NOR**	**HOV-NW**
Private Automobile	**$13.9**	**$12.7**	**$4.5**	**$70.7**	**$45.4**
Commercial Automobile	**$3.0**	**$3.0**	**$1.4**	**$14.8**	**$14.6**
Transit	**$0.5**	**$1.3**	**$1.7**	**$0.5**	**$0.8**
Truck	**$8.0**	**$5.8**	**$3.1**	**$76.7**	**$33.0**

FIGURE 5.1

MEASURING BENEFITS IN A TWO MODE ENVIRONMENT



The benefits to travelers who divert from highway to transit use are computed using the rule of halves:[3]

$$0.5(H_1 - H_2)[(c_1 - c_2) + (p_1 - p_2)] \qquad \textbf{(5.2)}$$

Eq. (5.2) provides a computational solution which assures that the total gain realized by switchers is at least as great as the gain they would have realized if they had not switched at all. Eq. (2) averages two measures of traveler gain from switching: (1) the gain travelers would have realized if they had not switched modes but if the price had dropped anyhow, and (2) the gain they would have realized if they had always been users of the mode they switch to. Averaging the two heavily shaded areas in Fig. 5.1 represents the gain from switching.

A fixed trip table is one in which the sum of the highway and transit person-trip volumes before and after the improvement is exactly the same. A fixed trip table violates economic principles which hold that the lower overall price level resulting from an increase in transportation capacity should lead to a higher overall level of travel. If travel models permitted this outcome, the benefits to new transit travelers would equal the triangular area $0.5(c_1-c_2)(T_3-T_2)$.

[3]Button, K.A., *Transport Economics*, 1993, p. 182 - 184.

BENEFIT-COST ANALYSIS

The benefit-cost methodology differs from the AASHTO user benefit analysis in three ways: (1) different generalized cost functions; (2) accounting for non-user benefits; and (3) a separate determination of investment worthiness for each financial participant. In the benefit-cost framework, user benefits include travel time and out-of-pocket expenditures, with out-of-vehicle time weighted 1.5 times to reflect the greater impedance most studies indicate travelers associate with walking, waiting, and transferring.[4] AASHTO recommends valuing time savings of similar magnitudes and trip purpose at the same rate. Benefits are further distinguished by whether they are local or non-local. Non-user benefits include air quality improvement and noise and vibration reduction.

Financial perspectives refer to the populations risking money in the proposed investment. The benefit-cost test in this context is the financial efficiency test discussed in Chapter one. Performing such a test requires disaggregating total benefits according to whom the benefits accrue, as shown in Table 5.4. A separate benefit-cost test is performed for each group, with the benefits realized compared to the costs born by that group. A project which is worthy of investment from one perspective but not from another indicates the existence of transfer payments.

[4]Beimborn and Horowitz, *op. cit.*, pp. 71-76.

Funding Scenarios

Benefit-cost analysis requires that the source and amount of funding be specified. Table 5.5 shows two funding scenarios for the five Oklahoma City fixed guideway alternatives. All financial participants share equally in the project's cost.

Local governments typically raise money for major capital investments through one of two mechanisms: general obligation bonds, and special revenue sources such as local option sales taxes and hotel/lodging taxes. Revenue bonds are occasionally used when an investment generates income, as in the case of toll roads and bridges.

In addition to bond financing, states have available a broad and rich tax base from which to draw money for capital investment. Funding sources include the general fund, deriving its revenues from non-earmarked taxes, and, in the case of highway improvements, from motor fuel taxes. The federal government finances urban transportation improvements through one of two possible funding sources: the Highway Trust Fund, supported by earmarked federal motor fuel taxes, and the general revenues of the Department of Treasury.

TABLE 5.4

BENEFITS OF THE OKLAHOMA CITY FIXED GUIDEWAY ALTERNATIVES

	Millions of dollars				
	TSM	**LRT-NOR**	**LRT-NW**	**HOV-NOR**	**HOV-NW**
Local User:					
Private Auto	$10.7	$10.7	$3.3	$59.6	$36.7
Commercial Auto	$1.6	$2.3	$1.0	$8.9	$8.8
Commercial Truck	$2.5	$2.8	$1.2	$55.8	$12.1
Transit	$0.3	$1.3	$0.4	$0.5	$0.8
Non-Local User:					
Private Auto	$3.1	$1.7	$1.1	$7.6	$7.8
Commercial Auto	$1.4	$0.8	$0.5	$5.9	$5.8
Commercial Truck	$5.5	$2.9	$1.9	$21.0	$20.9
Non-User					
Parking Subsidies	$2.8	$6.0	$3.0	($5.2)	$3.3
Transit Subsidies	($2.7)	($4.7)	($8.9)	($6.6)	($7.6)
HOV Operating Costs	$0.0	$0.0	$0.0	($0.8)	($0.5)
Air Pollution	$0.5	$0.7	$0.2	($2.8)	($3.7)
Noise and Vibration	$0.0	$0.1	$0.0	$0.0	$0.1
TOTAL	$25.7	$24.6	$3.5	$143.8	$84.4

TABLE 5.5

CAPITAL COST FUNDING SOURCES

	Scenario 1			Scenario 2		
Alternative	Local	State	Federal	Local	State	Federal
TSM	GO		GT	GO		GR
LRT-Nor	GO		GT	GO	GR	GR
LRT-NW	GO		GT	GO	GR	GR
HOV-NOR	GO		GT	GO	GR	GR
HOV-NW	GO		GT	GO	GR	GR

GO = General Obligation Bonds

GT = Gasoline Tax

GR = General Revenue

Scenario One

In scenario one, federal revenues come from gasoline taxes, which are returned to the states according to a formula. This produces a federal fiduciary responsibility to gasoline tax payers, and need for a financial efficiency test. The locality raises money through a general obligation bond issue, and thus confronts the economic and financial efficiency tests.

Local officials test economic efficiency by comparing the sum of local user and non-user benefits from Table 5.4 with the transaction costs of the bond issue. Transaction costs are not known but are likely to be less than the partial totals in Table 5.4, with the possible exception of LRT-NW.

The financial efficiency test compares local benefits to local contributions. Contributors to a general obligation bond issue include all property owners, so benefits must be community-wide. Since there is a general election on the bond issue, political criteria substitute for economic factors in deciding local participation, allowing intra-jurisdictional shifting of tax burden which cannot easily be isolated from the benefit categories in Table 5.4. Financial net present value for the local government appears in Table 5.6. The locality will treat the federal portion of the grant as a benefit. Although HOV-NOR yields the greatest net present value, all of the benefits accrue to users. As indicated in Table 5.4, non-user benefits for HOV-NOR are negative. The net transfer payment from non-users to users is the sum of non-user benefits, $15.4 millions for HOV-NOR, plus the amount of the project cost shifted by users onto non-users in the form of higher property taxes.

The federal financial efficiency test compares benefits to motor fuel tax payers, i.e. users, with project cost (Table 5.7). Absent a budget constraint, both the locality and the federal government would agree on HOV-NOR as the best investment. With a budget constraint, only the TSM option has lower annualized costs and yields positive net benefits. However, all the build alternatives are significantly inferior to HOV-NOR (Figure 5.2).

The state serves as a pass-through agent for the federally-allocated formula grant. The worst outcome for the state is that the project results in a net loss in state output. This is an economic efficiency test. The formula-based nature of the grant assures that the money will be spent somewhere in the state, so the state will not count the amount of the grant as a benefit. The state may or may not count non-user benefits, depending on who bears the cost of transit and parking subsidies, and the severity of the environmental impacts. Adding the user and non-user benefits in Table 5.4 shows that the state gains most with the HOV-NOR option.

TABLE 5.6

FINANCIAL EFFICIENCY TESTS FOR OKLAHOMA CITY FIXED GUIDEWAY ALTERNATIVES UNDER SCENARIO ONE: LOCAL PERSPECTIVE

	Millions of Dollars				
	TSM	LRT-NOR	LRT-NW	HOV-NOR	HOV-NW
Local Benefits	$15.8	$19.3	$0.0	$109.3	$49.8
Less Local Costs (a)	$2.4	$20.4	$15.2	$5.7	$7.7
Plus Federal Grant (a)	$2.4	$20.4	$15.2	$5.7	$7.7
Net Present Value	$15.8	$19.3	$0.0	$109.3	$49.8

(a) equals one-half of the annualized capital cost.

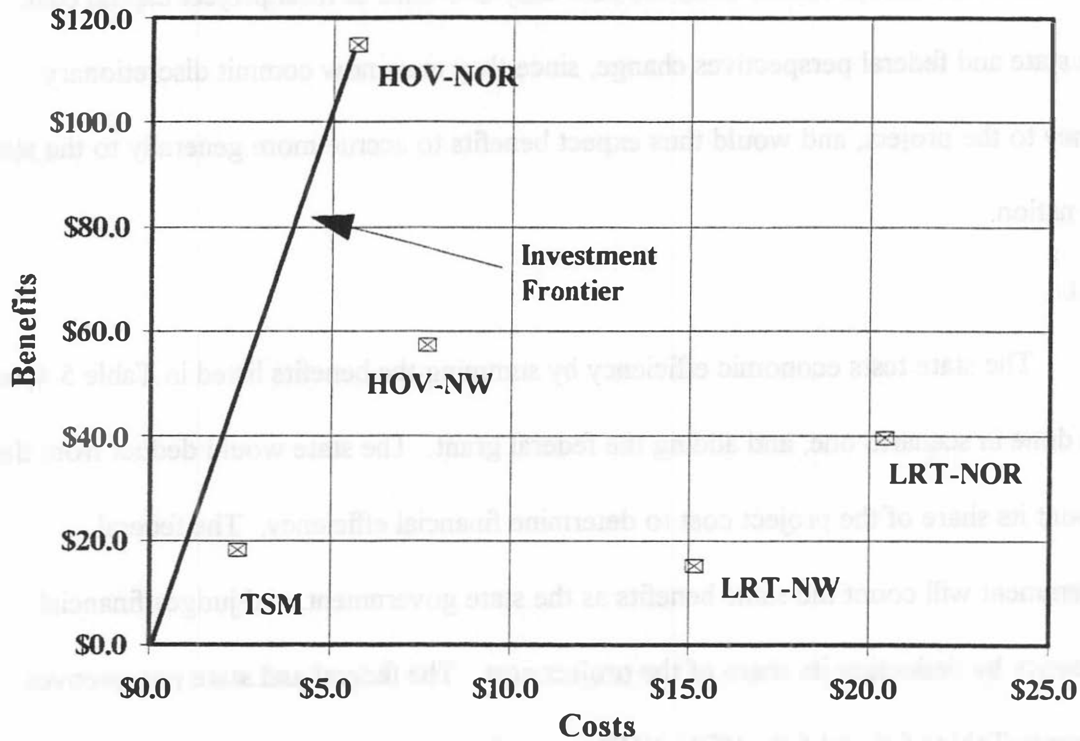
TABLE 5.7

FINANCIAL EFFICIENCY TESTS FOR OKLAHOMA CITY FIXED GUIDEWAY ALTERNATIVES UNDER SCENARIO ONE: FEDERAL PERSPECTIVE

	Millions of dollars				
	TSM	LRT-NOR	LRT-NW	HOV-NOR	HOV-NW
Benefits to Gasoline Tax Payers	$24.7	$21.2	$8.8	$158.8	$92.1
Less Cost to Gasoline Tax Payers	$2.4	$20.4	$15.2	$5.7	$7.7
Net Present Value	$22.3	$0.8	($6.4)	$153.1	$84.5

FIGURE 5.2

INVESTMENT FRONTIER FOR OKLAHOMA CITY FIXED GUIDEWAY ALTERNATIVES



Scenario Two

The second scenario involves three-party discretionary funding with state and federal participation derived from general revenues. The local perspective would be the same as in scenario one except capital costs are now only one-third of total project capital cost. The state and federal perspectives change, since they must now commit discretionary money to the project, and would thus expect benefits to accrue more generally to the state and nation.

The state tests economic efficiency by summing the benefits listed in Table 5.4, as was done in scenario one, and adding the federal grant. The state would deduct from this amount its share of the project cost to determine financial efficiency. The federal government will count the same benefits as the state government, and judges financial efficiency by deducting its share of the project cost. The federal and state perspectives appear in Tables 5.8 and 5.9. HOV-NOR outperforms the other alternatives from all three perspectives using both economic and financial efficiency tests.

TABLE 5.8

FINANCIAL FEASIBILITY TESTS FOR OKLAHOMA CITY FIXED GUIDEWAY ALTERNATIVES UNDER SCENARIO TWO: STATE PERSPECTIVE

	Millions of dollars				
	TSM	**LRT-NOR**	**LRT-NW**	**HOV-NOR**	**HOV-NW**
User Benefits	$25.1	$22.5	$9.2	$159.3	$92.9
Non-User Benefits	$0.7	$2.1	($5.7)	($15.5)	($8.5)
Plus Federal Grant	$1.6	$13.6	$10.1	$3.8	$5.1
Less State Cost	$1.6	$13.6	$10.1	$3.8	$5.1
Net Present Value	$25.7	$24.6	$3.5	$143.8	$84.4

TABLE 5.9

FINANCIAL FEASIBILITY TESTS FOR OKLAHOMA CITY FIXED GUIDEWAY ALTERNATIVES UNDER SCENARIO TWO: FEDERAL PERSPECTIVE

	Millions of dollars				
	TSM	**LRT-NOR**	**LRT-NW**	**HOV-NOR**	**HOV-NW**
User Benefits	**$25.1**	**$22.5**	**$9.2**	**$159.3**	**$92.9**
Non-User Benefits	**$0.7**	**$2.1**	**($5.7)**	**($15.5)**	**($8.5)**
Less Federal Grant	**$1.6**	**$8.9**	**$0.0**	**$0.0**	**$8.9**
Net Present Value	**$24.1**	**$15.8**	**$3.5**	**$143.8**	**$75.5**

CHAPTER SIX

SENSITIVITY TESTS

The Chapter five results can be summarized as follows: none of the Oklahoma City fixed guideway alternatives would be desirable according to FTA's new rider index, while the user benefit and benefit-cost analyses both identified an economically and financially efficient investment, HOV-NOR, which far outperformed the other alternatives. In practice, the object of the sensitivity tests is to see if the preferred alternative might be different under another plausible set of circumstances. Sensitivity tests can also reveal how close two alternatives can be in terms of *NPV* before they must be judged equally desirable. With two of the tests reporting HOV-NOR vastly superior to the other options, and the third test indicating it is the best among five alternatives, it is unlikely that changes in any of the input values will undermine its apparent high return on investment. Dropping the HOV-NOR and the clearly inferior LRT-NW options from the sensitivity tests should allow better assessment of the importance of input variables. In this chapter, only the sensitivity results for TSM, LRT-NOR, and HOV-NW are reported.

Within the context of public decisionmaking, the error tolerance for sensitivity analysis is the amount of variance which can occur in an input before a different project would be selected. The inputs of greatest interest to decisionmakers are those over which they have control, organized into two groups as follows:

Non-User Costs and Policies

1. scheduling capital costs;
2. matching ratios;
3. operating and maintenance (O&M) subsidies;
4. interest rates; and
5. environmental and social unit costs.

User Costs

6. value of time; and
7. vehicle operating costs.

NON-USER COSTS AND POLICIES

Non-user costs and benefits are not perceived by travelers and therefore do not affect travel volumes. Sensitivity tests on these cost elements can reveal effects on investment priorities and project selection. Sensitivity tests should be conducted on all controversial or questionable features of an evaluation procedure, or where substantial uncertainty regarding a parameter value exists.

Spreading Capital Costs over Five Years

The CRA analysis found that the FTA method of estimating annual equivalent capital costs overstated these costs. Appendix D shows the capital costs scheduled over five years, then discounted to present value and converted to an annual equivalent amount in the manner recommended by CRA. All of the indices in Chapter 5 use the annual equivalent capital costs scheduled in Appendix D. The capital costs used to compute cost effectiveness in the original fixed guideway study are higher than the amounts contained in Appendix C even though both sets of values were developed from the same cost estimates. Table 6.1 shows the effect of using unscheduled capital costs.

The FTA index is highly sensitive to capital cost. The TSM option always appears most cost effective when it is available. Without the TSM option, the treatment of capital costs determines project selection. Neither the user benefit nor benefit-cost indices were as sensitive as FTA's cost effectiveness index; the other indices consistently preferred HOV-NW with TSM second and LRT-NOR not financially feasible.

The Importance of Perspective

The rationale for computing benefits and costs for different groups is that perspective can have an impact on project selection. Table 6.2 shows net present value for a benefit-cost analysis of the three build options with the locality paying all of the capital costs instead of sharing costs with the federal government. From the local perspective, LRT-NOR goes from financially efficient to infeasible. Net present value is greatest for HOV-NW, as it was in Chapter five. None of the other perspectives are particularly influenced by who pays the capital costs.

Operating and Maintenance Costs

CRA, in its assessment of FTA evaluation practices, argued that only changes in O&M subsidies should be included in the benefit- cost analysis. Including the total change in O&M costs ignores the fact that users paid for that benefit through their fares, which is a transfer payment, not a real savings. It is for this reason that vehicle operating costs always exclude gasoline taxes when these taxes are used for highway improvements.

Using operating subsidies rather than operating costs reduces the influence of this element. All of the Oklahoma City build options involve higher operating costs and subsidies compared to no build, but costs will rise more than subsidies (see Table 6.3). Since higher O&M costs or subsidies enter the evaluation indices as negatives, increases in either would reduce benefits. Although replacing O&M subsidies with O&M costs would not influence the ranking or decisions rendered on the available options, benefits will decrease for all the options.

TABLE 6.1

COST EFFECTIVENESS WITH FTA ESTIMATED CAPITAL COSTS

	Fixed Guideway	Chapter five Values		Lump Sum Annualization	
Alternative	Study Index	No Build Benchmark	TSM Benchmark	No Build Benchmark	TSM Benchmark
TSM		$ 6.28		$10.96	
LRT-NOR	$86.67	10.70	$12.49	14.86	$11.61
HOV-NW	7.94	11.26	$19.09	12.42	5.57

Based on regulated value of time ($4.00 per hour for work and $2.00 per hour for non-work.

TABLE 6.2

FINANCIAL EFFICIENCY WITH THE LOCALITY PAYING ALL CAPITAL COSTS

	(millions)		
	TSM	LRT-NOR	HOV-NW
Local Benefits	$15.8	$19.3	$49.8
Local Costs	4.8	40.8	15.4
Net Present Value	$11.0	($21.5)	$34.4

TABLE 6.3

ANNUAL OPERATING AND MAINTENANCE COSTS AND SUBSIDIES

	Change in (millions of dollars)	
Alternative	O&M Costs	O&M Subsidies
TSM	$ 3.6	$ 2.7
LRT-NOR	8.1	4.7
HOV-NW	9.3	7.6

Interest Rates

The interest rate affects the annual equivalent capital costs developed in Appendix D. High interest rates make short-range projects with low capital costs more attractive than expensive projects with long construction cycles. The analytic framework does not discount benefits to present value (see Chapter three), so the interest rate has no effect on benefits, only on capital costs. Table 6.4 shows the effect of different interest rates on net present value from the federal perspective for scenario one funding.

Changing the interest rate has no effect on project rankings but does impact LRT-NOR more than the other two options. Table 6.4 shows LRT-NOR varying nearly $21,000,000 in annual net present value with the interest rate ranging from 0% to 20%. The project becomes infeasible at an interest rate of 10%.

Appendix D shows the LRT-NOR option to have heavy expenditures throughout its construction cycle and especially in its early years with mainline construction. High interest rates make the early expenditures more influential. As noted earlier in the section on scheduling capital cost, LRT-NOR is particularly sensitive to the manner in which capital costs are calculated.

TABLE 6.4

EFFECT OF DIFFERENT INTEREST RATES ON NET PRESENT VALUE

	Net Present Value in millions		
Interest Rate	TSM	LRT-NOR	HOV-NW
0%	$23.4	$12.2	$87.5
5%	22.9	6.6	86.0
10%	22.3	0.8	84.5
15%	21.7	(4.4)	83.2
20%	21.1	(8.7)	82.1

Financial efficiency test, federal perspective, scenario one.

Environmental/Social Unit Costs

Environmental and social costs consist of air quality and noise impacts, and subsidies. The effect of transit subsidies versus operating and maintenance costs has already been examined. Air quality and noise costs, and parking subsidies are the subject of this section.

Air Quality

Air quality impacts accrue at the rate of $0.032 per mile of travel. The aggregate benefit is the change in VMT measured against no build multiplied by the air quality unit cost. As is evident in Table 5.4, HOV-NW actually leads to a degradation in air quality since the effect of the project is to increase highway use. Both the TSM and LRT-NOR projects lead to lower levels of air pollution, but not enough to offset the larger quantity of user benefits produced by HOV-NW. Given the error tolerance of a change in project selection, the sensitivity test seeks to determine if there is an air quality unit cost which would make TSM or LRT-NOR more attractive than HOV-NW. Table 6.5 shows the effect on financial efficiency from the perspective of the federal government in scenario two. At about $0.42 per mile, TSM and HOV-NW generate approximately the same amount of net benefit. At $1.00 per mile, HOV-NW is no longer efficient, and LRT-NOR and TSM are about equally attractive.

Performing sensitivity tests of the sort demonstrated here is especially important in non-attainment areas or areas close to thresholds. Were Oklahoma City threatened with loss of federal transportation funds because of air quality standard violations, there might be an additional premium placed on reducing emissions. Project selection would not be affected even if air quality costs accrued at the rate of $1.00 per vehicle-mile, although the analysis indicates a worsening of air quality due to the overall increase in VMT.

There is an alternative to the VMT based method of valuing air quality impacts which uses relates vehicle type, hours of operation, and speed. The preceding analysis indicates a worsening of air quality with the HOV-NW project because VMT rises. But average highway speed also rises which will result in lower emissions for some pollutants. Table 6.6 shows the average speed for automobiles, transit riders, and single and combination trucks for each of the alternatives. There is improvement in every group compared to no-build, with HOV-NW producing the greatest change. Different air quality costs could be applied to individual vehicle types operating at certain speeds.

TABLE 6.5

EFFECT OF DIFFERENT AIR QUALITY UNIT COSTS

Cost per Mile of VMT	*NPV* in millions TSM	LRT-NOR	HOV-NW
$0.01	$23.8	$15.2	$78.1
$0.032 (default)	24.1	15.8	75.5
0.10	25.1	17.3	67.6
0.15	25.9	18.5	61.9
0.20	26.7	19.6	56.1
0.42	30.0	24.6	30.5
0.50	31.2	26.5	21.3
1.00	38.7	37.9	(36.7)

Financial efficiency test, federal perspective, scenario two funding.

TABLE 6.6

AVERAGE SPEED PER VEHICLE TYPE (MILES PER HOUR)

Vehicle Type	No-Bld	TSM	LRT-NOR	HOV-NW
Automobile	25.08	25.41	25.47	27.78
Truck (Single Unit and Combination)	24.65	25.00	24.90	27.57
Transit	8.43	9.55	9.67	9.66

Noise and Vibration

CRA estimated noise and vibration impacts at $0.03 per auto trip diverted to transit. The value is low since automobiles cause less vibration and noise pollution than trucks, and diverting freight traffic to other modes is not realistic with any of the alternatives under consideration. Table 6.7 shows that the number of automobile trips diverted to transit is small compared to the population, and the resulting benefit modest. A one-hundred fold increase in the value of noise and vibration reduction, to $3.00 per automobile-trip diverted, produces little change in project net benefits and no change in project ranking.

Parking Subsidies

One of the largest subsidies conveyed to auto commuters is the value of employer provided free parking.[1] Projects which divert auto trips to transit reduce the need to provide land for parking. Making this land available for other uses would be an efficiency gain. A local survey estimated the annual value of the subsidy at $513 dollars in the Oklahoma City central business district (CBD), and $443 outside the CBD.

[1]Shoup, Donald C., *Cashing out employer paid parking*, U.S. Dept. of Transportation Report FTA-CA-11-0035-92-1, Washington, D.C., Dec., 1992.

TABLE 6.7

CHANGE IN AUTOMOBILE TRIPS AND NOISE AND VIBRATION BENEFITS

	Millions of auto trips per year		Annual
Alternative	Total	Diverted to Transit	Benefit
No Build	589.8		
TSM	588.4	1.4	$41,852
LRT-NOR	586.7	3.1	91,560
HOV-NW	588.1	1.7	63,983

Local perspective, scenario one funding, financial feasibility test.

Table 5.4 indicates that parking subsidies can be a large component of project benefits, particularly for the two light rail alternatives. These benefits were estimated using the upper limit of the parking subsidy, $513, in order to be conservative with respect to the light rail options. The consequences of using higher and lower unit costs are shown in Table 6.8. At ten times the default value ($513),LRT-NOR becomes competitive with HOV-NW as an investment. This indicates that the parking subsidy is most influential where land values and densities are high.

PARAMETERS

Unlike non-user unit costs, user cost parameter affect traveler decisions on paths and modes. A properly conducted sensitivity analysis should develop a new trip tables each time the value of a user cost parameter changes. With three build alternatives, several dozen model runs might be necessary to examine a range of parameter values. This level of effort is not required to demonstrate how to conduct sensitivity tests, nor to determine whether a parameter's value is likely to have a significant effect on project selection. Preliminary sensitivity tests can be conducted without developing new trip tables. Those parameters shown through the preliminary sensitivity tests to significantly influence the evaluation index should be examined further with new trip tables developed from revised generalized cost expressions. The preliminary sensitivity tests and the detailed tests are identical except for the input travel data.

TABLE 6.8

EFFECT OF CHANGING PARKING SUBSIDIES

Annual Value of Parking Subsidy	Net Present Value in millions		
	TSM	LRT-NOR	HOV-NW
$ 400	$ 15.2	$ 18.0	$ 49.1
500	15.7	19.1	49.7
600	16.3	20.3	50.4
1000	18.5	24.9	52.9
5000	40.3	71.3	78.6

Local perspective, financial efficiency, scenario one funding.

The Value of Time

The most critical variable in the entire analysis is the value of time. AASHTO recommends summing travel time savings separately for different income groups and different amounts of time savings per trip.[2] It is difficult to sum travel time savings in this manner. The procedure would involve determining the travel time savings for each origin-destination pair and multiplying by the number of travelers. In a multimodal study, existing travelers on a path must be distinguished from new users. Values of time would vary with zonal characteristics and the amount of savings per trip; as the amount of savings increased, so also would the value of time. To be consistent with the generalized cost functions used in path building and mode split, travel forecasts would have to be disaggregated to distinguish when travel occurred, fleet mix, in-vehicle and out-of-vehicle time, and trip purpose. Organizing the data as recommended by AASHTO involves a substantial amount of time and many computer runs. Identifying the circumstances which might warrant the AASHTO procedure plus the further disaggregation by private and commercial travel required by benefit-cost analysis lies beyond the scope of this study. A simpler procedure employs the aggregate travel time summaries by mode and trip purpose produced by the travel forecasting modeling package. Implementing the AASHTO recommendation might be appropriate when there are two or more closely competing alternatives and significant multimodal elements.

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

The appropriate sensitivity test, given the stated error tolerance, is one which determines if there is any reasonable range over which the value of time can vary which would change project selection. Table 6.9 shows the effect on net present value caused by different values of time for several modes, including trucks, transit, commercial auto travel, and private auto travel. The data is from the AASHTO dataset, which uses the same unit cost for both in- and out-of-vehicle travel time. Each row of the table represents either a doubling or halving of the unit costs reported in Appendix A and which produced the ranking in Chapter five. None of the changes in the value of time taken one at a time affect project ranking; HOV-NW is always preferred, and HOV-NW is always inefficient. With all low values of time, the two efficient alternatives, TSM and HOV-NW, generate approximately the same amount of benefit.

Using the data in Table 6.9, ***elasticities*** relating the change in the value of time to the change in user benefits can be computed:

$$\varepsilon_{vot} = \frac{\%\Delta \; User \; Benefits}{\%\Delta \; Value \; of \; Time} \tag{6.1}$$

The elasticities are shown in Table 6.10. All are inelastic which is not surprising given the mix of modes and travel purposes. The high elasticities for all of the alternatives with respect to private work trips indicate a need for detailed sensitivity tests using new trip tables based on revised generalized cost functions. HOV-NW and TSM benefits also vary significantly with the value of single unit truck time.

TABLE 6.9

VALUE OF TIME SENSITIVITY TESTS

		NPV in millions		
Mode	Value of Time	TSM	LRT-NOR	HOV-NW
Combination Truck	$45.06	$19.4	($21.5)	$ 79.8
	11.27	16.9	(23.3)	65.6
Single Unit Truck	30.02	24.1	(18.1)	106.1
	7.51	14.6	(25.0)	52.4
Commercial Auto	19.50	20.7	(19.7)	86.9
	4.88	16.3	(24.2)	62.0
Private Auto (Work)	10.50	25.5	(14.6)	111.8
	2.63	13.9	(26.7)	49.6
Private Auto (Non-Work)	5.25	22.2	(16.7)	97.6
	1.32	15.5	(25.7)	56.7
All Low Values of Time		6.2	(34.2)	5.1
Default Values of Time		17.7	(22.7)	70.3
All High Values of Time		40.9	0.2	200.9

Default Unit Costs:

Combination Truck	$22.53
Single Unit Truck	15.01
Commercial Auto	9.75
Private Auto (work)	5.25
Private Auto (non-work)	2.63

TABLE 6.10

ELASTICITY OF NET PRESENT VALUE WITH RESPECT TO THE VALUE OF TIME

	Elasticity		
	TSM	LRT-NOR	HOV-NW
Combination Trucks	0.091	-0.053	0.134
Single Unit Trucks	0.356	-0.203	0.510
Commercial Automobile	0.164	-0.132	0.236
Private Automobile (work)	0.435	-0.355	0.590
Private Automobile (non-work)	0.253	-0.265	0.389

AASHTO User Benefit Data

The negative sign on LRT-NOR elasticities results from the overall negative net benefits. LRT-NOR is inefficient at all values of time under the user benefit test, i.e. user benefits are negative. Elasticities compute to be negative since the denominator is always negative in the benefit portion of Eq. (6.1). No travel time values could be found which would change the preferred alternative from HOV-NW under scenario one funding from either the local or federal perspectives.

Vehicle Operating Costs

Table 6.11 reports elasticities for changes in net present value as a result of changes in vehicle operating costs from the federal perspective under scenario two funding. As is apparent, neither TSM nor LRT-NOR generate any significant vehicle operating cost savings for trucks. There is a change of signs on the elasticity for auto operating costs. As auto operating costs rise, TSM benefits also rise. For LRT-NOR and HOV-NW, the increase in auto operating costs reduces benefits. Highway vehicle operating costs impact the HOV-NW option the most. HOV-NW is the preferred option over a wide range of vehicle operating costs. LRT-NOR is always the least preferred option, but always remains feasible.

TABLE 6.11

ELASTICITY OF NET PRESENT VALUE[a] WITH RESPECT TO VEHICLE OPERATING COSTS

	Elasticity		
Vehicle Type	TSM	LRT-NOR	HOV-NW
Combination Truck	0.000	0.000	-0.039
Single Unit Truck	0.000	0.000	-0.124
Automobile	0.085	-0.006	-0.299

[a]Financial efficiency test, federal perspective, scenario two funding.

CHAPTER 7

FINDINGS

This study has demonstrated that different evaluation measures, parameter values, and perspectives can produce different investment decisions. In the Oklahoma City Fixed Guideway System Study, the FTA evaluation framework suggests none of the alternatives is worthy of investment, although LRT-NOR ranks highest some of the time, and TSM ranks highest under slightly different circumstances. The user benefit and benefit-cost analyses show HOV-NOR to be best alternative. The sensitivity tests showed that the preferred alternative under and *UBI* are unlikely to be influenced by a small number of small parameter changes. The *NRI* was clearly sensitive to capital costs.

In Chapter 3, the two questions proposed -- are there projects in either corridor worthy of investment? and, is the choice of project affected by the evaluation method? -- can now be answered. The FTA evaluation process did not find any project attractive for investment, whereas both the user benefit analysis and benefit-cost study found several. Second, the FTA procedure resulted in a different investment decision than the user benefit and benefit-cost analyses.

A number of methodological innovations were tested in this study. These include distinguishing local and non-local benefits and costs, accounting for the effect proposed financing has on perspectives, calculating consumer surplus under a fixed trip table assumption, disaggregating benefits and costs by vehicle type and trip purpose, including non-user costs and benefits in the calculations, and use of different generalized cost functions. Findings on these methodological innovations are presented in five sections:

1. Evaluation processes and indices;
2. modeling and data;
3. commercial traffic;
4. Oklahoma City alternatives; and
5. recommended practices

EVALUATION INDICES

Since different evaluation indices can lead to different investment priorities, decisionmakers could confront conflicting information on the merits of alternatives. When such situations arise, analysts should recognize that the *NRI* produces outcomes different than those obtained from user benefit and benefit-cost analyses under very plausible conditions. The *UBI* and *NPV* index have solid theoretical foundations; the *NRI* mixes different measurement units in a peculiar formula using an unusual benchmark to arrive at an investment statistic loosely characterized as the average cost per new rider. Problems with the FTA index were itemized in Chapter two. These shortcomings cannot be solved by implementing the CRA revisions.

The *UBI* and *NPV* measures produced the same project rankings but did not agree on which alternatives were efficient. The *UBI* found all the LRT options to be inefficient, whereas the *NPV*, by including the income effect of the federal grant, determined that only LRT-NW was inefficient.

Benefit-cost analysis provides more information than the *UBI*. If financing is an issue, *NPV*, computed for each financial participant, can help establish levels of participation. *NPV* can also indicate the presence of transfer payments which may be germane to project selection.

The AASHTO procedure has much to recommend it. Even if a more comprehensive benefit-cost analysis is conducted, a user benefit analysis will be a major component. The *UBI* offers a good foundation upon which to build a comprehensive benefit-cost analysis procedure. Specific methodological recommendations appear later in this chapter.

MODELING AND DATA

Travel modeling for multimodal major investment studies requires consistency among the impedances used in trip distribution, mode split, and converting travel savings into monetary units. Current modeling definitions make strict economic interpretations of travel model output difficult. For example, transforming the trip assignments from the form produced by the model into a form useful for distinguishing private and commercial travel required original data and unvalidated assumptions. Also, trip purpose definitions which combine private and commercial auto travel into a single non-home-based category means that both sets of users must confront the same impedances. These impedances should vary by trip purpose and vehicle type.

Multi-modal studies would also benefit if modeling programs allowed more complete integration of the transit and highway networks. The modeling program used in this research allowed carpools and other vehicles to be assigned to the same network, whereas transit had its own network and separate trip table. Fully integrated transit, highway, and truck networks would permit much easier analysis of interactions among the modes.

The greatest modeling difficulty of all is simply the amount of time involved in setting up different model runs. Even where model runs might be warranted, such as in sensitivity tests on the unit cost parameters, analysts are deterred by the effort required to produce the additional data. This problem is not easily or quickly solved.

Model development cannot advance without supportive data collection efforts. Data on local commercial travel patterns is almost totally unavailable. External categories include only autos and trucks, and these are modes, not trip purposes to which travel value can be assigned. Non-user social unit cost data is also scarce.

Data on traveler perception of modal safety would help in better estimating the accident benefit derived from mode or route switching. CRA's recommended value of $0.19 per auto trip diverted to transit is unsatisfactory for benefit-cost studies since it cannot be incorporated into generalized cost. The value of accident reduction can only be determined if accident cost is expressed on a per-mile basis.

COMMERCIAL TRAFFIC

This study placed great emphasis on distinguishing commercial traffic and its value from private traffic. Commercial traffic refers to trip-makers who are paid for their time while traveling. These trips, in the procedures outlined in this report, are valued at a higher per hour rate than non-commercial trips, for the reasons outlined in Chapter three. Principal beneficiaries of this treatment are truck and commercial travel. The values assigned to commercial and private travel are key policy issues. One reason HOV-NOR appears to be such an attractive investment is its location in an interstate highway corridor with high commercial traffic volumes.

OKLAHOMA CITY FIXED GUIDEWAY ALTERNATIVES

Although the analysis showed HOV-NOR to be significantly superior to all other alternatives, the findings do not provide a clear signal to proceed with the project. There are two reasons to exercise caution: the alternatives considered were too limited, and the modeling conventions used violated some recommended procedures.

The Norman corridor HOVway appears to be the best investment when compared to other possible transit projects in the region, but it was not compared to constructing a general purpose lane on I-35 at what would likely be a lower cost. There are institutional impediments to conducting multimodal studies when planning, construction, and operating responsibilities are divided among different agencies, as was the case in Oklahoma City. Since FTA funded the Oklahoma City study, all the alternatives contained significant transit components. Another agency with different funding might develop alternatives for the same corridors in which transit plays little if any role. Proceeding with HOV-NOR, the preferred alternative, depends on whether the region's goal is to invest in transit services as a means of increasing welfare, or to invest in projects which net the greatest increase in user and/or social benefit. The former objective implies the region seeks a welfare goal which is not fully captured in the benefit-cost framework, such as might arise from a desire to redistribute income and influence development patterns, often justifications for rail transit. The data developed in this study does not allow the second objective to be addressed.

The other reason for caution is that some of the analytic procedures deviate from recommended practice. In some instances the impedances used to develop trip tables differed from those used to calculate benefits. The *UBI* and *NPV* analyses are based on conditions in a single forecast year rather than on an expenditure and benefit stream over a twenty year period. Some of the cost data for the no-build option had to be estimated since no-build was not included in the original fixed guideway study. Most of the unit costs were taken from secondary sources. The two field surveys conducted in connection with this study (value of the parking subsidies, and the commercial/non-commercial vehicle-type proportions) are not sufficiently reliable given the sensitivity of the results. And, not all indicated sensitivity tests were performed.

RECOMMENDED PRACTICES

The preferred evaluation procedure is the comprehensive, multimodal benefit-cost analysis described as the economic and financial efficiency tests in this study. The AASHTO procedures for calculating user benefits are sound and can be followed with two exceptions. One is that the method of calculating benefits to travelers switching modes illustrated in Fig. 5.1 replace the AASHTO procedure. The second is that user benefits must be calculated using the same impedances as employed in the trip distribution and mode split analyses.

The scarcity and poor quality of non-user unit cost data does not obviate the need to assign some value to non-user impacts. Extensive sensitivity testing on these unit costs will have to substitute for good primary data for the foreseeable future.

Modeling

Good evaluation studies require many model runs. Comprehensive data is required for three points in time, current, ten years, and twenty years, with reasonable interpolations for intermediate years. AASHTO recommends a method for interpolating intermediate years. All critical intermediate year variables should be individually forecasted, requiring decisions on the timing of construction and assumptions regarding trends in VMT and VHT.

The no-build option should be conservative; the existing network without any improvement would be best. No-build is not intended to represent a desirable or even feasible future state, but rather to provide the best vantage point from which to view future benefits and costs.

Travel Time Savings

The value of time is clearly the critical variable in determining user benefits, which more often than not will constitute the major project justification. Policy issues regarding the relative importance of values assigned to commercial and non-commercial travel have already been discussed. Contradictory research findings on the value of time lead some analysts to conclude that benefit-cost analysis is intractable. The most practical approach is to adopt the locally prevailing average wage, from which a set of values similar to those in Appendix A can be developed. After obtaining an initial solution, extensive sensitivity testing under a variety of scenarios will reveal how an alternative performs with different policies in place.

The AASHTO method of estimating travel time savings is the most conservative approach and therefore recommended. Aggregating minute interzonal travel time savings which are well within model error tolerance risks selecting projects which are from the user's perspective inefficient. Implementing the AASHTO method requires more and better data and model aggregation procedures.

Perspective

The substantial benefit surplus generated by HOV-NOR should not obscure the fact that additional non-user costs amount to $16 million each year. These non-users would quite rationally resist any investment (especially where they are contributing some of the money) which reduces their welfare unless provided compensation commensurate with the loss. If users escape compensating non-users for these additional costs, users enjoy a windfall and non-users suffer a loss, which is neither optimal nor desirable when economic efficiency is the objective. As long as the price of travel as captured in generalized cost does not reflect all project impacts, users to some extent shift costs to non-users except in the rare instance where there are no non-users.

Separate determinations of investment worthiness by each financial participant invites further disaggregation by interest group and affected party. At one level this is healthy since presumably better information leads to better investments. But the practice also invites abuse, providing another venue which can be used by parties opposed to certain transportation projects.

The procedure in Chapter five used political perspectives to illustrate the effect of different perceptions of benefits and costs. Government perspectives are a compromise between total aggregation, as in user benefit analysis, and further disaggregation which would strain the resources of planning agencies. Governments can best use the benefit-cost analysis information in their processes and forums. Government perspectives must be addressed in any event, since project advancement requires government authorization.

CONCLUSION

Current urban transportation major investment study practices do not reliably guide decision-makers in setting priorities or in determining investment worthiness. Cross-modal impacts are usually ignored or poorly modeled, as are non-user costs. Many other problems undermine the utility of investment studies, making planners regard such studies more as administrative tasks than as an important planning effort.

Improvement is possible with existing data and methods, and the direction for future development is clear. Advancing the state-of-the-art is more problematic and dependent on data collection and travel model improvements.

Competition among urban areas for investment is intense and unlikely to diminish anytime in the near future. This creates a supply-side oriented development environment in which urban areas seek to reduce the cost of doing business. Viewed in this manner, transportation investments are not unlike subsidies provided to performing arts and sports franchises; the payor expects to get back the subsidy plus an additional return. Given an economic efficiency objective, this view can only be realized with a multimodal perspective and analytic methodology.

APPENDIX A

UNIT COSTS

The unit costs used to conduct the investment study are all expressed in 1990 dollars. Different sources provided the values. The following list of acronyms and references supplements the unit costs and sources listed in Table A.1.

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.

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.

TABLE A.1

UNIT COSTS

Benefit/Cost Category	Benefit/Cost Measure	Cost Paramete	Source
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	See Table 3.1
Auto Drive Alone	Travel Time Savings	Same as Transit User	Same as Transit Users
	Veh. Operating Cost	$0.25/mile	Same as HOV
Commercial Auto	Travel Time Savings	$9.75/hr.	See Table 3.3
	Veh. Operating Cost	$0.169/mile	See Tables 3.1 and 3.2; excludes depreciation
Single Unit Trucks	Operator Cost/Hour	$15.01/hr.	See Table 3.3; includes depreciation
	Veh. Operating Cost	$0.415/mile	See Table 3.3; excludes depreciation
Combination Trucks	Operator Cost/Hour	$22.53/hr.	See Table 3.3; includes depreciation
	Veh. Operating Cost	$0.743/mile	See Table 3.3; excludes depreciation
Benefits of Auto Travel Diversion to Transit/HOV			
Transit	Travel Time Savings	Same as Transit Users	Same as Transit Users
	Accident Savings	$0.19 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

APPENDIX B

AVERAGE WEEKDAY TRAVEL FORECASTS

This appendix lists the model output for the five Oklahoma City build alternatives plus the no build benchmark. Forecast values represent average weekday volumes in the year 2005. Although original network files and trip generation data was used, these forecasts may differ from the Oklahoma City Fixed Guideway Systems Study for various reasons. Details on the modeling procedures can be found in Putta.[1]

[1]Putta, *op. cit.*

TABLE B.1

YEAR 2005 TRAVEL FORECAST FOR THE NO BUILD ALTERNATIVE

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

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

** Out-of-vehicle travel time (OVTT) includes wait time (WT).

TABLE B.2

YEAR 2005 TRAVEL FORECAST FOR THE TRANSPORTATION SYSTEM MANAGEMENT ALTERNATIVE

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

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

Category	Passenger trips	Passenger miles	Passenger hours (IVT)	Passenger hours (OVTT)	Transfers	Passenger hours (WT)**
Auto access	4839	33802	1781	1322	1915	871
Walk Access	19401	115067	6821	5665	8060	3331
Total	24240	148869	8602	6986	9975	4202

** Out-of-vehicle travel time (OVTT) includes wait time (WT).

TABLE B.3

YEAR 2005 TRAVEL FORECAST FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORMAN CORRIDOR

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

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

Category	Passenger trips	Passenger miles	Passenger hours (IVT)	Passenger hours (OVTT)	Transfers	Passenger hours (WT) **
Auto access	7887	48492	1429	1722	3640	1138
Walk access	24792	131928	8907	6607	10658	4083
Total	32679	180420	10336	8329	14298	5221

** Out of vehicle travel time (OVTT) includes wait time (WT).

TABLE B.4

YEAR 2005 TRAVEL FORECAST FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORTHWEST CORRIDOR

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

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

** Out-of-vehicle travel time (OVTT) includes wait time (WT).

TABLE B.5

YEAR 2005 TRAVEL FORECAST FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORMAN CORRIDOR

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	924900	34675
All Other	1418278	2048729	8211116	287820	11822245	413157
Total	2439674	3151473	19567795	698536	24485253	865816

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	29887	2702	1738	1923	1371
Walk access	21101	101773	6055	5012	8022	3319
Total	26375	131660	8757	6750	9945	4691

** Out-of-vehicle travel time (OVTT) includes wait time (WT).

TABLE B.6

YEAR 2005 TRAVEL FORECAST FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORTHWEST CORRIDOR

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	924900	34505
All Other	1418278	2048726	8215069	291410	11827740	413412
Total	2423029	3151462	19701550	709783	24473412	461751

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

** Out-of-vehicle travel time (OVTT) includes wait time (WT).

APPENDIX C

ANNUALIZED TRAVEL FORECAST DATA

Investment analysis considers a benefit and cost stream over a fifteen to twenty five year period measured in annual increments. The average weekday travel reported in Appendix B converts to annualized equivalent volumes after applying the adjustments and expansion factors described in Chapter three. This appendix reports the results of the annualization and conversion process.

TABLE C.1

ANNUALIZED TRAVEL FORECAST DATA FOR THE NO BUILD ALTERNATIVE

DRIVE ALONE

	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	35676285	34889836	21489898	92056019
VEHICLE-MILES	874849665	907272429	559594305	2341716399
PERSON-HOURS	45613125	49948266	30755394	126316785
PERSON-MILES	1137064635	1301179820	802112074	3240356529
NO. OF VEHICLE TRIPS	123915210	142482352	110265214	376662776
NO. OF PERSON TRIPS	143616510	228612933	140918944	513148387
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.1 (Cond.)

SHARED RIDE

	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	2115990	21113111	5990790	29219891
VEHICLE-MILES	46819275	549023605	155999435	751842315
PERSON-HOURS	4764165	30225516	8573754	43563435
PERSON-MILES	105791085	787391319	223606691	1116789095
NO. OF VEHICLE TRIPS	4420935	86221262	30738896	121381094
NO. OF PERSON TRIPS	9807810	138342016	39284309	187434135
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.1 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE NO BUILD ALTERNATIVE

	COMMERCIAL CAR	TRUCK SINGLE UNIT	COMBINATION
VEHICLE HOURS	7535027	10073456	1777669
VEHICLE-MILES	196211187	262908863	46395682
PERSON-HOURS	10783799	10073456	1777669
PERSON-MILES	281245468	262908863	46395682
NO. OF VEHICLE TRIPS	38662335	49419650	8721115
NO. OF PERSON TRIPS	49410585	49419650	8721115
NO. OF TRANSFERS	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A

TABLE C.1 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE NO BUILD ALTERNATIVE

TRANSIT

	HB WORK	HB OTHER	NH BASED	TOTAL
VEHICLE HOURS	N/A	N/A	N/A	N/A
VEHICLE-MILES	N/A	N/A	N/A	N/A
PERSON-HOURS	3207390	1012751	752312	4972453
PERSON-MILES	27063915	8545579	6348002	41957496
NO. OF VEHICLE TRIPS	N/A	N/A	N/A	N/A
NO. OF PERSON TRIPS	5337660	1685395	1251980	8275035
NO. OF TRANSFERS	1987470	627555	466173	3081197
IN-VEHICLE TRAVEL TIME	1830390	577956	429329	2837675
OUT-OF-VEHICLE T.T.	1377000	434795	322984	2134779

TABLE C.1 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE NO BUILD ALTERNATIVE

INTERNAL-EXTERNAL TRIPS

	PRIVATE CAR	COMMERCIAL CAR	TRUCK SINGLE UNIT	COMBINATION
VEHICLE HOURS	34427670	8495861	16850123	2973551
VEHICLE MILES	820759255	202542203	401708703	70889771
PERSON HOURS	34427670	8495861	16850123	2973551
PERSON MILES	820759255	202542203	401708703	70889771
NO. OF VEHICLE TRIPS	38691565	9548080	18937025	3341828
NO. OF PERSON TRIPS	38691565	9548080	18937025	3341828

TABLE C.1 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE NO BUILD ALTERNATIVE

EXTERNAL-EXTERNAL TRIPS

	PRIVATE CAR	COMMERCIAL CAR	TRUCK SINGLE UNIT	COMBINATION
VEHICLE HOURS	5881785	967649	3290005	580589
VEHICLE MILES	143359500	23584950	80188830	14150970
PERSON HOURS	5881785	967649	3290005	580589
PERSON MILES	143359500	23584950	80188830	14150970
NO. OF VEHICLE TRIPS	4144080	681768	2318011	409061
NO. OF PERSON TRIPS	4144080	681768	2318011	409061

TABLE C.2

ANNUALIZED TRAVEL FORECAST DATA FOR THE TRANSPORTATION SYSTEM MANAGEMENT ALTERNATIVE

DRIVE ALONE

	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	34958460	34403637	21187036	90549133
VEHICLE-MILES	862552545	906712022	559248653	2328513220
PERSON-HOURS	44778765	49217586	30297540	124293892
PERSON-MILES	1129135920	1298594621	800391075	3228121616
NO. OF VEHICLE TRIPS	122626440	142487137	110255866	375369444
NO. OF PERSON TRIPS	143004000	228446995	140764205	512215200
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.2 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE TRANSPORTATION SYSTEM MANAGEMENT ALTERNATIVE

SHARED RIDE

	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	1988490	20818894	5906360	28713744
VEHICLE-MILES	45469560	548684482	155903077	750057119
PERSON-HOURS	4475250	29783355	8446117	42704722
PERSON-MILES	102717060	1298594621	800391075	2201702756
NO. OF VEHICLE TRIPS	4319190	86224159	30736290	121279639
NO. OF PERSON TRIPS	9576780	138241601	39241172	187059553
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.2 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE TRANSPORTATION SYSTEM MANAGEMENT ALTERNATIVE

		TRUCK	
	COMMERCIAL	SINGLE	
	CAR	UNIT	COMBINATION
VEHICLE HOURS	7428835	9941672	1754413
VEHICLE-MILES	196089991	262908863	46395682
PERSON-HOURS	10623261	9941672	1754413
PERSON-MILES	280642032	262908863	46395682
NO. OF VEHICLE TRIPS	38662335	49419650	8721115
NO. OF PERSON TRIPS	49410585	49419650	8721115
NO. OF TRANSFERS	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A

TABLE C.2 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE TRANSPORTATION SYSTEM MANAGEMENT ALTERNATIVE

TRANSIT

	HB WORK	HB OTHER	NH BASED	TOTAL
VEHICLE HOURS	N/A	N/A	N/A	N/A
VEHICLE-MILES	N/A	N/A	N/A	N/A
PERSON-HOURS	3646817	1151502	855383	5653702
PERSON-MILES	34827942	10997114	8169101	53994157
NO. OF VEHICLE TRIPS	N/A	N/A	N/A	N/A
NO. OF PERSON TRIPS	6181200	1951748	1449837	9582785
NO. OF TRANSFERS	2333654	736864	547372	3617890
IN-VEHICLE TRAVEL TIME	2012440	635439	472030	3119909
OUT-OF-VEHICLE T.T.	1634377	516063	383353	2533793

TABLE C.2 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE TRANSPORTATION SYSTEM MANAGEMENT ALTERNATIVE

INTERNAL-EXTERNAL TRIPS

			TRUCK	
	PRIVATE CAR	COMMERCIAL CAR	SINGLE UNIT	COMBINATION
VEHICLE HOURS	33894780	8364357	16589308	2927525
VEHICLE MILES	820759255	202542203	401708703	70889771
PERSON HOURS	33894780	8364357	16589308	2927525
PERSON MILES	820759255	202542203	401708703	70889771
NO. OF VEHICLE TRIPS	38691565	9548080	18937025	3341828
NO. OF PERSON TRIPS	38691565	9548080	18937025	3341828

TABLE C.2 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE TRANSPORTATION SYSTEM MANAGEMENT ALTERNATIVE

EXTERNAL-EXTERNAL TRIPS

			TRUCK	
	PRIVATE	COMMERCIAL	SINGLE	
	CAR	CAR	UNIT	COMBINATION
VEHICLE HOURS	5830015	959132	3261047	575479
VEHICLE MILES	143359500	23584950	80188830	14150970
PERSON HOURS	5830015	959132	3261047	575479
PERSON MILES	143359500	23584950	80188830	14150970
NO. OF VEHICLE TRIPS	4144080	681768	2318011	409061
NO. OF PERSON TRIPS	4144080	681768	2318011	409061

TABLE C.3

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORMAN CORRIDOR

DRIVE ALONE

	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	34440014	34226712	21067758	89734484
VEHICLE-MILES	856284949	906666782	559220750	2322172481
PERSON-HOURS	44071963	48910393	30089946	123072302
PERSON-MILES	1115459242	1296110346	798676855	3210246443
NO. OF VEHICLE TRIPS	121707987	142292989	110020336	374021313
NO. OF PERSON TRIPS	141219957	228040624	140385294	509645876
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.3 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORMAN CORRIDOR

SHARED RIDE

	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	1916447	20711830	5873109	28501386
VEHICLE-MILES	44051774	548657106	155895299	748604178
PERSON-HOURS	4312888	29597461	8388246	42298595
PERSON-MILES	99464437	1296110346	798676855	2194251638
NO. OF VEHICLE TRIPS	4193268	86106673	30670631	120970571
NO. OF PERSON TRIPS	9295044	137995691	39135542	186426277
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.3 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORMAN CORRIDOR

		TRUCK	
	COMMERCIAL	SINGLE	
	CAR	UNIT	COMBINATION
VEHICLE HOURS	7387012	9923682	1751238
VEHICLE-MILES	196080207	262908863	46395682
PERSON-HOURS	10550472	9923682	1751238
PERSON-MILES	280040973	262908863	46395682
NO. OF VEHICLE TRIPS	38662335	49419650	8721115
NO. OF PERSON TRIPS	49410585	49419650	8721115
NO. OF TRANSFERS	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A

TABLE C.3 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORMAN CORRIDOR

TRANSIT

	HB WORK	HB OTHER	NH BASED	TOTAL
VEHICLE HOURS	N/A	N/A	N/A	N/A
VEHICLE-MILES	N/A	N/A	N/A	N/A
PERSON-HOURS	4760166	1503049	1116525	7379740
PERSON-MILES	46007355	14527074	10791298	71325728
NO. OF VEHICLE TRIPS	N/A	N/A	N/A	N/A
NO. OF PERSON TRIPS	8246979	2604029	1934378	12785386
NO. OF TRANSFERS	3645990	1151241	855189	5652420
IN-VEHICLE TRAVEL TIME	2636271	832417	618353	4087041
OUT-OF-VEHICLE T.T.	2123895	670631	498172	3292699

TABLE C.3 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORMAN CORRIDOR

INTERNAL-EXTERNAL TRIPS

			TRUCK	
	PRIVATE CAR	COMMERCIAL CAR	SINGLE UNIT	COMBINATION
VEHICLE HOURS	34122475	8420546	16700750	2947191
VEHICLE MILES	820759255	202542203	401708703	70889771
PERSON HOURS	34122475	8420546	16700750	2947191
PERSON MILES	820759255	202542203	401708703	70889771
NO. OF VEHICLE TRIPS	38691565	9548080	18937025	3341828
NO. OF PERSON TRIPS	38691565	9548080	18937025	3341828

TABLE C.3 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORMAN CORRIDOR

EXTERNAL-EXTERNAL TRIPS

	PRIVATE CAR	COMMERCIAL CAR	TRUCK SINGLE UNIT	COMBINATION
VEHICLE HOURS	5871245	965915	3284109	579549
VEHICLE MILES	143359500	23584950	80188830	14150970
PERSON HOURS	5871245	965915	3284109	579549
PERSON MILES	143359500	23584950	80188830	14150970
NO. OF VEHICLE TRIPS	4144080	681768	2318011	409061
NO. OF PERSON TRIPS	4144080	681768	2318011	409061

TABLE C.4

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORTHWEST CORRIDOR

DRIVE ALONE

	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	34440014	34226712	21067758	89734484
VEHICLE-MILES	856284949	906666782	559220750	2322172481
PERSON-HOURS	44071963	48910393	30089946	123072302
PERSON-MILES	1115459242	1296110346	798676855	3210246443
NO. OF VEHICLE TRIPS	121707987	142292989	110020336	374021313
NO. OF PERSON TRIPS	141219957	228040624	140385294	509645876
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.4 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORTHWEST CORRIDOR

SHARED RIDE

	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	1916447	20711830	5873109	28501386
VEHICLE-MILES	44051774	548657106	155895299	748604178
PERSON-HOURS	4312888	29597461	8388246	42298595
PERSON-MILES	99464437	1296110346	798676855	2194251638
NO. OF VEHICLE TRIPS	4193268	86106673	30670631	120970571
NO. OF PERSON TRIPS	9295044	137995691	39135542	186426277
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.4 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORTHWEST CORRIDOR

		TRUCK	
	COMMERCIAL	SINGLE	
	CAR	UNIT	COMBINATION
VEHICLE HOURS	7387012	9923682	1751238
VEHICLE-MILES	196080207	262908863	46395682
PERSON-HOURS	10550472	9923682	1751238
PERSON-MILES	280040973	262908863	46395682
NO. OF VEHICLE TRIPS	38662335	49419650	8721115
NO. OF PERSON TRIPS	49410585	49419650	8721115
NO. OF TRANSFERS	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIME	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A

TABLE C.4 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORTHWEST CORRIDOR

	TRANSIT			
	HB WORK	HB OTHER	NH BASED	TOTAL
VEHICLE HOURS	N/A	N/A	N/A	N/A
VEHICLE-MILES	N/A	N/A	N/A	N/A
PERSON-HOURS	4760166	1503049	1116525	7379740
PERSON-MILES	46007355	14527074	10791298	71325728
NO. OF VEHICLE TRIPS	N/A	N/A	N/A	N/A
NO. OF PERSON TRIPS	8246979	2604029	1934378	12785386
NO. OF TRANSFERS	3645990	1151241	855189	5652420
IN-VEHICLE TRAVEL TIME	2636271	832417	618353	4087041
OUT-OF-VEHICLE T.T.	2123895	670631	498172	3292699

TABLE C.4 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORTHWEST CORRIDOR

INTERNAL-EXTERNAL TRIPS

			TRUCK	
	PRIVATE CAR	COMMERCIAL CAR	SINGLE UNIT	COMBINATION
VEHICLE HOURS	34122475	8420546	16700750	2947191
VEHICLE MILES	820759255	202542203	401708703	70889771
PERSON HOURS	34122475	8420546	16700750	2947191
PERSON MILES	820759255	202542203	401708703	70889771
NO. OF VEHICLE TRIPS	38691565	9548080	18937025	3341828
NO. OF PERSON TRIPS	38691565	9548080	18937025	3341828

TABLE C.4 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORTHWEST CORRIDOR

EXTERNAL-EXTERNAL TRIPS

	PRIVATE CAR	COMMERCIAL CAR	TRUCK SINGLE UNIT	COMBINATION
VEHICLE HOURS	5871245	965915	3284109	579549
VEHICLE MILES	143359500	23584950	80188830	14150970
PERSON HOURS	5871245	965915	3284109	579549
PERSON MILES	143359500	23584950	80188830	14150970
NO. OF VEHICLE TRIPS	4144080	681768	2318011	409061
NO. OF PERSON TRIPS	4144080	681768	2318011	409061

TABLE C.5

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORMAN CORRIDOR

DRIVE ALONE

	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	29707407	31825064	19593020	81125491
VEHICLE-MILES	788309517	920467761	567733021	2276510298
PERSON-HOURS	36134813	45536517	28022107	109693437
PERSON-MILES	1003739295	1317843620	812216077	3133798992
NO. OF VEHICLE TRIPS	123311761	142315036	110069426	375696223
NO. OF PERSON TRIPS	133813948	228344475	140668612	502827035
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TI	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.5 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORMAN CORRIDOR

SHARED RIDE

	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	3243816	19258506	5461993	27964315
VEHICLE-MILES	110457966	557008581	158268285	825734831
PERSON-HOURS	7474880	27555806	7811789	42842475
PERSON-MILES	255502150	1317843620	812216077	2385561846
NO. OF VEHICLE TRIPS	8075869	86120014	30684316	124880198
NO. OF PERSON TRIPS	18245670	138179562	39214523	195639755
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TII	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.5 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORMAN CORRIDOR

	COMMERCIAL CAR	TRUCK SINGLE UNIT	COMBINATION
VEHICLE HOURS	6869923	9184565	1620805
VEHICLE-MILES	199064874	267511116	47207844
PERSON-HOURS	9825423	9184565	1620805
PERSON-MILES	284788246	267511116	47207844
NO. OF VEHICLE TRIPS	38662335	49419650	8721115
NO. OF PERSON TRIPS	49410585	49419650	8721115
NO. OF TRANSFERS	N/A	N/A	N/A
IN-VEHICLE TRAVEL TI	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A

TABLE C.5 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORMAN CORRIDOR

TRANSIT

	HB WORK	HB OTHER	NH BASED	TOTAL
VEHICLE HOURS	N/A	N/A	N/A	N/A
VEHICLE-MILES	N/A	N/A	N/A	N/A
PERSON-HOURS	3954321	1248598	927509	6130429
PERSON-MILES	37754025	11921040	8855431	58530496
NO. OF VEHICLE TRIPS	N/A	N/A	N/A	N/A
NO. OF PERSON TRIPS	6702361	2116307	1572079	10390747
NO. OF TRANSFERS	2535975	800748	594828	3931551
IN-VEHICLE TRAVEL TI	2233087	705110	523784	3461981
OUT-OF-VEHICLE T.T.	1721234	543489	403726	2668448

TABLE C.5 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORMAN CORRIDOR

INTERNAL-EXTERNAL TRIPS

	PRIVATE CAR	COMMERCIAL CAR	TRUCK SINGLE UNIT	COMBINATION
VEHICLE HOURS	31619690	7802923	15475798	2731023
VEHICLE MILES	860028970	212232955	420928695	74281534
PERSON HOURS	31619690	7802923	15475798	2731023
PERSON MILES	860028970	212232955	420928695	74281534
NO. OF VEHICLE TRIPS	38691565	9548080	18937025	3341828
NO. OF PERSON TRIPS	38691565	9548080	18937025	3341828

TABLE C.5 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORMAN CORRIDOR

EXTERNAL-EXTERNAL TRIPS

	PRIVATE CAR	COMMERCIAL CAR	TRUCK SINGLE UNIT	COMBINATION
VEHICLE HOURS	5374625	884213	3006323	530528
VEHICLE MILES	143359500	23584950	80188830	14150970
PERSON HOURS	5374625	884213	3006323	530528
PERSON MILES	143359500	23584950	80188830	14150970
NO. OF VEHICLE TRIPS	4144080	681768	2318011	409061
NO. OF PERSON TRIPS	4144080	681768	2318011	409061

TABLE C.6

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORTHWEST CORRIDOR

	DRIVE ALONE			
	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	32728107	32236246	19847349	84811703
VEHICLE-MILES	877954824	920912241	568007171	2366874236
PERSON-HOURS	41403187	45571803	28044418	115019408
PERSON-MILES	1138404793	1318438850	812581334	3269424978
NO. OF VEHICLE TRIPS	122306963	142313235	110067318	374687516
NO. OF PERSON TRIPS	141307307	228341585	140665918	510314810
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIM	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.6 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORTHWEST CORRIDOR

SHARED RIDE

	HB WORK	HB OTHER	NON-HB	TOTAL
VEHICLE HOURS	1872185	19507327	5532893	26912405
VEHICLE-MILES	52594738	557277552	158344710	768217001
PERSON-HOURS	4220040	27577159	7818009	39615208
PERSON-MILES	118832952	1318438850	812581334	2249853136
NO. OF VEHICLE TRIPS	4840290	86118924	30683728	121642942
NO. OF PERSON TRIPS	10737623	138177813	39213772	188129209
NO. OF TRANSFERS	N/A	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIMI	N/A	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A	N/A

TABLE C.6 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORTHWEST CORRIDOR

	COMMERCIAL CAR	TRUCK SINGLE UNIT	COMBINATION
VEHICLE HOURS	6959099	9298792	1640963
VEHICLE-MILES	199161000	267653738	47233013
PERSON-HOURS	9833246	9298792	1640963
PERSON-MILES	284916316	267653738	47233013
NO. OF VEHICLE TRIPS	38662335	49419650	8721115
NO. OF PERSON TRIPS	49410585	49419650	8721115
NO. OF TRANSFERS	N/A	N/A	N/A
IN-VEHICLE TRAVEL TIM	N/A	N/A	N/A
OUT-OF-VEHICLE T.T.	N/A	N/A	N/A

TABLE C.6 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORTHWEST CORRIDOR

	TRANSIT			
	HB WORK	HB OTHER	NH BASED	TOTAL
VEHICLE HOURS	N/A	N/A	N/A	N/A
VEHICLE-MILES	N/A	N/A	N/A	N/A
PERSON-HOURS	3920625	1237959	919606	6078190
PERSON-MILES	37869285	11957434	8882466	58709185
NO. OF VEHICLE TRIPS	N/A	N/A	N/A	N/A
NO. OF PERSON TRIPS	6717049	2120945	1575524	10413518
NO. OF TRANSFERS	2551785	805740	598536	3956061
IN-VEHICLE TRAVEL TIME	2188920	691163	513424	3393508
OUT-OF-VEHICLE T.T.	1731705	546795	406182	2684682

TABLE C.6 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORTHWEST CORRIDOR

INTERNAL-EXTERNAL TRIPS

	PRIVATE CAR	COMMERCIAL CAR	TRUCK SINGLE UNIT	COMBINATION
VEHICLE HOURS	31745085	7833868	15537171	2741854
VEHICLE MILES	856906030	211462295	419400217	74011803
PERSON HOURS	31745085	7833868	15537171	2741854
PERSON MILES	858456030	211844795	420158842	74145678
NO. OF VEHICLE TRIPS	38691565	9548080	18937025	3341828
NO. OF PERSON TRIPS	38691565	9548080	18937025	3341828

TABLE C.6 (COND.)

ANNUALIZED TRAVEL FORECAST DATA FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORTHWEST CORRIDOR

EXTERNAL-EXTERNAL TRIPS

	PRIVATE CAR	COMMERCIAL CAR	TRUCK SINGLE UNIT	TRUCK COMBINATION
VEHICLE HOURS	5348275	879878	2991583	527926
VEHICLE MILES	143359500	23584950	80188830	14150970
PERSON HOURS	5348275	879878	2991583	527926
PERSON MILES	143359500	23584950	80188830	14150970
NO. OF VEHICLE TRIPS	4144080	681768	2318011	409061
NO. OF PERSON TRIPS	4144080	681768	2318011	409061

APPENDIX D

CAPITAL COST SCHEDULING

CRA recommends spreading capital expenditures over a five year period to better reflect actual cash flow. This appendix presents the expenditure schedule for each of the alternatives by project element, e.g. right-of-way, rolling stock, structures, earthwork, and stations. The tables show the present value of the expenditures and an annual equivalent amount. The project annual equivalent amount is the sum of the annual equivalent amounts for each project element. Estimates of asset life come from the Federal Transit Administration guidelines.[2] Abbreviations used in the tables are:

LRT:	Light rail transit
M&S:	Maintenance and storage
ROW:	Right of way

[2]Federal Transit Administration, *Procedures and Technical Methods for Transit Project Planning, op. cit.*

TABLE D.1

CAPITAL EXPENDITURE SCHEDULE AND PRESENT VALUE CALCULATIONS FOR THE TRANSPORTATION SYSTEM MANAGEMENT ALTERNATIVE

Year of Expenditure	Busway	LRT Mainline	Buses	LRT Cars	Bus/LRT Stations	Bus M&S Facilities	LRT M&S Facilities	ROW	TOTALS
(millions)									
1			$8.90			$6.20			$15.10
2			$8.90			$6.20			$15.10
3			$8.90			$6.20			$15.10
4									$0.00
5									$0.00
TOTALS	$0.00	$0.00	$26.70	$0.00	$0.00	$18.60	$0.00	$0.00	$45.30
Present Value	$0.00		$22.13	$0.00	$0.00	$15.42	$0.00	$0.00	
Life of Asset (yr.s)	20	30	12	25	30	30	30	100	
Annual Equivalent			$3.25			$1.64			$4.88

TABLE D.2

CAPITAL EXPENDITURE SCHEDULE AND PRESENT VALUE CALCULATIONS FOR THE LIGHT RAIL TRANSIT ALTERNATIVE INTHE NORMAN CORRIDOR

(millions)									
Year of Expenditure	Busway	LRT Mainline	Buses	LRT Cars	Bus/LRT Stations	Bus M&S Facilities	LRT M&S Facilities	ROW	TOTALS
1		$79.40			$4.60		$1.20	$10.80	$96.00
2		$79.40			$4.60		$1.20		$85.20
3		$79.40	$9.30	$6.40	$4.60	$6.20	$1.20		$107.10
4		$79.40	$9.30	$6.40	$4.60	$6.20	$1.20		$107.10
5		$79.40	$9.30	$6.40	$4.60	$6.20	$1.20		$107.10
TOTALS	$0.00	$397.00	$27.90	$19.20	$23.00	$18.60	$6.00	$10.80	$502.50
Present Value	$0.00	$300.99	$19.11	$13.15	$17.44	$12.74	$4.55	$9.82	
Life of Asset (yr.s)	20	30	12	25	30	30	30	100	
Annual Equivalent	$0.00	$31.93	$2.81	$1.45	$1.85	$1.35	$0.48	$0.98	$40.85

TABLE D.3

CAPITAL EXPENDITURE SCHEDULE AND PRESENT VALUE CALCULATIONS FOR THE LIGHT RAIL TRANSIT ALTERNATIVE IN THE NORTHWEST CORRIDOR

	(millions)								
Year of Expenditure	Busway	LRT Main-Mainline	Buses	LRT Cars	Bus/LRT Stations	Bus M&S Facilities	LRT M&S Facilities	ROW	TOTALS
1		$53.60	$12.40		$3.50	$6.20	$0.50	$4.10	$80.30
2		$53.60	$12.40		$3.50	$6.20	$0.50		$76.20
3		$53.60	$12.40	$2.90	$3.50	$6.20	$0.50		$79.10
4		$53.60		$2.90	$3.50		$0.50		$60.50
5		$53.60		$2.90	$3.50		$0.50		$60.50
TOTALS	$0.00	$268.00	$37.20	$8.70	$17.50	$18.60	$2.50	$4.10	$356.60
Present Value	$0.00	$203.19	$30.84	$5.96	$13.27	$15.42	$1.90	$3.73	
Life of Asset (yr.s)	20	30	12	25	30	30	30	100	
Annual Equivalent	$0.00	$21.55	$4.53	$0.66	$1.41	$1.64	$0.20	$0.37	$30.35

TABLE D.4

CAPITAL EXPENDITURE SCHEDULE AND PRESENT VALUE CALCULATIONS FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORMAN CORRIDOR

	(millions)								
Year of Expenditure	Busway	LRT Mainline	Buses	LRT Cars	Bus/LRT Stations	Bus M&S Facilities	LRT M&S Facilities	ROW	TOTALS
1	$12.90				$0.40			$6.30	$19.60
2	$12.90				$0.40				$13.30
3	$12.90		$11.70		$0.40	$6.20			$31.20
4	$12.90		$11.70		$0.40	$6.20			$31.20
5	$12.90		$11.70		$0.40	$6.20			$31.20
TOTALS	$64.50	$0.00	$35.10	$0.00	$2.00	$18.60	$0.00	$6.30	$126.50
Present Value	$48.90	$0.00	$24.05	$0.00	$1.52	$12.74	$0.00	$5.73	
Life of Asset (yr.s)	20	30	12	25	30	30	30	100	
Annual Equivalent	$5.74	$0.00	$3.53	$0.00	$0.16	$1.35	$0.00	$0.57	$11.36

TABLE D.5

CAPITAL EXPENDITURE SCHEDULE AND PRESENT VALUE CALCULATIONS FOR THE HIGH OCCUPANCY VEHICLE ALTERNATIVE IN THE NORTHWEST CORRIDOR

	(millions)								
Year of Expenditure	Busway	LRT Mainline	New Buses	LRT Cars	Bus/LRT Stations	Bus M&S Facilities	LRT M&S Facilities	ROW	TOTALS
1	$22.10				$0.20			$3.10	$25.40
2	$22.10				$0.20				$22.30
3	$22.10		$12.50		$0.20	$6.20			$41.00
4	$22.10		$12.50		$0.20	$6.20			$41.00
5	$22.10		$12.50		$0.20	$6.20			$41.00
TOTALS	$110.50	$0.00	$37.50	$0.00	$1.00	$18.60	$0.00	$3.10	$170.70
Present Value	$83.78	$0.00	$25.69	$0.00	$0.76	$12.74	$0.00	$2.82	
Life of Asset (yr.s)	20	30	12	25	30	30	30	100	
Annual Equivalent	$9.84	$0.00	$3.77	$0.00	$0.08	$1.35	$0.00	$0.28	$15.32

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