TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTATX811066-2F		

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
A Generalized Approach To Evaluating Impacts Of Short Range Transit Alternatives	5. August 1981 6.
7. Author(s) Margaret K. Chui and Jesse L. Buffington	8. Performing Organization Report No. Technical Report 1066-2F
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843	10. Work Unit No. 11. Contract or Grant No. Study 2-10-80-1066
12. Sponsoring Agency Name and Address State Department of Highways and Public Transportation; Transportation Planning Division P. O. Box 5051 Austin, Texas 78763	13. Type of Report and Period Covered Interim-September 1977 - August 1981 14. Sponsoring Agency Code

15. Supplementary Notes

The study was conducted in cooperation with the Urban Mass Transportation Administration.

16. Abstract

Demand for better transportation rises as a city grows. Often transporttation officials are faced with the necessity of choosing one improvement over several other alternatives proposed. The recommended impact evaluation approach outlined in the interim report is fully developed in this study. It utilizes the three commonly used evaluation methods: the economic efficiency method for evaluating monetary impacts; the cost effectiveness method for nonmonetary impacts; and the scoring method for assigning categorical and subcategorical weights.

Ratios of benefits received by users and nonusers to costs spent by a transit system are rated within each impact subcategories. The ratings are further weighted by the weights assigned to arrive at scores which can be summed up to yield the overall total scores for the alternatives which, in turn, determine the ranking of alternatives.

Unit cost estimation techniques and data requirements for impact evaluation are presented. Subjectiveness involved in the scoring method is believed to be kept to a minimum by the requirement of preliminary studies on relevant areas and by the weight assignment procedures. Double counting is expected to be avoided by the introduction of a separate impact category, namely, the society impacts. It is hoped that the recommended impact evaluation approach can better serve transportation officials in their decision-making process.

17. Key Words	18. Distribution Statement
Short Range Transit Alternatives, Impact Evaluation	No restrictions. This document is available to the public through the National Technical Information Service Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	153	

Form DOT F 1700.7 (8-69)

PREFACE

The authors would like to express their appreciation to Mr. D. T. Chapman of the Texas State Department of Highways and Public Transportation for his valuable comments, and to those at Texas Transportation Institute who have assisted or facilitated this study. Special acknowledgement is gratefully extended to Miss Kiazan Morey for her painstaking efforts in typing the manuscript.

The contents of this report reflect the views of the authors and not necessarily the views or policies of the Federal Urban Mass Transportation Administration. The authors are responsible for the facts and the accuracy of the data presented herein. This report does not constitute a standard, specification, or regulation.

ABSTRACT

Demand for better transportation rises as a city grows. Often transportation officials are faced with the necessity of choosing one improvement over several other alternatives proposed. The recommended impact evaluation approach outlined in the interim report is fully developed in this study. It utilizes the three commonly used evaluation methods: the economic efficiency method for evaluating monetary impacts; the cost effectiveness method for nonmonetary impacts; and the scoring method for assigning categorical and subcategorical weights.

Ratios of benefits received by users and nonusers to costs spent by a transit system are rated within each impact subcategories. The ratings are further weighted by the weights assigned to arrive at scores which can be summed up to yield the overall total scores for the alternatives which, in turn, determine the ranking of alternatives.

Unit cost estimation techniques and data requirements for impact evaluation are presented. Subjectiveness involved in the scoring method is believed to be kept to a minimum by the requirement of preliminary studies on relevant areas and by the weight assignment procedures. Double counting is expected to be avoided by the introduction of a separate impact category, namely, the society impacts. It is hoped that the recommended impact evaluation approach can better serve transportation officials in their decision-making process.

SUMMARY

Traffic problems tend to intensify as a city grows. The continued urbanization trend of cities, together with population growth and recent concerns of energy conservation contributes heavily to the demand for better transportation by the public. Since each transportation improvement impacts users and nonusers differently, state and city officials are frequently faced with challenges of providing the best feasible solution to a traffic problem. It is hoped that the recommended approach, initiated in the interim report and fully developed in this study, can help decision-makers in transportation in their decision-making process when they have to choose one out of the several proposed alternatives.

Preliminary studies on several areas are felt essential since they should provide guidelines to transportation officials and to committee members in the weight assignment process which is required in the recommended impact evaluation approach. These areas include identification of: (1) relevant short range alternatives, (2) funding available for a specific improvement, (3) local needs and goals, (4) projected traffic and rider demand, (5) city size characteristics and (6) relevant impacts for evaluation.

The recommended impact evaluation method utilizes the three commonly used evaluation methods. The economic efficiency method is used for evaluating monetary impacts while the cost effectiveness method is applied in the non-monetary impact evaluation. The common measurement used in both methods is the benefit-cost ratio. The scoring method is used to rate the estimated ratios within each impact subcategory. The ratings are then adjusted by the weights assigned to arrive at scores which can be summed up to give the overall total scores for the alternatives which, in turn, dictate the overall ranking of alternatives.

Estimation techniques used and data required for evaluating monetary and nonmonetary impacts are presented. Unit cost methods are chosen instead of other more complex estimation procedures because the present study is concerned primarily with short range transit considerations.

The problem of subjectiveness involved in the scoring method is believed to be kept to a minimum by the categorical and subcategorical weight assignment processes adopted in the study. Also double counting is avoided by the introduction of a separate impact category, the society impacts which include business activity, accessibility, fuel consumption and ridership. Estimation results of these impacts do not enter into the overall ranking of alternatives since they have been implicitly or explicitly accounted for in other impact categories.

Because many impacts and variables affecting each impact may be involved, the recommended impact evaluation approach can be rather tedious. Therefore, it is recommended that the approach should be computerized so that efficiency and ease of utilizing this approach can be greatly enhanced, and transportation officials can be better served.

IMPLEMENTATION STATEMENT

This report describes a recommended approach developed by the authors for evaluating both user and nonuser impacts of short range transportation alternatives. If implemented, these findings can facilitate transit planners and officials in their decisionmakeing process and assist them when they are faced with the problem of choosing one out of the several alternatives which have been proposed.

TABLE OF CONTENTS

LIST OF TABLES

Page

APPENDIX TABLES

Page

LIST OF FIGURES

INTRODUCTION

The interim report [9] indicates that continued urbanization has been the major factor behind the steady increase in demand for transit. However, population growth and the current concerns over energy conservation are also determining factors for this increase.

In comparison to the older cities in the eastern United States, cities in Texas are more decentralized with respect to places of residence and places of employment. Therefore, there is a greater need for exploring improvement strategies that increase the efficiency of the existing transportation system. The most imminent need is to implement immediate action on short range transit improvements to alleviate the current traffic problems while long range solutions are being sought.

In the interim report, a full range of short range transit alternatives and their relevant impacts are identified. However, evaluation procedures developed so far have been mostly applicable for long range transit studies and have focused mainly on evaluation of user costs and benefits. The need for the development of an impact evaluation procedure for short range transit improvements have been recognized by state and federal transportation officials. As a result, the study as reported in the interim report and this report was authorized.

Objective and Scope of Study

The objective of this study is to fully develop a recommended approach to impact evaluation of short range transit alternatives. The scope of the study is restricted to areas defined by the objective. Long range improvements involving rail or major facility construction are therefore automatically excluded from consideration. Estimation methods for the various impact categories are also discussed fully in this report.

Contents of Report

This report presents the fully developed model of impact evaluation for short range transportation improvements. Estimation methods which are applicable in short range transit alternatives for the various impact categories are also discussed. An extensive bibliography used for both the interim and this final report is listed by appropriate category and is included at the end of this report.

The major divisions of the body of the report are as follows: (1) preliminary determinations, (2) recommended impact evaluation approach and (3) conclusions and recommendations.

PRELIMINARY DETERMINATIONS

A growing city is continually plagued by traffic congestion and increasing demand for improved transportation. Providing adequate and dependable public transportation for a city presents complex problems and great challenges to transportation officials and planners. For any short range transportation improvement that needs to be done, these officials have to know, at the preliminary stage of planning, what short range improvements are possible. Then out of the large range of possible alternatives, only one may be chosen for implementation. The selection process can be tedious, time consuming, as well as costly, if an efficient approach is not adopted. It is hoped that the recommended approach to impact evaluation proposed in this study will help these officials in their selection process.

Several preliminary considerations are important before the impact evaluation process is to begin. They will not only serve in improving the efficiency of the evaluation process, but also help in providing information on which the officials must rely later in applying the weighting procedure required in the recommended evaluation approach. These preliminary considerations include the identification of relevant short range alternatives, funding availability, local needs and objectives, projected traffic and rider demand for each alternative, city size characteristics and, lastly, the relevant impacts of the proposed alternatives. All of these considerations and their relevancy to the evaluation process are discussed in this section.

Relevant Short Range Transit Alternatives

When officials and planners of a city realize their need to improve the traffic situation, it is helpful for them to know what alternatives have been undertaken in the past, or are being undertaken at present, in their city or other cities. From these past or present experiences, they can develop innovative transit ideas or adopt a few appropriate alternatives which can be proposed for impact evaluation.

In the interim report, two major types of short range transit alternatives are identified: the conventional bus system (FFT) and the demand responsive system (DRT). The two systems differ from each other in the way services are rendered to passengers. The conventional bus runs on fixed routes and fixed schedules, generally disregarding the fact whether or not the service is demanded, while the demand responsive vehicles run only on demand by users. It has been shown that demand responsive transits can better serve areas with low density where conventional bus systems are not economically feasible or operable.

Although differing in types of services offered, the two systems have many transit elements in common. They both have fleets of vehicles, routes, scheduling, facilities construction, fare structure and marketing techniques. These elements together with a set of unique services of DRT form seven relevant categories of short range transit alternatives for consideration. Variations and improvements in each of the alternatives constitute subcategories of short range transit alternatives. Table 1 lists the seven major categories and subcategories under each category of the short range transit alternatives.

For more detailed information, readers are advised to refer to the

Table 1. Categories and Subcategories of Short Range Transit Alternatives

Category	Subcategory
I. Fleet Adjustments (FFT & DRT)	Changing size of Fleet Changing Fleet Composition Upgrading/Rehabilitating Fleet
II. Route Adjustments (FFT & DRT)	Adding/Subtracting Routes Altering Existing Routes
III. Schedule Adjustments (FFT & DRT)	Changing Headways Changing Operating Hours Improving Reliability of Operations
IV. Facility Adjustments (FFT & DRT)	Adding Shelters/Benches Adding Park-n-Ride Service Providing Exclusive Treatments for HOV's: Ramps Lanes Signal Preemption Providing Auto Restricted Zone
V. Fare Adjustments (FFT & DRT)	Fare Structure Changes Providing Peak/Off-Peak Fare Differentials Road/Parking Pricing
VI. Marketing Adjustments (FFT & DRT)	
VII. DRT Adjustments	Altering Charter Service Stimulating Carpool/Vanpool Changing Shuttle Service Changing Subscription Service

section on relevant short range alternatives in the interim report.

Funding

Public transportation improvements can be funded from several sources. Other than fares received, subsidies, grants and loans from local, state and federal governments are funding sources for transportation. Quite often though, certain requirements are attached to the use of the funds available. For example, a capital grant for purchasing buses cannot be used for the installation of traffic signs and temporary barriers for high occupancy vehicle (HOV) treatments (or for other transit improvements consideration). If no other funding is available, such HOV treatments can be eliminated from consideration at this stage. Therefore, the availability of funding plays an important role, even in the preliminary stage of planning, in determining the feasibility of an alternative. The large list of alternatives identified by the planners and officials will be reduced, thus saving time and money to implement the impact analysis.

It is imperative, therefore, to know not only the sources of funding, but also the amounts and requirements of the different funds at the preliminary planning stage so that a more efficient evaluation process will result. Funding sources of fares, subsidies, federal grants and loans are each described briefly below.

Fares

Revenues from fares have been used by many transit systems to support operating costs, but revenues from fareboxes alone usually are not able to finance capital improvements. Demonstration projects by Urban Mass

Transit Administration (UMTA) have proved that a decrease in fare does not seem to result in a significant increase in ridership. It is believed that a combination of fare and quality of service will significantly affect ridership. Evidences have shown that a rider responds least to fare changes on rapid transit and other transit modes where quality of service is exceptionally good or costs of alternate modes are high [17].

Short term transit elasticity estimated from various economic models ranges from -.09 by Charles River Associates [8] to -.96 by Warner, as reported by Pucher and Rothenberg [18]. The Curtin's rule which is widely used in the transit industry, states that an overall fare increase of 1 percent will shrink ridership by roughly one-third of 1 percent [17]. The relationship is expressed in mathematical form as follows:

$$Y = 0.08 + 0.30\ X$$

where Y represents the loss in ridership as expressed in percentage of prior ridership and X is the increase in fare as expressed in percentage of prior fare. Figure 1 illustrates this relationship in graphic form.

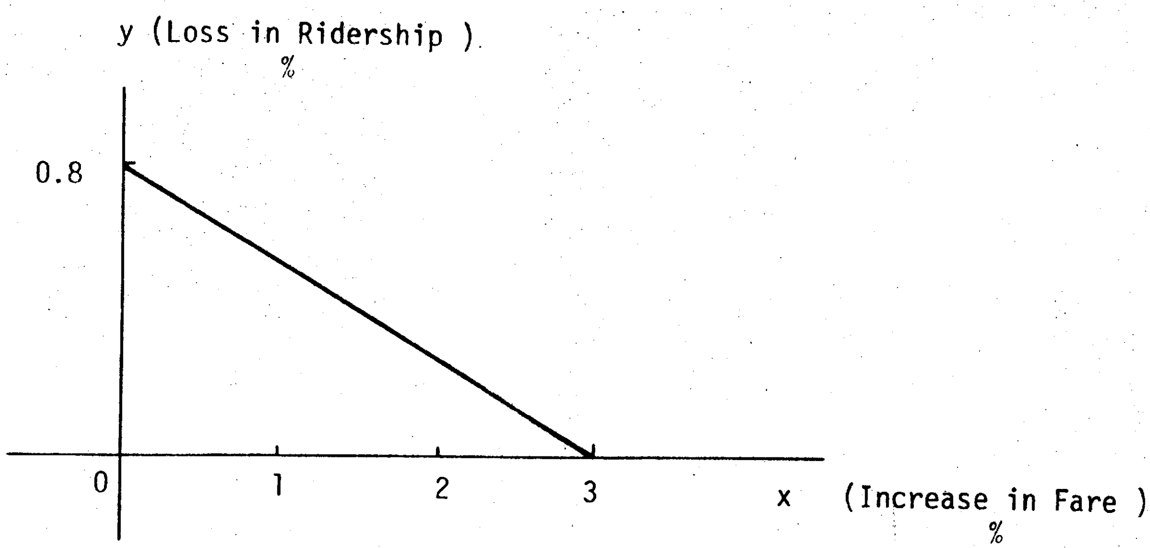

Figure 1. Curtin's Rule of Ridership Shrinkage

If fares are raised in hope of increasing revenues for the support of the system, ridership may decrease, resulting in lower revenues over time. Therefore, ideally, transit systems should consider using fare revenues to cover only operating costs and using tax levies or other funds for furnishing capital improvements. In general practice, few transit systems can rely on fares alone to operate for very long.

Subsidies

Subsidies are aids by government to transit systems. The most common use of subsidies is for capital improvements. In recent years, capital subsidies have tended to be matching funds by the cities or states to grants from the federal government. Often a subsidy is intended to be utilized as an interim means of providing funds for transit while a long run solution is being sought. Many small cities, however, have difficulties in providing subsidies out of general taxes over an extended period of time.

Federal Grants and Loans

Since 1961 the federal government has provided grants and loans to transit systems under the following types: capital grants, technical studies grants and demonstration grants. Application procedure for a grant is the same as for a loan. As a result, it is less attractive to apply for a federal loan.

Capital Grants. Out of the total costs of the improvement, capital grants can provide two-thirds and the remaining one-third has to come out of local sources such as local bond sales or tax revenues.

Technical Studies Grants. These federal grants are made to cities for their planning studies to improve mass transit. Up to two-thirds of the total project cost can be met by these grants.

Demonstration Grants. Demonstration grants are given to transit systems for testing new ideas or methods in transportation. These grants cover one hundred percent of the total cost for this type of project. However, they cannot be used to finance long term capital improvements.

For financing improvements, the sources of funding, as discussed above, can be multiple; requirements of and procedures for application can be many. A strong agency is needed to coordinate and expedite any planning and implementation process, to lay down guidelines and to set goals for the project. Prudent guidelines can increase transit efficiency and effectiveness in the use of government subsidies which tend to diminish motivation to provide the best possible service. However, it is imperative these guidelines and objectives be set in conjunction with financial policies both within the transit operation and between transit operation and the levels of government involved in the funding. It is meaningless to set standards so high that they are infeasible to be met within the available financial structure.

Local Needs and Goals

A good knowledge of the local conditions of transportation or transportation related problems is an asset to officials in charge of transportation planning. Without it, planners will arrive at solutions to a traffic problem which do not fill the needs of the local people or solve the local transportation problem in the best possible way.

Preceeding the use of the recommended approach to impact evaluation, a preliminary study of the local transportation needs should be conducted. It is hoped that through such a study, brief as it may be, local needs, short term and long term, will be revealed.

Other transportation related problems, such as the general effects on environments, energy, land use, etc., should also be briefly reviewed. Curry and Anderson [12] found automobiles traveling at different uniform speeds have different effects on the amount of pollutants emitted. Figure 2 shows the 1968 emission rates of hydrocarbons and carbon monoxides emitted by automobiles traveling at various uniform speeds. Noise pollution is another environmental concern of transportation. According to Young and Woods [25] traffic density and speed account for most of the variations in noise level. Figure 3 illustrates the mean noise level at 100 feet from a lane by density of automobiles traveling at selected speeds.

Results of such review and others should be helpful to planners and officials in the weighting process used in both the monetary and nonmonetary impact analyses. Weights are assigned according to how well each alternative under evaluation attains the local objectives. Thus, subjectiveness can be held to a minimum.

Projected Traffic and Rider Demand

Plannings for short run transit improvements should embrace as much insights of the future as possible. The "future" is defined as the period for which an improvement is defined or intended to serve. As time goes by, society changes and demand changes. If transit planning does not consider adequately these changes, the improvements made may become obsolete or inadequate before they are finished.

Transportation improvements are sensitive to society changes such as population growth, job opportunity changes, demographic changes among

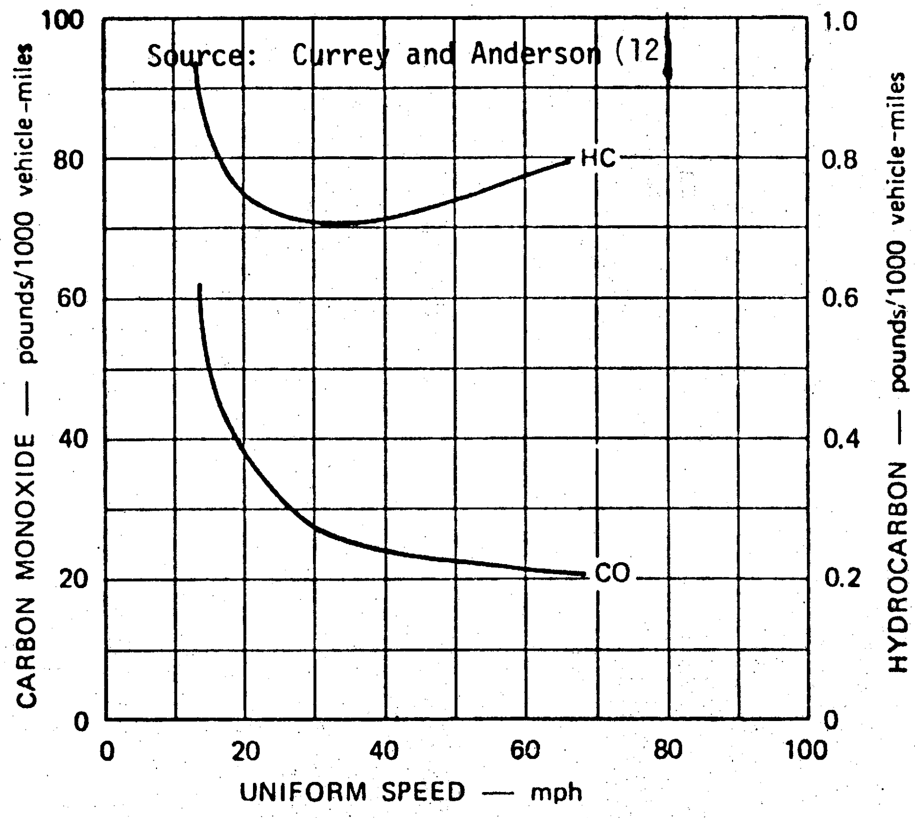

Figure 2. Hydrocarbon and Carbon Monoxide Emissions per 1,000 Miles of Driving at Uniform Speed (Reference Automobile)

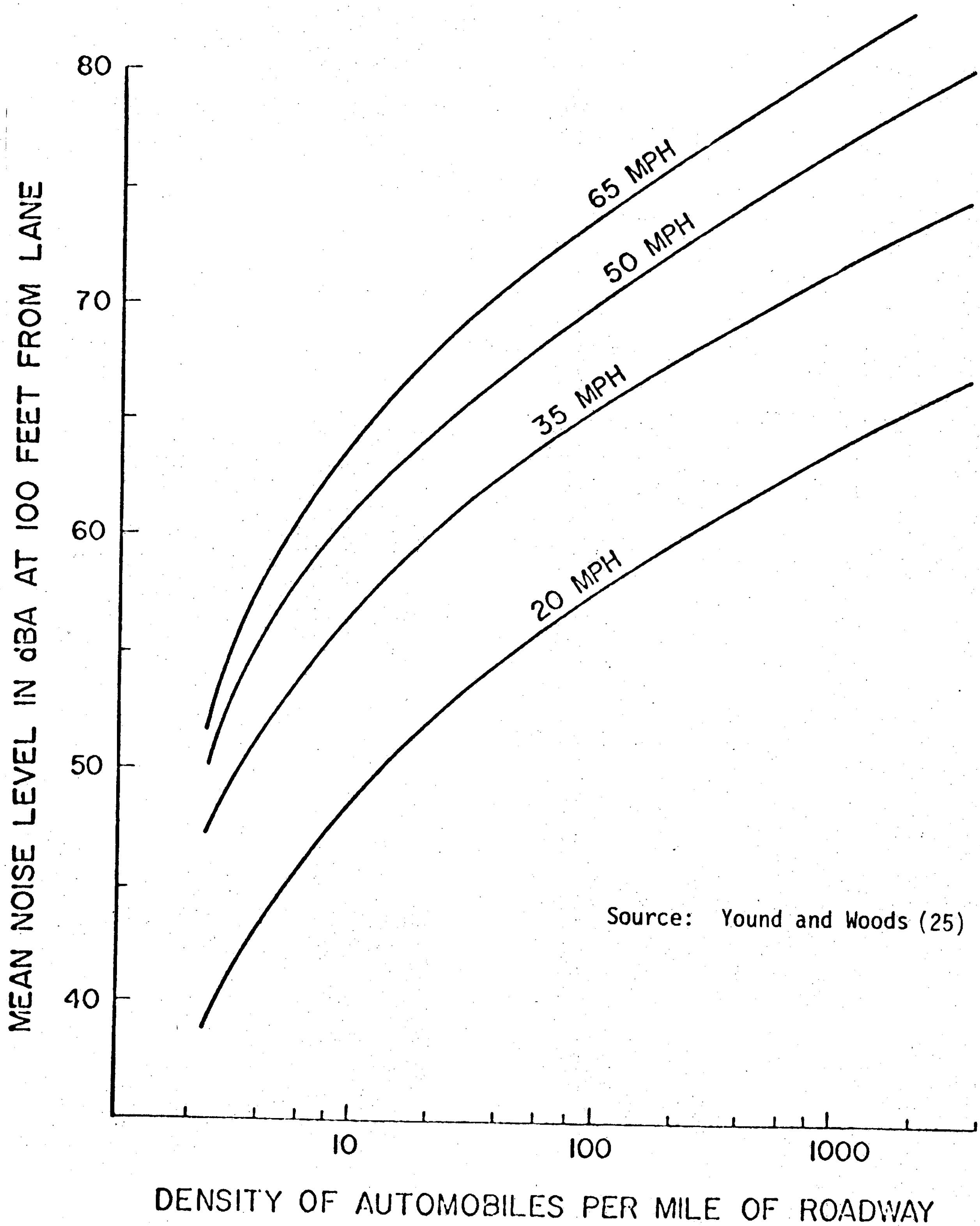

Figure 3. Mean Noise Level at 100 Feet from a Lane, by Density of Automobiles per Mile of Roadway for Selected Speeds.

residents, etc. A city which is projected to have a big population growth should direct its attention to mass transit for its traffic improvements. Therefore, projection of the overall rate of change in future traffic of a city is essential. However, attention should also be placed on traffic projection and rider demand in different sections within a city. For some economical or sociological reasons, some parts of a city may grow faster than other parts. The closer an estimate of the overall or sectional growth, not only in number of people, but also by demographic groups, the better the planning of improvements is in meeting the future needs of a city. Also travel forecasts for the different proposed alternatives are essential to impact evaluation since impacts, such as travel time, vehicle operating costs, accident costs, air and noise pollution, gasoline consumption and others are all affected by travel demand.

Since travel forecasts occupy such important role in impact evaluation of transit improvements, many econometric models are being developed or improved constantly in hope of finding one which is simple in application and is more accurate in forecasting rider demand or projecting traffic volumes.

Because of the high correlation between ridership and the quality of service, Guseman, et al.,[13] claim that transit demand modeling which is based on population characteristics and service can predict demand rather successfully. Chadder and Mulinazzi's transit demand model [7] for small cities of 50,000 population expresses daily ridership as a function of fares, median family income and population of 65 years and over as follows:

(Daily Ridership) = 238 + (0.24 X Population 65+) + (4,480 X Fare in Dollars) - (0.09 X Median Family Income in Dollars).

In the model developed by Guseman, et al., [13], for cities of 100,000-500,000 population, daily ridership is expressed as a function of average headways, population size and number of buses in regular service as follows:

(Daily ridership) = -76,864 + (970.35 X Average Headways) + (0.1456 X Population Size) + (265.88 X Number of Buses in Regular Service).

Both models are believed to provide a sufficiently effective base for the preliminary estimation of transit ridership in a city.

For predicting traffic volume not only in a city, but also along a particular route or for a specific transit mode, Memmott and Buffington [16] found five functional forms expressing average daily traffic (ADT) as a function of time period (Year) to be a simple prediction model for ADT projection. These functions are listed as follows:

(1) $\ln ADT_t = a + bt$,

(2) $\ln ADT_t = a + b \ln t$,

(3) $ADT_t = a + bt$,

(4) $ADT_t = a + b \ln t$ and

(5) $\left(\frac{ADT_t}{10,000}\right)^2 = a + bt$

where, ADT = Average Daily Traffic,
t = Time Period (year) and
a,b = Parameters.

The one function which best fits the historical data of traffic volume should be the appropriate one to be used for forecasting traffic volume on that specific route or for a particular transit mode. This simple regression model does not consider the effect of capacity changes on ADT. However, for short range transportation improvements capacity changes are irrelevant. Therefore, for the purpose of this study, this regression model is adequate and is recommended because of its simplicity and its minimum data collection required.

Even though the period of implementation of short range transit improvements is limited to two years as specified in the interim report, the useful lives of most of these improvements (alternatives) can run from five to ten years. In other words, most of the improvements undertaken will serve the demand for such a span of time. Preliminary consideration of a traffic improvement, therefore, should include rider demand forecast for this improvement and also traffic projections along sections where the improvement is to take place.

City Size Characteristics

In the interim report, it is shown that the size of a city plays an influential role in the determination of the availability or feasibility of a certain transit mode or alternative, and the alternative in turn exerts impacts of different types and of various magnitudes depending on the city size. An alternative which is applicable in a large city may not be economically feasible in a small city, and one which is suitable for a small city may prove to be unsuitable in a large city.

Results of a telephone survey in the interim report reveals that top transportation priority improvements are being focused on fleet adjustments, route adjustments and frequency of service adjustments. Among the three, route adjustments are receiving top priority among short range alternatives, as chosen by all three city sizes. Other alternatives sensitive to city sizes are priority treatments for HOV which are favored by large cities but not available in either the medium-sized or small cities. Also, many demand responsive system adjustments have higher overall ratings in the small cities than in the larger ones.

It is hoped that such information will help officials to delete from further consideration transit alternatives that have been found to be unfavorable for their city size and to enable them to focus their attention to others which have been shown to be more favorable to their city size.

Relevant Impacts for Evaluation

A transit improvement can affect users and nonusers in many ways, from travel time, passenger discomforts, to air pollutants emitted by transit vehicles. In order to conduct an effective evaluation, it is important to have the relevant impacts identified for considerations so that savings in time and resources can be obtained by eliminating the nonrelevant impacts for considerations. Therefore, a preliminary study on relevant impacts includes not only the identification of the relevant impacts but also a general understanding of the nature of these impacts.

In the interim report, most of the impacts identified for short range transit considerations are found to be influenced by population and population density, two of the city characteristics that determine the size of a city. In general, the larger the city, the greater the impacts. For improvement consideration within a city, the magnitudes of the impacts from each alternative will be revealed only after the estimation procedures presented in the latter part of this report are applied.

Relevant impacts from short range transit alternatives have been identified and discussed in the interim report. They include monetary and nonmonetary costs. However, they are grouped and classified differently here from the way they were in the interim report. The impacts are separated into three categories: monetary, nonmonetary and society costs. Monetary impacts further include two major categories: user and system costs. Specific impacts identified under each of these impact categories are discussed individually in the interim report, so they are only briefly discussed in this report.

Transit impacts included in the user category are: travel time, discomforts and inconveniences, vehicle operating costs, accidents, parking fees, and fares and tolls. The category of system costs covers transit vehicle operating costs, operation and maintenance road costs and capital costs of an improvement alternative. In the nonmonetary impact category, air and noise pollution and land use are the three impacts to be evaluated. The category of society costs includes impacts of business activity, accessibility to job opportunity, fuel consumption and ridership.

Evaluation results of society costs play no direct role in the overall evaluation process of choosing the best transit alternatives, because this category of impacts is indirectly included in the monetary and/or nonmonetary impact evaluation. The problem of doublecounting is thus avoided.

For example, fuel consumption has been included in both the user impact of vehicle operating costs and the system impact of transit vehicle operating costs, of which oil and fuel are two of the elements. With the recent concern for saving energy, it is thought that information on this impact, presented separately, will be valuable to those who must address this problem.

The impact of accessibility is included in the user impact category of travel time. How accessible it is for one to get to one's job can be expressed in the amount of time one saves by using a specific mode or type of facility.

Business activity is expressed by the amount of commercial development (land use) impact in the nonmonetary impact category. The degree of business activity is directly related to the amount of commercial development.

Lastly, ridership is believed to be directly related to the quality of service, of which travel time saving is the representative measure. Other impacts influence ridership also, although to lesser degrees. High vehicle operating costs or scarcity of fuel will induce more ridership on public transit, and environmentally conscious groups will react accordingly to alternatives which affect air or noise pollution.

Table 2 lists the three impact categories and their specific impacts. The appropriate units of measurements are also presented.

Table 2. Relevant Impacts by Category, with Unit Measurements

Category	Impacts	Unit of Measurement
Monetary User Costs	Travel Time	$/passenger-hour
	Discomforts & Inconveniences	$/passenger-hour
	Vehicle Operating Costs	$/vehicle-mile
	Accidents	$/accident
	Parking Fees	$/space
	Fares and Tolls	$/passenger, $/vehicle
System Costs	Transit Vehicle Operating Costs	$/vehicle-mile
	Operation & Maintenance Road/ Highway Costs	$/vehicle-mile
	Capital Costs	$
Nonmonetary Costs	Air Pollution	Grams
	Noise Pollution	dBA
	Land Use	Acres
Society Costs	Business Activity	Descriptive
	Accessibility to Job Opportunity	Descriptive
	Energy Consumption	gallons
	Ridership	# of passengers

RECOMMENDED IMPACT EVALUATION APPROACH

The three commonly used impact evaluation methods identified in the interim report are the economic efficiency method, the cost effectiveness method and the scoring method. Each of these methods has its strengths and weaknesses which are discussed in detail in the above report. Also, a recommended approach utilizing all three methods are outlined in that report.

Although the scoring method has been criticized for involving subjectiveness of the evaluators, it is used here together with the economic efficiency method and cost effectiveness method to provide a common unit of measurement for evaluating impacts in both monetary and nonmonetary categories. User impacts are expressed in terms of dollars; impact of air pollution are expressed in terms of grams; noise pollution is measured in terms of decibals; and land use impacts are measured in acres. In order to combine all the estimated impact values to arrive at a total saving of an alternative, all these different units must be converted to a common base.

An economic efficiency analysis is performed on the user impact category and a cost effectiveness method is adopted to measure the nonmonetary impacts. The common measurement of performance used in both methods is the benefit-cost ratio. The ratios obtained are further rated within impact subcategories. Based on information obtained from preliminary determinations, these ratings are then adjusted by the respective impact category weights assigned to arrive at scores which can be summed up across impact categories to yield total scores for the alternatives under evaluation. The overall ranking of alternatives depends on the size of the total scores for each alternative. The higher the score, the higher the ranking.

The methodology of the recommended approach presented in this section includes a discussion of some definitions and assumptions necessary for the approach, an outline of the evaluation approach, a discussion of updating procedures for user costs and air pollution emission, a presentation of the various estimation techniques necessary for evaluating each of monetary and nonmonetary impacts and the data requirements for each procedure, and lastly, an illustration of the approach by using a hypothetical case study.

Definitions and Assumptions

In the user impact evaluation approach recommended in this study, the benefit-cost ratio is adopted as a measure of the economic effectiveness of each transit alternative. Because of the controversies arising from this economic measurement, it is felt that a definition of this subject is warranted. Also, there are five assumptions which are necessary for this recommended impact evaluation approach. They are: definition of an analysis period, adoption of a discount rate, consideration of a growth rate, treatment of capital costs of the "do-nothing" alternative and of residue values, handling of the rating relationship, setting of the maximum rating scale, and lastly, choice of unit costs.

Benefit-Cost Ratio

In economic analyses, two benefit-cost ratios have been used. Arguments over the superiority of one over the other arise frequently. The controversy stems from the definitions of benefits which appear in the numerator and the costs which are put in the denominator. The aggregated benefit-cost ratio is defined as user benefits divided by the aggregate of the initial investment and operating and maintenance costs while the netted benefit-cost ratio has the benefits netted out the operating and maintenance costs in the numerator and the initial investment in the denominator.

Schwab and Lusztig [21] favor the netted ratio on grounds that it does not violate some basic economic rules. The netted ratio, they argue, recognizes the differences between costs which an investor has to provide and costs which are covered by benefits derived. The Highway Economic Evaluation Model (HEEM), developed for the Texas State Department of Highways and Public Transportation uses the netted ratio. The AASHTO [1] recommends the aggregated ratio for all highway and transit applications for reasons that both the investment budget and the future operating and maintenance budgets are constrained. Furthermore, the two budgets are interchangeable. Quinin [19] and Bain [3] also argue for the aggregated ratio on similar grounds.

Even though the netted ratio is more rational, the aggregated ratio is adopted in the recommended impact evaluation approach, partly for the reasons that the AASHTO mentions but mainly because the netted ratio is not applicable in evaluating the net benefits of the nonmonetary impacts. While the nonmonetary impacts have units of grams, decibals, and acres, the operating and maintenance costs have dollars as their units of measurements. The difference in units makes it impossible to net out the operating costs from the benefits. It is because of these reasons that the aggregated ratio is used for the recommended approach in this study, and for the same argument last mentioned, the net present value is not used.

Analysis Period

An analysis period is defined for the purpose of evaluating projects. Within this period, one or two study years are chosen for the analysis. Often the first and last years in the period are chosen to be the study years. Benefits and costs analysed based on data collected or projected for the study years are extended to cover the whole analysis period to arrive at the final benefits and costs for a specific improvement. For any short range transit consideration, an analysis period is suggested to be ten years. This length of time is chosen because it more or less represents the average life of vehicles, such as buses, vans or automobiles, used for short range transportation alternatives. At the end of the analysis period, thus, the residue values can be assumed to be insignificantly small. Consequently, the evaluation process is made one step simpler. Alternatives may have different lives, depending on lives of equipments or facilities used for the alternative. In order to generate comparative results among alternatives, a uniform analysis period has to be defined. For the alternatives which have shorter lives, net beneifts at the end of the respective lives are extended to the end of the analysis period. Then the present value of each stream of benefits is obtained. Figure 4 illustrates the different years in the analysis period and their possible effects on traffic volumes and ridership as a hypothetical alternative S is adopted.

Discount Rate

A discount rate represents the common market rate of return on or the opportunity costs of capital investments made for undertaking an

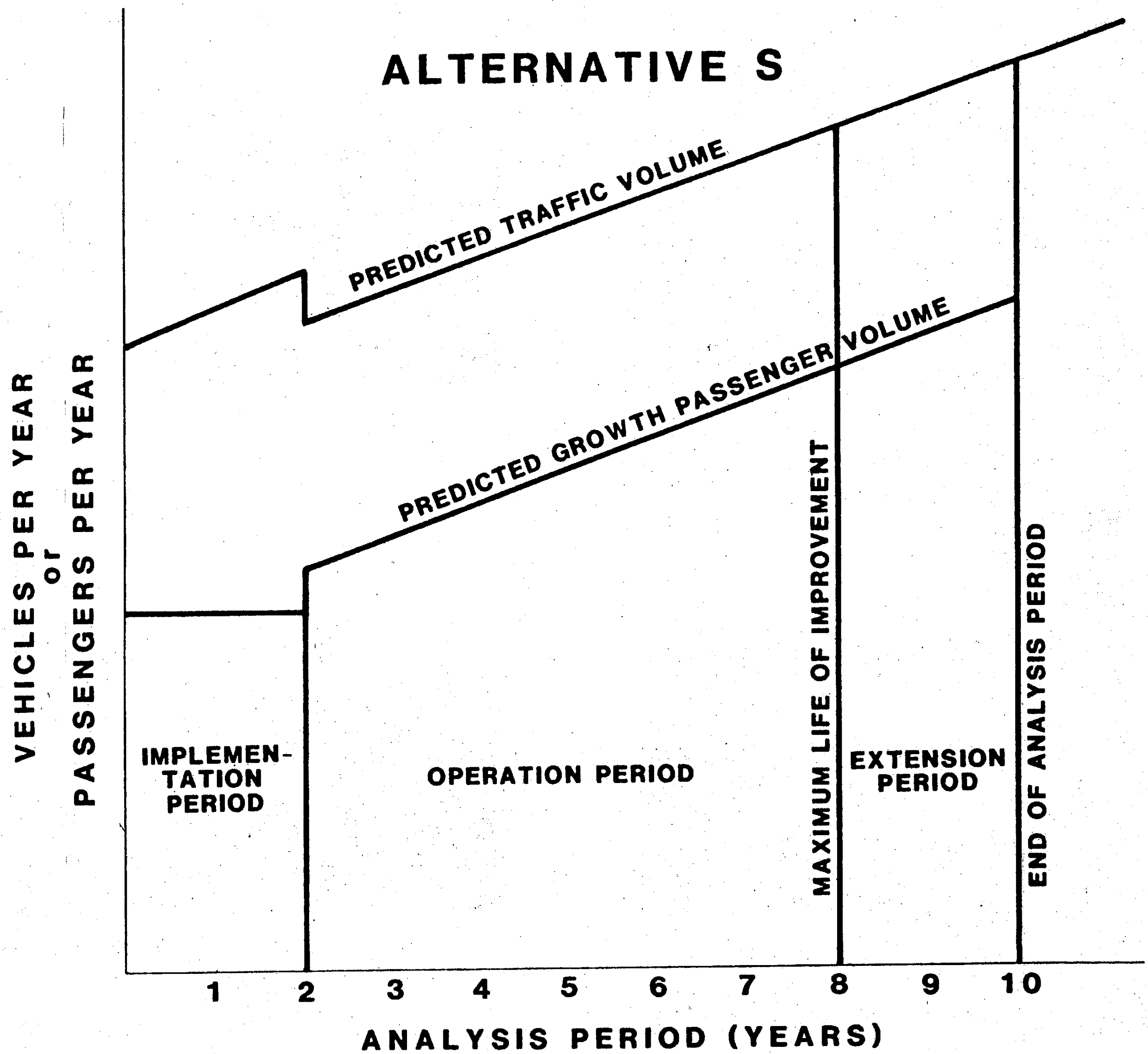

Figure 4 Illustration of Key Years in the Analysis Period and their Possible Relationship with the Predicted Traffic or Passenger Volume

alternative. A common discount rate is required for obtaining the present value of the monetary benefits and costs.

While the definition of the discount rate is well defined, disagreement arises among authors as to what rate is appropriate for adoption. The HEEM uses a discount rate of twenty percent in the model. The AASHTO [1] recommends a four to five percent for data expressed in constant dollars and Buffinton, McFarland and Rollins [5] concour with the recommendation in their study. They further conclude that any discount rate higher than this implicitly includes the inflation rate. McLeod and Adair [15] use a ten percent discount rate in their analysis and no additional inflation factor is applied.

Considering the current market conditions of interest rate, a discount rate of eight to ten percent, for benefits and costs expressed in constant dollars, is believed to be in line with the AASHTO's recommendation in 1977, and therefore is recommended in this study. An inflation factor is not considered since it is felt unnecessary and inappropriate in calculating present values.

Growth Rate

A growth rate in transportation is defined as the rate at which the average daily traffic (ADT) grows in time. In recent years, transportation in most big cities of Texas has been experiencing a 2-3 percent growth rate. As discussed in the previous section, traffic volume (or passenger volume) may increase or decrease as a result of improvements made on a traffic route. Different improvements may have different effects on ADT. In order to give a more accurate evaluation, travel forecasts made at the outset will give a growth rate which can be incorporated into the analysis.

Although a variable growth rate which changes from year to year is more realistic, a constant growth rate which stays the same over the years is more practical in the application of a noncomputerized model. It is questionable whether or not the additional accuracy resulting from using a variable growth rate can outweight the extra costs needed to obtain and to use a variable growth rate in impact evaluation. Therefore, in the recommended approach, each alternative assumes a constant growth rate over the whole analysis period for user impacts, transit operating costs and the nonmonetary costs. As for the system's O & M road/highway costs, a uniform series which assumes an equal amount of costs to be incurred annually over the whole period, is recommended.

Residue Value and Capital Costs

Reside Values. If the economic value of any equipment or facility becomes insignificant at the end of the analysis period, it is safe to assume a zero residue value for the project. However, if the economic value at the end of the analysis period significantly influences the cost factors, the residue value, then, is required to be deducted from the original cost to give the time cost of the alternative.

Capital Costs. If some of the capital costs are to be spent in year other than year 1, they have to be discounted back from the year when they are intended for expenditure to the present. Capital costs for the "do-nothing" alternative are assumed to be zero since this alternative by definition requires nothing to be done.

Relationship Between Ratings and Estimated Results

In the rating procedure adopted in the recommended approach to impact evaluation, the relationship between the ratings and the estimated results of each impact for all the alternatives under consideration is assumed to be linear and continuous. Hibbard and Miller [14] in their proposed rating treatment of effects of highway improvements, assume such relationship to be linear but discrete. The assumption of linearity is believed to be acceptable for evaluating short range transit alternatives. However it is thought that a continuous relationship is more realistic than a discrete relationship. Also, by assuming a continuous relationship, subjectiveness involved in the scoring method is thought to be lessened.

Maximum Rating

The maximum rating is defined as the highest rating assigned to the highest benefit-cost ratio within an impact category. It is used in the recommended impact evaluation approach when all the benefit-cost ratios are to be rated. It equates itself to the highest benefit-cost ratio in an impact category and thus sets the proportionality factor for other ratios in the same category to be rated proportionally.

A maximum rating of 3 is chosen based more or less on the conventional three-grade rating: excellent, good and fair. Actually the choice of the number does not affect the final outcome of ranking alternatives since all the ratios will be rated on the same scale. The magnitudes of the ratings may change as a result of using a different number for the maximum rating, but they are uniformly inflated or deflated, depending on whether the number chosen is bigger or smaller than 3, by a common factor within one impact category. The order of ranking does not change.

Unit Costs

In estimating the various impacts, the unit cost method is recommended for adoption. The unit cost for an impact is assumed to be the most appropriate one chosen for the study.

Outline of Impact Evaluation Approach

An outline of the recommended impact evaluation approach to be performed on a step by step basis is presented as follows:

I. Describe characteristics of proposed alternatives evolving from the preliminary determinations including:

1. Relevant short range transit alternatives,
2. Funding sources,
3. Local needs and goals,
4. Projected traffic and rider demand,
5. City size characteristics and
6. Relevant impacts for evaluation.

II. Determine the assumptions necessary for the study including:

1. Analysis period,
2. Discount rate,
3. Growth rate,
4. Residue values and capital costs,
5. Relationship between ratings and estimated results,
6. Maximum rating and
7. Unit costs.

III. Update monetary and nonmonetary unit costs.

IV. Determine relevant monetary impacts for each transit alternative for each study year. (The estimation procedure for each impact will be discussed later in this report.)

1. Estimate annual highway and transit user costs which include:

A. Passenger time costs, while:

   (a) In vehicle (bus and/or private car),
   (b) Transferring,
   (c) Walking and
   (d) Waiting.

B. Discomforts and inconveniences costs (bus and/or private car)

C. Private vehicle operating costs including:

   (a) Depreciation,
   (b) Fuel,
   (c) Oil,
   (d) Tires and
   (e) Maintenance.

D. Accident costs (to user only),

E. Private vehicle parking and toll costs and

F. Fare costs.

2. Estimate annual transit vehicle operating costs which include:

   A. Driver time cost,

   B. Vehicle operating costs covering:

      (a) Depreciation,
      (b) Fuel,
      (c) Oil,
      (d) Tires,
      (e) Maintenance and
      (f) Insurance.

3. Estimate annual transit system fare revenues

4. Estimate annual operation and maintenance road costs.

5. Estimate annual transit system capital costs including:

   A. Equipment and

   B. Facilities

6. Calculate the annual user benefits of each type of user costs (impacts) listed in IV-1 for each transit alternative--by subtracting the estimated user costs for each

proposed alternative from the user costs for the "do-nothing" alternative.

7. Calculate total annual user benefits for each alternative--by summing all the annual user benefits for each alternative in IV-6.

8. Calculate the present value (PV) of the total user benefits--by

   A. Extending the total annual user benefits for each alternative in IV-7 to cover the entire analysis period and

   B. Calculating the PV of this stream of user benefits.

9. Calculate the annual change in transit vehicle operating costs of types listed in IV-2 for each transit alternative--by subtracting the estimated annual transit vehicle operating costs for the "do-nothing" alternative from transit vehicle operating costs for each proposed alternative.

10. Calculate the total annual change in transit vehicle operating costs for each alternative--by summing the annual changes in all transit vehicle operating costs obtained in IV-9 for each alternative.

11. Calculate the annual change in transit fare revenues in IV-3--by subtracting the estimated annual fare revenues for the "do-nothing" alternative from the estimated annual fare revenues for each proposed alternative.

12. Calculate the total annual change in net transit vehicle operating costs for each alternative--by subtracting the annual change in transit fare revenues in IV-11 from the annual change in transit vehicle operating costs in IV-10.

13. Calculate the PV of the total change in net transit vehicle operating costs obtained in IV-12--by

    A. Extending the total annual change in net transit vehicle operating costs to the entire analysis period and

    B. Calculating the PV of this stream of changes in net transit vehicle operating costs.

14. Calculate the annual change in operation and maintenance road costs in IV-4--by subtracting the estimated operation and maintenance road costs for the "do-nothing" alternative from the operation and maintenance road costs for each proposed alternative.

15. Calculate the PV of the total change in operation and maintenance road costs in IV - 14--by

    A. Extending the annual change in operation and maintenance road costs to the entire analysis period and

    B. Calculating the PV of this stream of changes in operation and maintenance road costs.

16. Calculate the annual change in transit system capital costs in IV-5--by subtracting the capital costs for the

"do-nothing" alternative from the capital costs for each proposed alternative.

17. Calculate the PV of total change in capital costs in IV-16--by discounting the capital costs for the number of year(s) from the year expenditure is expected to year 0.
18. Calculate the PV of total change in system costs for each alternative for the anaylsis period--by adding the estimated PV of total change in net transit vehicle operating costs (IV-13), the PV of total change in operation and maintenance road costs (IV-15) and the PV of the total change in capital costs (IV-17).
19. Calculate the beneift-cost ratio--by dividing the PV of the total user benefits obtained in IV-8 by the PV of total change in system costs calculated in IV-18.
20. Delete any alternative with benefit-cost ratio, calculated in IV-19, of less than one from further consideration.

V. Determine the nonmonetary impacts for each transit alternative for each study year. (The estimation methods for individual nonmonetary impacts will be presented later in this section.)

1. Estimate the annual amounts of air pollution in grams generated from each transit alternative. The pollutants are:
    A. Carbon monoxide (CO),
    B. Hydrocarbons (HC) and
    C. Nitrogen oxide (NO_x).

2. Estimate the annual noise pollution in decibals (dBA) for each alternative.

3. Estimate annual land uses in acres for each alternative including:

   A. Residential,

   B. Commercial and industrial and

   C. Other.

4. Calculate annual benefits of each nonmonetary impact for each transit alternative--by comparing the estimated effects from each of the proposed alternatives to those from the "do-nothing" alternative.

5. Calculate the "PV"[a] of total nonmonetary benefits from each impact subcategory for each alternative--by multiplying the annual benefits from each impact subcategory by the present value factor used in obtaining the PV of total user benefits (IV-8).

6. Calculate the "pseudo" benefit-cost ratio for each alternative in each nonmonetary impact subcategory--by dividing "PV" of total benefits of each nonmonetary impact obtained in (V-5) by the PV of total change in system costs (IV-18).

[a]Because the nonmonetary benefits derived are in non-dollar units, PV used here deviates slightly from the conventional meaning. It is assumed here that these benefits imply dollar values; as a result, PV of these benefits can be calculated by adopting a discount factor.

VI. Establish weights for monetary and nonmonetary impact categories and subcategories.

1. Form a committee consisting of:

   A. Transportation planning officials and

   B. Citizen representatives.

2. Determine weight distribution between monetary and non-monetary impact categories by:

   A. Giving every member 100 points to be distributed between the monetary and nonmonetary categories, and

   B. Finding the average points (categorical weights) for each category.

3. Determine weight distribution among impact subcategories within the nonmonetary category by:

   A. Giving every member 100 points to be distributed among impacts within the nonmonetary category and

   B. Finding the average points (subcategorical weights, expressed in percentages) for each impact in this category.

VII. Rate all the benefit-cost ratios calculated in IV-19 and V-6.

1. Assign a maximum rating of 3 to the alternative with the highest benefit-cost ratio in the monetary impact category and in each of the nonmonetary subcategories.

2. Calculate the ratings for the remaining ratios in the same impact category or subcategory for other transit alternatives -- by multiplying each benefit-cost ratio by the respective proportionality factor established in VII-1, between the maximum rating and the highest ratio.

VIII. Determine the total score for each alternative.

1. Calculate the impact scores for the nonmonetary impact subcategories for each transit alternative--by multiplying the ratio ratings in each subcategory (VII-1 and VII-2) by the corresponding subcategorical weight for this nonmonetary impact subcategory (VI-3-B).
2. Calculate the total impact score for the nonmonetary impact category--by summing all the impact scores for the three nonmonetary impact subcategories obtained in VIII-1.
3. Calculate the total score for the nonmonetary impact category--by multiplying the total impact score for the nonmonetary impact category by the corresponding categorical weight determined in VI-2-B.
4. Calculate the total score for the monetary impact category--by multiplying the ratio ratings obtained in VII-1 and VII-2 for the monetary impact category by the corresponding categorical weight determined in VI-2-B.
5. Calculate the overall final score for each alternative--by adding the total scores for the monetary and nonmonetary impact categories calculated in VIII-4 and VIII-3.

The recommended approach for short range transportation impact evaluation has been outlined step by step. Figure 5 shows the flow chart for illustrating the approach. The alternative with the highest total score from the analysis should be the optimal choice among the proposed alternatives which have been evaluated.

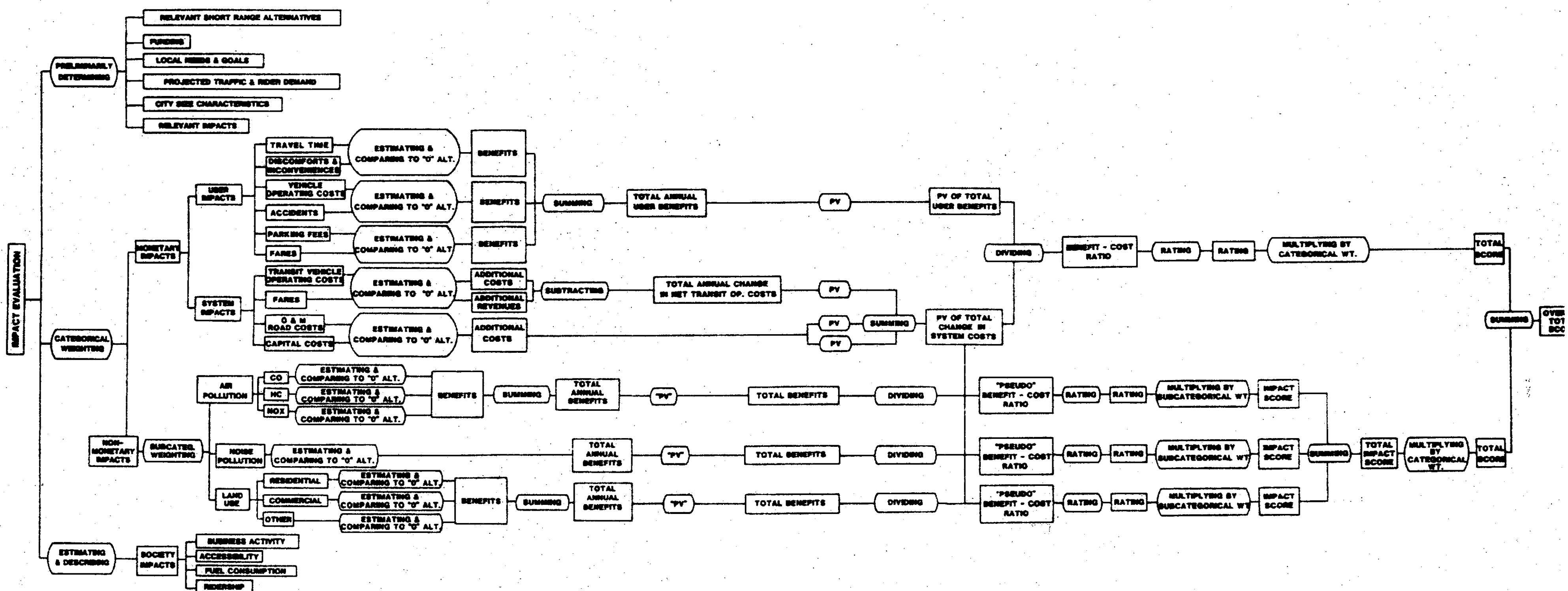

FIGURE 5. FLOW CHART ILLUSTRATING THE RECOMMENDED IMPACT EVALUATION APPROACH

NOTE:

(rounded box) REPRESENTS METHOD OR TECHNIQUE USED

(rectangle) REPRESENTS INPUTS OR OUTPUTS

" " REFERS SPECIAL MEANING MENTIONED IN THE TEXT

It is to be noted here that the methodology developed above, stresses heavily the picking of the optimal alternative. It assumes that the desirability criteria for implementing an alternative rests on the benefit-cost ratio analysis of the user impacts. Alternatives with user benefit-cost ratios less than one are economically undesirable and should be eliminated from further consideration. For transportation in Texas cities where air or noise pollutions, so far, have not affected the environment to such a serious degree as some of the other cities, like Los Angeles or St. Louis, this assumption poses little problem. However, in the future, if any of the Texas cities becomes so badly affected by the nonmonetary impacts that user benefits no longer dominate the desirability criterion, extra steps will then be required to insure the inclusion of a desirability criterion based on the nonmonetary impacts as well as the monetary impacts.

If such case arises, the necessary additional procedure calls for setting equivalent monetary values for the nonmonetary impacts. A willingness-to-pay approach which is in line with AASHTO's methodology in some of the cost estimations, can be adopted. The same committee which sets the categorical and subcategorical weights in the recommended impact evaluation approach can perform this task provided informations and cost data of the various impacts from some of the badly affected cities, are made available to them. Such information and data will serve as guidelines to the members when they decide how much they are willing to pay for reducing a certain amount of pollutants or for inducing a specific acreage of land development. The average value among all those set by the members will be adopted as the equivalent monetary value for a unit of a specific nonmonetary impact. Once each nonmonetary impact has a equivalent monetary unit, it can be incorporated into the benefit-cost ratio analysis, treating it as an element of the total benefits. Categorical and subcategorical weights can be used to adjust the benefits distribution favored by the city between the monetary and nonmonetary categories and also among nonmonetary subcategories. The benefit-cost ratio, with total benefits and total changes in costs in the numberator and demoninator, respectively, of one or greater than one, will dictate the economical desirability of implementing any alternative just as it is conventionally used.

Obtaining the extra information and expert opinions on the various nonmonetary impacts adds extra cost which may prove unnecessary to cities, such as those in Texas. The recommended impact evaluation approach developed in this study is intended mainly for transportation in Texas cities where air or noise pollutions have not been severe. Other cities with similar backgrounds can adopt this approach without difficulty. It is cities which are greatly affected by some of the nonmonetary impacts that attentions should be directed to the above assumption.

Updating Procedures for User Costs and Air Pollution Emission

Over the years, general price level of the various unit costs change. Also, the price level of the components of some of the unit costs change more or less than the general price level. Therefore, before applying the pertinent unit cost from a source table to an analysis, it is necessary to update it from the reference year to the current year, and every 3-5 years, a component update is also essential to better represent the true increase of the unit cost.

Updating procedures for highway and transit user costs such as travel time, vehicle operating costs and accident costs have been developed by Buffington and McFarland [4]. A procedure for updating the emission rates of air pollutants is developed by Curry and Anderson [12]. These procedures are presented individually below with t and b representing the the current year and the base year, respectively.

Value of Time

The value of time cost can be updated by the ratio of per capita gross income of Texas for the current year to that for the base year, or the ratio of average hourly income for production workers in Texas for the current year to that for the base year. The updating factor for time cost in mathematical form becomes:

$$\frac{\text{Per Capita Gross Income of Texas}_t}{\text{Per Capita Gross Income of Texas}_b} ,$$

or

$$\frac{\text{Ave. Hourly Income for Production Workers in Texas}_t}{\text{Ave. Hourly Income for Production Workers in Texas}_b} .$$

Vehicle Running Costs

Running costs for vehicles include fuel, engine oil, tires, maintenance and repairs, and depreciation. A general procedure for updating running costs as a whole can be done by using a ratio of the consumer price index for the current year to that for the base year. The factor can be expressed as follows:

$$\frac{\text{Consumer Price Index}_t}{\text{Consumer Price Index}_b} \text{ ,}$$

Individual unit costs for the components of three vehicle types, passenger car (type 1), single-unit truck (type 2 and type 4) and 3-S2 diesel truck (type 3), have to be updated every 3-5 years in order to give a better estimate of running costs. The individual unit cost factor for updating, represented by the percentage increase of a component unit cost, is obtained by the following relationship:

$$\frac{\text{Component Price Index}_t - \text{Component Price Index}_b}{\text{Component Price Index}_b} \text{ .}$$

Each individual unit cost factor is first weighted by its proportion of the total running costs. Since the proportion is affected by traveling speed, the initially weighted individual unit cost factors are further weighted by the speed of travel. Four uniform speeds are chosen by Buffington and McFarland [4] for the weighting, based on Winfrey's component and total running costs tables [24, Table A-1 to A-4], 5, 30, 50, and 80 MPH for passenger cars; 5, 30, 50, and 65 MPH for single unit truck; and 5, 30, 50, and 60 MPH for 3-S2 diesel truck. The average of the weighted factors for the four speeds for a vehicle type can serve as the updating factor for running costs on freeways and on city streets, for excess running costs due to speed changes and for idling costs.

The above described updating procedure for a vehicle type can be illustrated in mathematical form below:

$$\frac{1}{4}\left[\sum_{i}\sum_{j}(C_i A_{ij})\right]$$

where $C_1,\ldots,C_5$ are percentage increase in component unit costs of fuel, oil, tires, maintenance and repairs, and depreciation, respectively, and $A_{1j},\ldots,A_{5j}$ are their corresponding proportional percentages to total costs at speeds of 5, 30, 50, and the highest speed for their specific vehicle types for $j = 1,\ldots,4$, respectively.

The proportional percentages of the components to the total vehicle operating costs should be calibrated from time to time.

Discomforts and Inconveniences

Updating factor for discomforts and inconveniences can be obtained by using a ratio of the consumer price index for the current year to that for the base year:

$$\frac{\text{Consumer Price Index}_t}{\text{Consumer Price Index}_b}\ .$$

Accidents

The updating factor for accident costs used by Buffington and McFarland [4] is represented by the ratio of the consumer price index for medical care for the current year to that for the base year. It is shown in mathematical form below:

$$\frac{\text{Consumer Price Index for Medical Care}_t}{\text{Consumer Price Index for Medical Care}_b} .$$

Air Pollutant

Curry and Anderson [12] developed a set of updating factors, converting the automobile emission rates for 1968 to any study year up to 1990, as shown in figure 6. Therefore, by utilizing the given factors in this figure, updating factor for air pollutant emissions from any base year to the current year can be obtained by the following expression:

$$\frac{\text{Emission Factor}_t}{\text{Emission Factor}_b} .$$

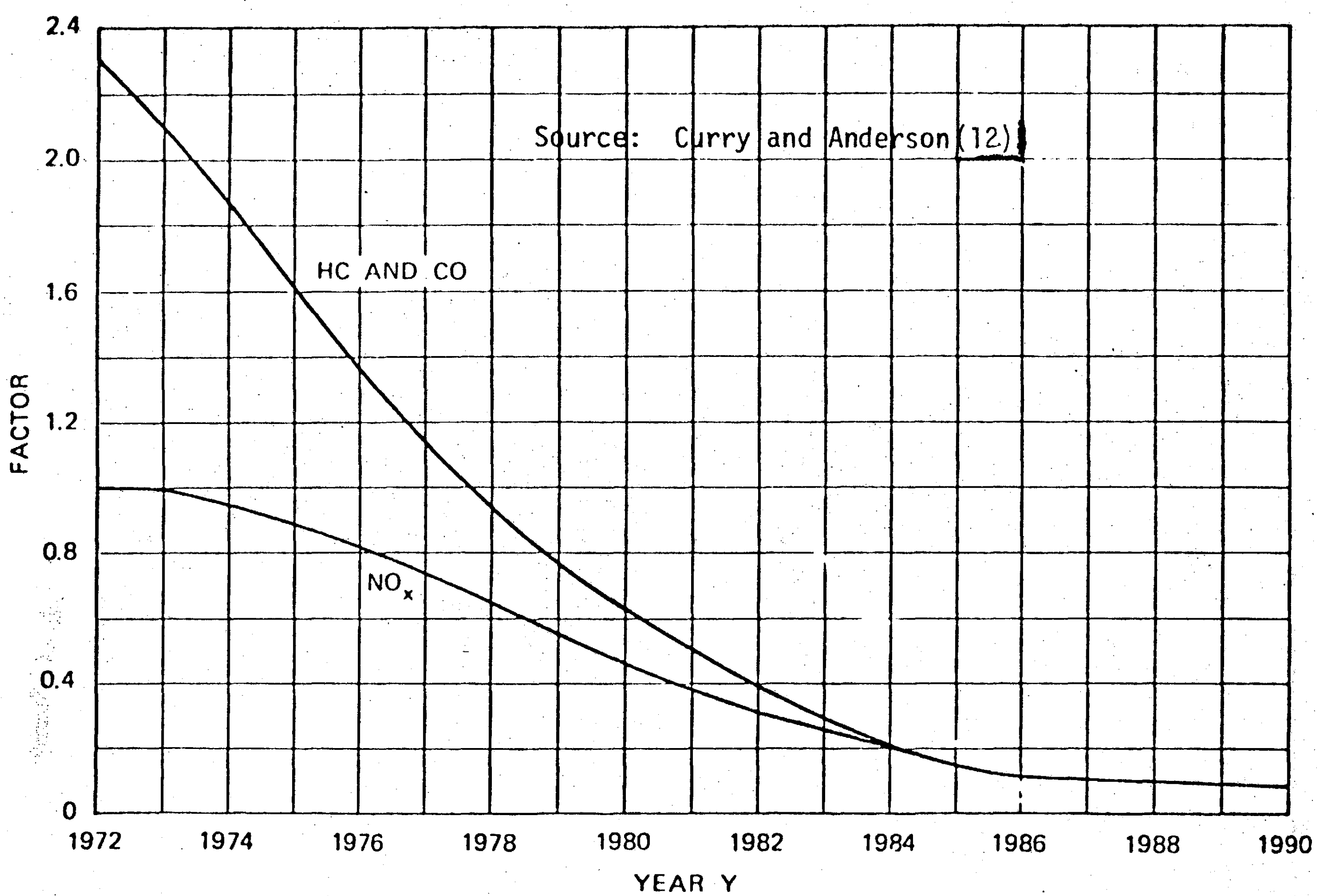

Figure 6. Factor to Convert Reference Year Emissions to Emissions in Year Y

Estimation Procedures and Data Requirements for Determining Highway and Transit User Impacts

The detailed estimation procedures and data requirements for determining highway and transit user impacts are presented here. As mentioned earlier in the report, those using highways and streets in an urban area can be classified into two groups: (1) highway users and (2) transit users. For analysis purposes, the highway users are those who do not use the currently available transit system to make partial or full trips, say, to and from work. On the otherhand, transit users are those who do use the transit system to make either full or partial trips for some purpose. Partial trips are those that involve the use of private vehicles to carry users to bus stops or park-n-ride terminals. From that point, they ride the transit buses to complete their trips.

The estimating procedures and data requirements for determining highway and transit user impacts depend partially on whether these two groups of users are evaluated separately or together and whether the basic data used to calculate transit user impacts are on a trip or vehicle-mile basis. Since the annual user benefits from short range bus transit improvement are defined as a reduction in user costs for highway and transit users, it may be justifiable as much as possible, not to separate the two groups for analysis purposes. This is the approach taken in this study, and most of the basic data required for calculating user impacts are put on a vehicle-mile basis.

Highway and bus transit user costs for most relevant transit improvement alternatives are sensitive to the following major factors:

1. Road type and capacity,
2. Vehicle type and occupancy,
3. Traffic volume and direction, and

4. Time and purpose of travel.

Also, transit improvement alternatives may involve only one or two existing or proposed transit routes. Even then, only certain segments of a route may be involved. For these reasons, it is recommended that the basic physical unit (facility and traffic) data required for calculating highway and transit users costs be collected on a route basis, with each route being segmented by road type and capacity. Figure 7 shows a sample of bus routes of a city divided into sections that represent different road types and road capacities. Appendix table A1 shows the basic facility and traffic segment data to be collected for each bus route. This form can be used to collect current peak period or nonpeak period data for traffic traveling in one direction. Also, the form can be used to record predicted facility and traffic conditions of each route segment for evaluating each transit alternative (build and no build).

Those routes or road segments not affected by any of the proposed transit alternatives could be ignored in the analysis. However, it is extremely important to know the existing conditions for each route segment during peak and nonpeak periods in order to identify problem segments and propose possible solutions. Route segments with similar facility, traffic conditions (current and predicted) could be treated in the same manner or combined for the analysis of user costs.

The bus route segment approach does present a problem with furnishing accurate data for estimating multiple mode user costs. Specifically, that portion of the trip in which a private automobile or pickup is used is where the problem lies. How long should this route segment be to represent that portion of the multiple mode user's trip? Perhaps the best solution is

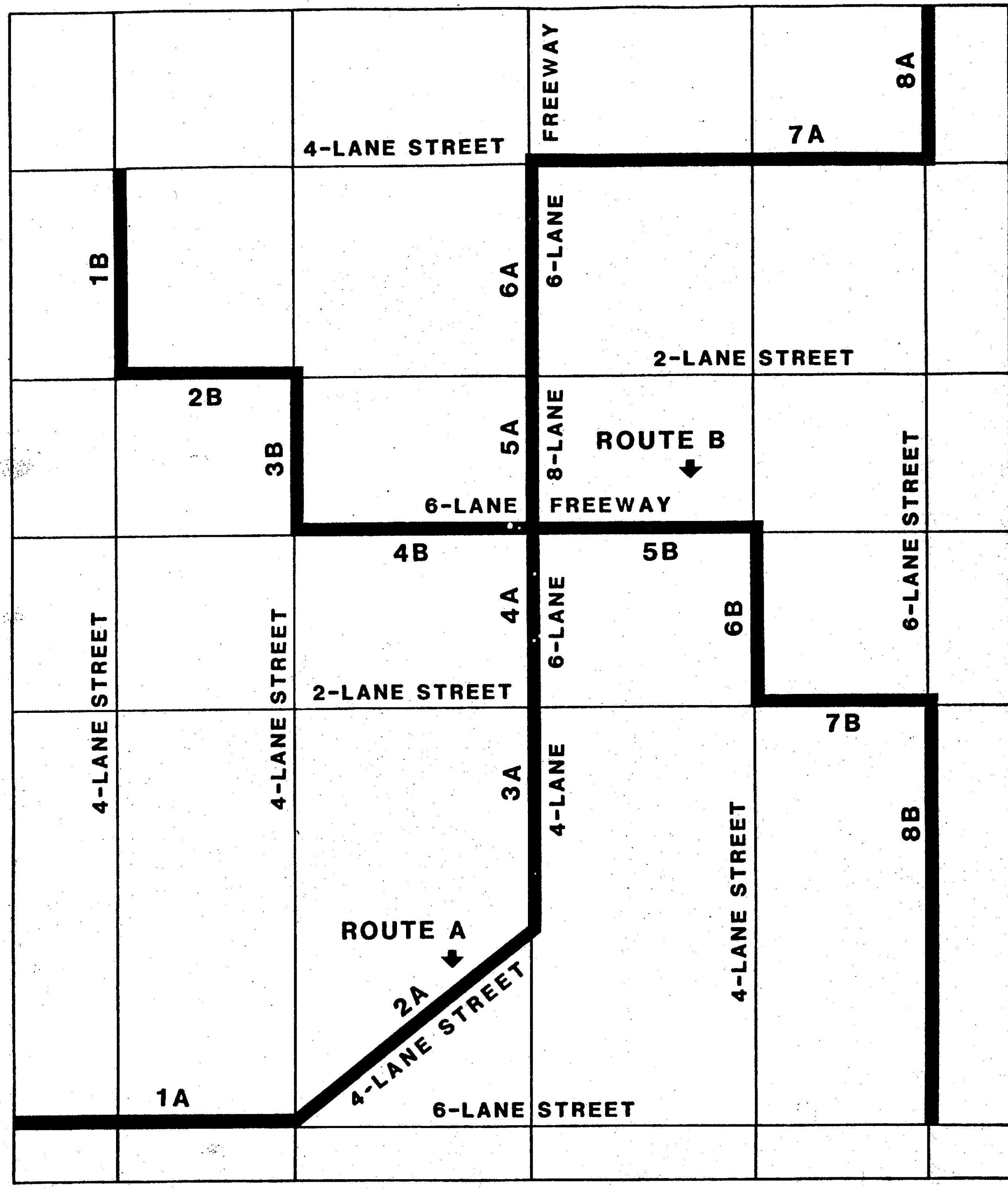

FIGURE 7 SAMPLE OF BUS ROUTES DIVIDED INTO SEGMENTS BASED ON A CHANGE IN NUMBER OF LANES.

to conduct an on board bus survey of such users and calculate the average length of the private vehicle portion of such trips. Appendix table A2 shows data that should be obtained by such a survey. (Part of the data in this table is needed for calculating the transit system costs.) Also, the other facility and traffic conditions of this terminal route segment could represent that of the most likely route taken by the multiple mode users to the bus stop or park-n-ride lot.

The other solution to the above problem is to calculate the multiple mode user's cost entirely on a trip basis by using data from transit operator files, such as shown in appendix table A3. This approach has the basic weakness of ignoring the specific facility and traffic conditions of each route segment used by the multiple mode trip users.

The bus route segment vehicle-mile approach is flexible in that the transit user cost analysis can be conducted on a partial route, whole route, multiple route, or whole transit system (all routes combined) basis. Also, the approach allows the analysis to take into account route segment transition user costs and users costs for different periods of the day or directions of travel. Lastly, the route segment data can be used in calculating the transit vehicle operating costs on a more comparable basis with the highway and bus transit user costs.

The basic data called for in appendix tables A1 and A3 can be collected from city and state traffic records and supplemented by use of instrumented vehicles and observers or interviewers on buses traveling each bus route. Appendix table A2 lists data that can be collected by onboard surveys.

Table 3 shows the final units of measurement and calculations required

Table 3. Final Units of Measurement and Calculations Required to Obtain Highway and Transit User Costs for Any Transit Alternative by Impact Category[a]

Highway and Transit User Impact Category	Final Unit of Measurement: Physical Unit	Final Unit of Measurement: Cost Unit	Final Calculation to Obtain User Cost($)
Travel Time Costs			
In-Vehicle (Private and Public)			
City Streets (arterial)			
Traveling at Uniform Speed	D-Hrs, P-Hrs	$/D-Hr, $/P-Hr	D-Hrs X $/D-Hr, P-Hrs X $/P-Hr
Additional for Stopping	" " , " "	" " , " "	" " " " " "," " " " "
Additional for Speed Changes	" " , " "	" " , " "	" " " " " "," " " " "
Additional for Segment Changes	" " , " "	" " , " "	" " " " " "," " " " "
Additional While Stopped	" " , " "	" " , " "	" " " " " "," " " " "
Freeways			
Traveling at Average Speed	" " , " "	" " , " "	" " " " " "," " " " "
Out-of-Vehicle			
Walking, Waiting, and Transferring	NA, " "	NA " "	- - - NA - - - " " " " "
Discomforts and Inconveniences (Private & Public)	LOV, " "	$/V-Hr	V-Hr X $/V-Hr
Vehicle Operating Costs (Private)			
City Streets (arterial)			
Traveling at Uniform Speed	Sp, V-Miles	¢/V-Mile	(V-Miles X ¢/V-Mile) ÷ 100
Additional for Stopping	Sp, Sp Reduction, Stops	¢/Stop	(Stops X ¢/Stop) ÷ 100
Additional for Speed Changes	Sp, Sp Change, Cycles	¢/Cycle	(Cycles X ¢/cycle) ÷ 100
Additional for Segment Changes	Sp, Sp Change, Segments	¢/Cycle	(Segments X ½ ¢/cycle) ÷ 100
Additional While Stopped	V-Hrs	¢/V-Hr	(V-Hrs X ¢/V-Hr) ÷ 100
Freeways			
Traveling at Average Speed	Sp, LOV, V-Miles	¢/V-Mile	(V-Miles X ¢/V-Mile) ÷ 100
Parking Costs (Private)	V-Hrs	$/V-Hr	V-Hrs X $/V-Hr
Fare and Toll Costs	Passengers, V	$/P, $/V	P X $/P, V X $/V
Accident Costs (Private)			
Fatal	Accidents, % Fatal	$/Accident	(Accidents X % Fatal) X $/Accident
Injury	" , " Injury	" "	(" " " Injury)" " "
Property Damage	" , " PD only	" "	(" " " PD only) " "

[a]Symbols mean follwoing: P-Hrs = passenger hours; D-Hrs = driver hours; V-Hrs = vehicle hours; NA = not applicable; LOV = level of service; Sp = speed; Sp Reduction = speed reduction to stop; V = vehicles; and PD = property damage.

to obtain highway and transit user costs for any transit alternative by separate user impact categories. The quantities of each physical unit must be obtained from the source tables shown in table 4. These quantities can be calculated from original data shown in appendix tables A1 and A2 and can be partially calculated by the use of secondary data from appendix tables A3-A7, A9, and A19-20.

The unit cost data called for in table 3 must be obtained from the source tables listed in table 4.

Demand responsive systems which involve vehicles, either automobiles or transit buses, or other alternatives which do not involve any vehicles such as facilities adjustments and marketing adjustments, can be evaluated in the same manner as the conventional bus system. In the demand responsive system, automobiles are considered in addition to buses while the non-vehicle alternative induce route users of automobiles or transit buses. Therefore users costs incurred to these users and system costs incurred for providing services to these users can be evaluated.

The procedures and data requirements for calculating highway and transit user costs by specific user impact category are presented below. The estimating procedures represent calculations for one road segment, one directional traffic and one period of the day. Total route costs for all road segments, two-way traffic and over both peak and nonpeak periods have to be summed up accordingly. Most of the estimation procedures will be described in mathematical forms. In general, user costs vary with vehicle types and road types, except fares, parking and toll fees and accident costs. Table 5 shows the four vehicle types categorized by Ritch and Buffington [20]. City streets and freeways are the two road types

Table 4. Source Tables for Physical Data and Unit Cost Data Required for Calculating Highway and Transit User Costs of Transit Alternatives by Impact Category

Highway and Transit User Impact Category	Source Tables		
	Physical Data		
	Basic Data	Secondary Data	Unit Cost Data
Travel Time Costs			
In-Vehicle (Private and Public)			
City Streets (arterials)			
Traveling at Uniform Speed	Table A1	Tables A2, A3	Table A8
Additional for Stopping	"	Tables A4, A5, A6, A7	"
Additional for Speed Changes	"	"	"
Additional for Segment Changes	"	"	"
Additional While Stopped	"	"	"
Freeways			
Traveling at Average Speed	"	Tables A2, A3	"
Out-of-Vehicle			
Walking, Waiting, & Transferring	Table A2		"
Discomforts and Inconveniences (Private & Public)	Table A1	Table A9	Table A10
Vehicle Operating Costs (Private)			
City Streets (arterials)			
Traveling at Uniform Speed	Table A1		Table A11
Additional for Stopping	"		Tables A12, A13, A14
Additional for Speed Changes	"		"
Additional for Segment Changes	"		"
Additional While Stopped	"		Table A15
Freeways			
Traveling at Average Speed	"		Tables A16, A17, A18
Parking Costs (Private)	Table A2		Table A3
Fare & Toll Costs	Tables A1, A2	Table A3	"
Accident Costs (Private)			
Fatal	Table A1	Tables A19, A20	Table A21
Injury	"	"	"
Property Damage	"	"	"

which are pertinent to this study. In addition to vehicle and road types, travel time costs change according to traveling modes (the in-moving-vehicle vs. the in-stopped-vehicle) and user types (drivers vs. passengers). Subscripts i and j in the equations listed in this section refer to vehicle type and road type, respectively.

Table 5. Description of Vehicle Types by Vehicle Type Number

Vehicle Type Number	Vehicle Type Description
1	Automobiles, pickups, and panel trucks (2-axle, 4-tire)
2	Single-unit trucks (other than 2-axle, 4-tire)
3	Truck-tractor-semitrailer or trailer combinations
4	Buses

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas May 1980.

Travel Time

User costs in travel time include both in-vehicle time and out-of-vehicle time. Besides actual travel time needed for traveling at uniform or average speed, in-vehicle time also includes extra time required for stopping, speed changes, segment changes and idling. Out-of-vehicle time refers to walking time, waiting time, and transferring time. Unit cost for out-of-vehicle travel time and in-vehicle idling time is more than that for in-vehicle moving time. For an average comfortable and safe condition outside of a vehicle, AASHTO [1] suggests the unit cost for out-of-vehicle travel time to be 1.5 times the unit cost for in-vehicle travel time and for below average comfortable and safe condition, a factor of 2 is appropriate. Unit travel time cost varies not only with vehicle type and traveling mode, but also with user type.

Procedure. Derivation of total travel time cost is illustrated below in functional forms. The additional subscript k refers to user types, i.e. drivers and passengers. In this procedure for estimating user travel time cost, driver type includes only drivers of trucks.

For vehicle type i, on road type j, with user type k, and

A. In-moving-vehicle traveling mode,

(1) out-of-vehicle time (V_OT_{ijk}), in hours, is defined as:

$$V_OT_{ijk} = W_KT_{ijk} + W_AT_{ijk} + T_RT_{ijk}$$

where W_KT = walking time, in hours,
W_AT = waiting time, in hours and
T_RT = transferring time, in hours;

(2) in-vehicle time (V_IT_{ijk}), in hours, is obtained by:

$$V_IT_{ijk} = \frac{VM_{ijk}}{S_{ij}}$$

where VM = vehicle-miles and
S = uniform speed on city streets or average speed on freeways;

(3) Excess time due to speed cycle changes ($X_C T_{ijk}$), in hours, is obtained as follows:

$$X_C T_{ijk} = \#SC_{ijk} \text{ X } Hr/SC_{ijk}$$

where SC = speed cycle;

(4) excess time due to segment changes ($X_G T_{ijk}$), in hours, such as going from one segment with 6 lanes to the next segment with 4 lanes, is time needed to complete half a cycle and therefore is calculated as:

$$X_G T_{ijk} = \#SG_{ijk} \text{ X } \tfrac{1}{2}\, Hr/SC_{ijk}$$

where SG = segment changes;

(5) excess time for stopping ($X_P T_{ijk}$), in hours, is defined as:

$$X_P T_{ijk} = \#SP_{ijk} \text{ X } Hr/SP_{ijk}$$

where SP = stopping;

(6) total travel time ($T_{M_{ijk}}$) for in-moving-vehicle mode, in hours, is defined as:

$$T_{M_{ijk}} = \alpha V_0 T_{ijk} + V_I T_{ijk} + V_C T_{ijk} + X_G T_{ijk} + X_P T_{ijk}$$

where α = 1.5 for average comfortable and safe condition or
= 2.0 for below average comfortable and safe condition;

(7) total travel time cost for both road type ($T_M C_{T_{ik}}$)[a] for in-moving-vehicle mode, in dollars, is obtained as follows:

$$T_M C_{T_{ik}} = \left(\sum_j T_{M_{ijk}} \right) \text{ X } C_{TM_{ik}}$$

[a]For route segment analysis, in general, there is only one road type involved since segments of the route are set up mostly by road type characteristics.

where C_{TM} = updated unit time cost[a], in \$/VH, for the in-moving-vehcile traveling mode;

B. in-stopped-vehicle traveling mode,

(1) excess time for idling ($X_I T_{ijk}$), in hours, is given as:

$$X_I T_{ijk} = \#I_{ijk} \text{ X } Hr/I_{ijk}$$

where I = idling;

(2) total travel time ($T_{S_{ijk}}$), for in-stopped-vehicle mode, in hours, is defined as:

$$T_{S_{ijk}} = X_I T_{ijk};$$

(3) total travel time cost for both road types $(T_S C_{TS_{ik}})$[b] for in-stopped-vehicle mode, in dollars, is obtained as follows:

$$T_S C_{TS_{ik}} = \left(\sum_j T_{S_{ijk}} \right) \text{ X } C_{TS_{ik}}$$

where C_{TS} = updated unit time cost[a], in \$/VH for the in-stopped-vehicle mode; and

C. total travel time cost ($TC_{T_{ik}}$), in dollars, for both modes is defined as:

$$TC_{T_{ik}} = T_M C_{TM_{ik}} + T_S C_{TS_{ik}} .$$

Therefore, total travel time cst (TC_T), in dollars, for all vehicle types and all user types is defined as:

$$TC_T = \sum_i \sum_j (TC_{T_{ij}}).$$

[a]Follow updating procedure suggested in the previous section.

[b]For route segment analysis, in general, there is only one road type involved since segments of the route are set up mostly by road type characteristics.

Data Requirements:

A. W_KT, W_AT and T_RT can be obtained from on-board survey such as suggested in appendix table A2;

B. VM, S, Hr/SC, #SC, #SP, Hr/SP, #I and Hr/I can be obtained from basic data collection as those suggested in appendix table A1 or from rate schedules shown in appendix tables A4-A7; and

C. C_{TM} and C_{TS} can be obtained from rate schedules shown in appendix table A8.

Discomforts and Inconveniences

Several studies have included discomforts and inconveniences as a cost to a user. The Florida Department of Transportation designates levels of discomforts and inconveniences corresponding to levels of service which are defined as traffic volume to capacity ratios. To each level of service, a unit value, in dollars per vehicle-hour is assigned [15]. Appendix table A9 shows freeway volume to capacity ratios, by number of lanes and level of service, developed by Curry and Anderson [12]. These ratios are assumed to be acceptable for city streets.

Procedure. Before estimating user costs of discomforts and inconveniences, level of service (s) has to be determined by calculating the volume to capacity ratio and referring the calculated ratio and the number of lanes at studied segment to appendix table A9.

Total user cost of discomforts and inconveniences for all vehicle types at level of service s $(TC_D)_s$, in dollars, can be obtained as follows:

$$(TC_D)_s = (\sum_i VH_i) \times (C_D)_s$$

where VH = vehicle-hour and

C_D = updated unit value[a] for discomforts and inconveniences, in \$/VH.

---

[a]Follow updating procedure suggested in previous section.

Data Requirements

A. Volume, capacity, # of lanes and VH can be obtained from basic data collection in appendix table A1 and

B. C_D can be obtained from appendix table A10.

Vehicle Operating Costs

Vehicle operating costs are related not only to the mileage a vehicle travels, but they also vary according to uniform speeds, vehicle types, street or road types, speed changes and idling delays. The unit costs referenced here include all the basic operating components such as oil, gasoline, parts, maintenance and depreciation.

Procedure. Estimation of vehicle operating costs can be divided according to road types. For vehicle type i,

A. on city streets,

1. at uniform speed, running cost ($O_U C_{OU_i}$), in cents, is obtained as follows:

$$O_U C_{OU_i} = VM_i \text{ X } C_{OU_i}$$

where VM = vehicle-miles and
C_{OU} = updated unit operating cost[a] at uniform speed, in ¢/VM;

2. excess running cost due to stopping ($X_P C_{OP_i}$), in cents, is obtained as follows:

$$X_P C_{OP_i} = \#SP_i \text{ X } C_{OP_i}$$

where SP = stopping and
C_{OP} = updated unit operating cost[a] due to stopping, in ¢/SP;

---

[a]Updating procedure is suggested in the previous section of this report.

3. excess running cost due to speed cycle changes ($X_C C_{OC_i}$), in cents, is defined as:

$$X_C C_{OC_i} = \#SC_i \times C_{OC_i}$$

where SC = speed cycle and
C_{OC} = updated unit operating cost[a] due to speed cycle changes, in ¢/SC;

4. excess running cost due to segment changes ($X_G C_{OG_i}$), in cents, is defined as:

$$X_G C_{OG_i} = \#SG \times \tfrac{1}{2} C_{OC_i}$$

where SG = segment changes and
C_{OC} = updated unit operating cost[a] due to speed cycle changes, in ¢/SC;

5. excess running cost due to idling ($X_I C_{OI_i}$), in cents, is calculated as follows:

$$X_I C_{OI_i} = (\#I_i \times Hr/I_i) \times C_{OI_i}$$

where I = idling and
C_{OI} = updated unit idling cost[a], in ¢/VH;

6. total vehicle operating costs on city streets ($T_S C_{OS_i}$), in cents, is defined as:

$$T_S C_{OS_i} = O_U C_{OU_i} + X_P C_{OP_i} + X_C O_{OC_i} + X_G C_{OG_i} + X_I C_{OI_i};$$

B. on freeway, at average speed p and level of service[b] s, running cost $(T_F C_{OF_i})_{sp}$, in cents, is defined as:

$$(T_F C_{OF_i})_{sp} = VM_i \times (C_{OF_i})_{sp}$$

---

[a]Follow updating procedure suggested in previous section.

[b]See determination of level of service in procedure presented for estimating discomforts and inconveniences costs.

where VM = vehicle-miles and

$(C_{OF_i})_{sp}$ = updated unit operating cost[a] at average speed p and level of service s on freeways, in ¢/VM; and

C. total operating cost both on city streets and on freeways (TC_{O_i}), in cents, is obtained as follows:

$$TC_{O_i} = T_S C_{OS_i} + T_F C_{OF_i}.$$

Therefore, total operating cost for all vehicle types (TC_O), in dollars, is obtained as follows:

$$TC_O = (\sum_i TC_{O_i}) \div 100.$$

Data Requirements:

A. VM, VH, #SC, #SP, #I, Hr/I can be obtained from basic data collection as those suggested in appendix table A1.

B. C_{OU}, C_{OP}, C_{OC}, C_{OI}, and C_{OF} can be obtained from rate schedules shown in appendix tables A11-A18.

Parking and Toll Costs

Parking fees charged to users for utilizing parking facilities around downtown areas or at park-n-ride lots are costs to users and so are toll fees charged to using a bridge or a section of a road. If the improvement under consideration takes place along areas which offer these facilities, and users of this particular improvement use them, then parking and toll fees should be included in the user costs evaluation.

Procedures. Estimation procedures can be carried out either

A. by obtaining records of receipts from the appropriate agency, or

B. by conducting onboard survey or interviews. Calculations for total

---

[a]Follow updating procedure suggested in previous section.

toll and parking fees can be expressed separately below:

Tolls = TL X # Vehicles

where TL = freeway and/or bridge toll, in $/vehicle; and

Parking Fees = $/hour X # veh-hours/day X 270 days[a]/year.

Data Reqirements.

A. Records of receipts kept by the appropriate agencies, or

B. Surveys such as those suggested in appendix table A2.

Fares

Any improvement involving transit vehicles imposes fares on users of the transit vehicles, but also generates revenues from these fares for a transit system. Therefore, in the impact evaluation process, fares are charged as costs to users but are entered as revenues to the transit system to upset transit operating costs. It is very probable that these two effects will not be netted out either because of bad record keeping or for other reasons. For alternatives which do not involve any transit vehicles, such as carpooling, this impact category will not be included in the impact evalustion.

Procedures. Estimation procedures can be carried out either

A. by obtaining records of fare receipts from the appropriate agency, or

B. by conducting onboard survey or interviews. Calculation can be expressed below:

Fares ($) = ¢/person X # Rider ÷ 100.

Data Requirements.

A. Records of receipts kept by the appropriate agencies, or

B. Surveys such as those suggested in appendix table A2.

---

[a]Only 5 working days per week are considered.

Accidents

Methods for evaluating accident costs, or values for specific accident costs are many. Winfrey [24] suggests that broad general accident costs be used only as the last resort. For short range transit consideration, it is believed the recently published accident costs are broken down far enough for the use in this study.

Unit accident costs adopted here refer to costs to persons, properties or vehicles directly involved in an accident. These costs cover the direct out-of-pocket costs as well as other indirect costs such as loss of future gross earnings and services to family or home of the victim injured or killed. Extra time costs, extra vehicle operating costs and extra pollution costs as a result of an accident, are not considered in these unit accident costs. Unit accident costs vary not only with types of accidents, but they also vary according to road types and location type (rural vs. urban).

Procedures.

For accident type l, on road type j, at location m,

A. number of accident l ($\#A_{lmj}$) is obtained either from

1. basic data collection or
2. by calculating in the following manner:

$$\#A_{lmj} = \%A_{lmj} \times \#A/VM_{mj} \times VM_{mj}$$

where A = total accidents and
VM = vehicle-miles;

B. costs of accident l ($AC_{A_{lmj}}$), in dollars, can be obtained as follows:

$$AC_{A_{lmj}} = \#A_{lmj} \times C_{A_{lmj}}$$

where C_A = updated unit accident cost[a], in dollars; and

---

[a]Follow updating procedure suggested in the previous section.

C. total accident costs for all accident types on both rural and urban location and on all road types (TC_A), in dollars, can be obtained as follows:

$$TC_A = \sum_{l}\sum_{m}\sum_{j}(AC_{A_{lmj}}).$$

Data Requirements:

A. #A, VM can be obtained from basic data collection as those suggested in appendix table A1.

B. #A/VM, $\%A_l$ and C_{A_l} are obtained from appendix tables A19, A20, and A21, respectively.

Estimation Techniques and Data Requirements for System Costs Evaluation

Costs involved in operating a transit system include not only transit vehicle operating costs, but also operating and maintenance (O & M) road costs and capital costs for capital expenditure in implementing a traffic improvement. Estimation methods for each of these costs are discussed separately below. Table 6 shows the various system costs (impacts), sources of their physical data and unit costs data, while table 7 shows the final units of measurement and calculations required to obtain system costs. Except for the addition of driver's wage and fringe benefits, transit vehicle operating costs for the recommended approach have the same sources of unit costs and procedures as those for the vehicle operating costs in the user impact category discussed earlier. An alternative approach to estimating transit vehcile operating costs is presented; the data sources and procedures are different. Both approaches refer to one segment, one period and one-way traffic analysis.

Table 6. Source Tables for Physical Data and Unit Cost Data Required for Estimating System Costs by Impact Category

Highway and Transit System Impact Category	Source Tables: Physical Data: Basic Data	Source Tables: Physical Data: Secondary Data	Source Tables: Unit Cost Data
Drivers' Wages			
In-Vehicle (Public)			
City Streets (arterial)			
Traveling at Uniform Speed	Table A1	Tables A2, A3	Table A9
Additional for Stopping	"	Tables A4, A5, A6, A7	"
Additional for Speed Changes	"	"	"
Additional for Segment Changes	"	"	"
Additional While Stopped	"	"	"
Freeways			
Traveling at Average Speed	"	Tables A2, A3	"
Vehicle Operating Costs (Public)			
City Streets (arterial)			
Traveling at Uniform Speed	Table A1	Table A3	Table A11
Additional for Stopping	"		Tables A16, A17, A18
Additional for Speed Changes	"		"
Additional for Segment Changes	"		"
Additional While Stopped	"		Table A15
Freeways			
Traveling at Average Speed	"		Tables A16, A17, A18
Fare and Toll Revenues	Tables A1, A2	Table A3	Table A19
O & M Road/Highway Costs		Table A3	NA
Capital Costs		Bids for project	NA

Table 7. Final Units of Measurement and Calculation Required to Obtain System Costs for Any Transit Alternative by Impact Category[a]

Highway and Transit System Impact Category	Final Unit of Measurement		Final Calculation to Obtain User Cost ($)
	Physical Unit	Cost Unit	
Drivers' Wages			
In-Vehicle (Public)			
City Streets (arterial)			
Traveling at Uniform Speed	D-Hrs	$/D-Hr	D-Hrs X $/D-Hr
Additional for Stopping	" "	" "	" " " " "
Additional for Speed Changes	" "	" "	" " " " "
Additional for Segment Changes	" "	" "	" " " " "
Additional While Stopped	" "	" "	" " " " "
Freeways			
Traveling at Average Speed	" "	" "	" " " " "
Vehicle Operating Costs (Public)			
City Streets (arterial)			
Traveling at Uniform Speed	Sp, V-Miles	¢/V-Mile	(V-Miles X ¢/V-Mile) ÷ 100
Additional for Stopping	Sp, Sp Reduction, Stops	¢/Stop	(Stops X ¢/Stop) ÷ 100
Additional for Speed Changes	Sp, Sp Change, Cycles	¢/Cycle	(Cycles X ¢/cycle) ÷ 100
Additional for Segment Changes	Sp, Sp Change, Segment	¢/Cycle	(Segments X ½¢/Cycle) ÷ 100
Additional While Stopped	V-Hrs	¢/V-Hr	(V-Hrs X ¢/V-Hr) ÷ 100
Freeways			
Traveling at Average Speed	Sp, LOV, V-Miles	¢/V-Mile	(V-Miles X ¢/V-Mile) ÷ 100
Fare and Toll Revenues	Passengers, V	$/P, $/V	P X $/P, V X $/V
O & M Road/Highway Costs	V-Miles	$/V-Mile	V-Miles X $/V-Mile
Capital Costs	NA	NA	NA

[a]Symbols mean following: D-Hrs = driver hours; V-Hrs = vehicle hours; NA = not applicable; LOV = level of service; Sp = speed; Sp Reduction = speed reduction to stop; and V = vehicles.

Transit Vehicle Operating Costs - Recommended Approach

Costs components of transit vehicle operating costs include wages and fringe benefits for transit vehicle drivers. In addition, fuel, oil, maintenance, depreciation, and insurance for operating and maintaining transit vehicles and facilities are also included. Among them, wages for drivers take the largest share. Cervero reports in his study [6] that public transit is a labor intensive industry with wage accounting for eighty percent of all transit vehicle operating costs. As a result, transit vehicle operating costs are highest during peak hours because of extra buses needed and consequently extra drivers hired to meet the demand. Fares received as revenues to the system are used towards operating expenses. Therefore, the net transit vehicle operating costs represent costs incurred from operating transit vehicles or facilities used for maintaining these vehicles less fares received. Transit accident costs are included as insurance costs for drivers and passengers,and these insurance costs are covered under drivers' wages.

Like vehicle operating costs in the user impact category, transit vehicle operating costs vary according to vehicle type (large or small buses) used by the system, speed at which vehicles travel, and also the number of stops and idlings that transit vehicles make. Therefore, procedures and data requirements for estimating transit vehicle operating costs include those used for estimating vehicle operating costs in the user impact category. In addition, drivers' wages and fringe benefits have to be estimated.

Procedure.

A. Drivers' wages, including fringe benefits, for vehicle type i, road type j, can be obtained by the following steps:

1. Total travel time for in-moving-vehicle mode ($T_{M_{ij}}$), in hours, can be calculated as described in the user impact section (pp.) with the exception that out-of-vehicle travel time (V_0T) is zero here;

2. Drivers' wages for both city streets and freeways[a] (W_{M_i}) for in-moving-vehicle mode, in dollars, can be obtained as follows:

$$W_{M_i} = (\sum_j T_{M_{ij}}) \times C_{TM_i}$$

where C_{TM} = updated unit time cost[b] for drivers, in \$/VH, for the in-moving-vehicle mode;

Transit Vehicle Operating Costs - Alternative Approach

System costs and revenues can be estimated by a simpler approach. If time and costs for impact evaluation are matters of concern, it may then be appropriate to consider this alternative approach. Instead of collecting basic data and going through the tabulation according to procedures described above, published data on unit total system operating costs and revenues of some transit system(s) are used. Procedure and data requirements for this alternative approach are presented below.

Procedures. Total transit operating costs (SC_{SO}) and total transit revenues (SR) for total vehicle-miles made by all transit vehicle types (i) are obtained, respectively, as follows:

$$SC_{SO} = (\sum_i VM_i) \times C_{SO};$$

---

[a]For route segement analysis, in general, there is only one road type involved since segments of the route are set up mostly by road type characteristics.

[b]Follow updating procedure suggested in the earlier section.

$$SR = (\sum_i VM_i) \times R_S;$$

where VM = vehicle-mile,
C_{SO} = (\$) transit operating costs/VM and
R_S = (\$) transit revenues/VM.

Data Requirements.

A. UM is obtained from basic data collection as suggested in appendix table A1.

B. C_{SO} and R_S can be obtained from the most current issue of Texas Transit Statistics published annually by the State Department of Highways and Public Transportation. These unit values vary according to system size. It is believed that the unit values from a similar system size should give better estimates and should be adopted. Appendix table 22 shows the 1979 unit transit operating costs and revenues per vehicle-mile of three Texas system sizes: A, B and C. The unit transit operating costs are further broken down into with and without administrative costs. For impact evaluation when costs and benefits are derived from comparing the "build" to the "no-build", unless the proposed alternative requires extra personnel to carry out the improvement, such as manning the park-n-ride lots or the installed metering signal, it is recommended those unit operating costs excluding the administrative costs be used in any short range impact evaluation.

O & M Road/Highway Costs

For short range transportation improvements, road or highway operating and maintenance costs should be a relatively small item compared to other costs. For example, the alternative of increasing bus fleet may cause a few more potholes, thus resulting in some maintenance expenses. However the alternatives of changing route or schedules which involve only redistribution of the fleet to different roads or different time periods, should incur little, if any, O & M road or highway costs.

Procedure:

Multiply unit cost from records kept by the maintenance department to total vehicle-miles to arrive at total O & M road costs.

Data Requirements:

Records kept by transit maintenance department.

Capital Costs

For implementing an improvement, capital costs include costs incurred from advance planning, preliminary engineering studies, to right-of-way purchases. Any sunk cost (whatever has been spent) should be excluded. Not all of the capital costs are necessarily incurred in one single year. Some may be spent in year one, other in year two, and still others in year three or later years of the analysis period. Therefore each of these costs should be discounted from the year it is intended for expenditure to the present in order to arrive at the present value of the total capital costs for implementing an improvement.

Procedures:

1. Obtain costs directly from bids given by contractors and suppliers.

2. Discount those capital costs which will be incurred in later years according to the number of years from planning to present.

3. Sum all costs incurred in year one and those in later years obtained from Step 2.

Data Requirements:

Bids from contractors and suppliers.

Estimation Techniques and Data Requirements for Nonmonetary Impact Evaluation

Three of the nonmonetary impacts are considered in the impact evaluation process proposed in this report. They are chosen for evaluation because of the recent concern and interest that society has placed on them. Evaluation techniques have been developed for estimating the effects of air pollution and noise pollution. However, the impact of land use, although studied in many case studies [2,11,10] does not seem to have a single impact effectiveness measure. For measuring land use impact, some suggests changes in land values, other considers business receipts and employment, and still others use acreage of residential, commercial, industrial and other developments. For simplicity, the last suggestion is recommended here for evaluating land use. Also, it is felt that this measurement directly or indirectly implies most of the aspects of land use, such as business receipts, employment, land values, etc. In order to avoid double counting, business activities and accessibilities to job opportunities will be discussed under the society impact category. Table 8 illustrates the source tables for physical data and unit costs data and units of measurement for evaluating nonmonetary impacts. Estimation procedures described in this section refer to analysis per segment, by period and direction of travel. Total effects have to be adjusted for all segment, periods and directions of travel.

Air Pollution

Traffic generates pollution in the air either from the exhaust of running vehicles or evaporation from an idling engine. The mix of vehicles, the number of stops and frequency of speed change made by vehicles, affect the amount of pollutants emitted into the air. The major pollutants in transportation are identified as carbon monoxides, hydrocarbons and nitrogen oxides,

Table 8. Source Tables for Physical Data and Unit Cost Data and Units of Measurement Required for Estimating Nonmonetary Impacts by Impact Category

Nonmonetary Impact Category	Source Table		Unit of Measurement	
	Physical Data	Unit Cost Data	Physical Unit	Cost Unit
Air Pollution				
Traveling Average Speed	Table A1	Table A23-A25	Grams	Grams/V-Mile
Additional due to Idling	"	Table A26	"	"
Noise Pollution	Table A1	Figure A1-A2	dBA	#V/Mile of Road
Land Use	City Maps	NA	Acre	NA

measured in grams.

Procedure. For vehicle type i, traveling on freeways or city streets,

A. at given average speed, p, amount of air pollutant type t emitted $(P_{A_{ti}})_p$, in grams, can be estimated by the followingequation:

$$(P_{A_{ti}})_p = (VM_i)_p \times (C_{PA_{ti}})_p$$

where VM = vehicle-mile and
C_{PA} = updated unit pollutant emission[a] for vehicle at average speed, in grams/VM;

B. additional emission of air pollutant type t due to idling $(P_{I_{ti}})$, in grams, can be calculated by the follwoing equation:

$$P_{I_{ti}} = \#I_i \times Hr/I_i \times C_{PI_{ti}} \times 60$$

where I = idling
C_{PI} = updated unit pollutant emission[a] due to idling, in grans/min; and

C. total amount of air pollutant type t emitted (P_{ti}), in grams, is calculated as follows:

$$P_{ti} = (P_{A_{ti}})_p + P_{I_{ti}}$$

Therefore, for all vehicle types and for all pollutant types, total pollutant emission (TP), in grams, is defined as below:

$$TP = \sum_{t}\sum_{i} P_{ti}$$

Data Requirements.

A. VM, #I, Hr/I and p are obtained from basic data collection as suggested in appendix table A1.

B. C_{PA} and C_{PI} can be obtained from rate schedules of emission for vehicle traveling at average speed in appendix tablesA23-A25, and for idling

---

[a]Updating procedure is suggested in earlier section.

engine in appendix table A26, respectively.

Noise Pollution

In addition to air pollution, transportation also contributes to noise pollution. Flowing traffic creates certain levels of noise pollution, but vehicles in idling position also increase levels of noise pollution. Young and Wood [25] found in their study that noise level is positively related to the density of vehciles, and the mix of vehicles and the traveling speed both play an influential role in this relationship. Estimation technique recommended in this study is based on the results obtained by these two authors.

Procedures. There are two steps involved:

A. Obtain the mean noise level at the given mix of vehicles traveling at 50 mph by reading it off from the graph appeared in figure A1.

B. Adjust the mean noise level obtained in step 1 to the level at which vehicles are traveling at the desired speed by referring the mean noise level to the graph in figure A2 and reading it off at the desired speed.

Data Requirements.

A. Vehicle traveling speeds, vehicle and truck mix, and density of automobiles per mile can be obtained from basic data collection (appendix table A1).

B. Graphs of mean noise level at 100 feet from a lane, by density of automobiles per mile of roadway at selected speeds and of mixed car and diesel truck traffic are obtained from Young and Wood's study [25].

Land Use

To evaluate land use, the measurement of this effect recommended here is acreage of residential, commercial and industrial developments and other developments which include schools, churches, parks and other public services. Any changes in the acreages of these developments may be the result of the transportation improvement, but they may also be caused by other factors. Therefore, care should be given to include if possible, only those changes that are caused by the improvement in the impact estimation process.

If the improvement takes place in a well developed area, these changes may be unnoticable or insignificantly small. Any meaningful measurement may be difficult to obtain. In such cases, it should be up to the planners and officials to decide whether or not to include this impact in the evaluation. A descriptive evaluation of business activities and accessibility to job opportunities as suggested later in the society costs category may be a sufficient guideline.

Procedures. Obtain changes in acreages (or square footage) of residential, commercial and industrial and other developments from similar improvements in the past.

Data Requirements. Change in acreages (or square footage) of residential, commercial and industrial and other developments due to the improvement.

Determination of Society Costs

The category of society costs is created for the purpose of providing data information in areas of interests to transportation planners, city officials and concerned citizen groups. The major characteristic of this category is that all impacts in this category have already been implicitly included in either the user or nonuser impacts. To avoid double counting, these impacts are pulled out, put under a separate category and are not included in the overall evaluation process.

Business activity, accessiblity to job opportunity, fuel consumption and ridership are impacts identified in this category. Both business activity and accessibility to job opportunity impact land use. How well land is used can be partially affected by business activities around the area and also by the accessibility to jobs for workers or employees. The measurement of commercial development has indirectly accounted for these two impacts.

The impact of energy consumption is included in the vehicle operating costs and transit vehicle operating costs in the form of fuel and oil consumption. With the recent concern over the energy issue, this impact category can provide valuable information for a cost effective measure of energy consumption. For example, together with total vehicle mileage traveled, a cost effective measure of gallons of fuel consumed per vehicle-mile is obtained, or with ridership, a cost effective measure of gallons of fuel consumed per rider is provided.

Ridership is another impact which is of interest to transit planners and officials. This impact is affected by all the user and nonmonetary impacts even though to different degrees. Among them, travel time is found to have the greatest impact on ridership.

The nonquantifiable impacts, such as business activity and accessibility to job opportunity, can be evaluated descriptively, while the quantifiable ones, such as fuel consumption and ridership, can be analysed by utilizing unit costs, published or obtained by survey. Table 9 lists the evaluation procedures and data requirements for each of the society impacts.

Business Avtivity

Procedures: Describe the changes in regard to the number of customers, total sale receipts, establishments of new businesses and expansion of old businesses as a result of the improvement.

Data Requirements: Number of customers, total sale receipts (if possible; however most businesses are unwilling to give out this information), establishments of new businesses and expansion of old businesses.

Accessibility to Job Opportunity

Procedures: Describe accessibility by evaluating how soon job openings are filled. (Pay scales of these jobs have to be competitive to the ongoing wage rate around the area in order to have a meaningful assessment.)

Data Requirements: Number of job openings and time required to fill those openings.

Fuel Consumption

The amount of fuel required to operate vehicles varies according to vehicle types. For a private automobile, energy required consists mainly of the amount of gasoline consumed in traveling from one point to another. For a conventional bus, it includes fuel in operating the bus either in traveling or in idling at the end of the run; it may even include energy needed for maintaining terminals or other facilities. However, factors such as passenger load, trip length, service speed, distance between stops

Table 9. Evaluation of Society Costs: Sources of Unit Costs and Procedure

Impact	Source of Unit Cost	Procedure
Business Activity	By Observation	Describe the change from before to after improvement implementation in regard to customer flow, sales, new business.
Accessibility to Job Opportunity	By Observation	Describe the change from before to after improvement implementation in regard to job openings and how soon openings are filled.
Fuel Consumption		
On City Streets		
at Uniform Speed	Table A27	gal/veh-mile X veh-mile
Additional due to Stopping	Tables A28-A30	gal/cycle X #stopping
Additional due to Speed Cycle Change	Table A28-A30	gal/cycle X #cycle change
Additional due to Segment Change	Tables A28-A30	½gal/cycle X #segment change
Additional due to Idling	Table A31	gal/hr X idling hour
On Freeways		
at Average Speed	Tables A32-A34	gal/veh-mile X veh-mile
Ridership	Tables A1-A2	Obtain from table A1 or from survey on table A2.

and road types are common to all vehicle types in their energy usage. To evaluate the impact of energy consumption, fuel consumption rates by vehicle type on freeway or on city streets can be used. Additional fuel is consumed due to idling and speed cycle changes.

Estimation procedures and data requirements for calculating fuel consumption are the same as those described for estimating vehicle operating costs in the user impact section. Gallons per mile are used here instead of cents per mile for estimating the fuel requirements of each transit alternative. The corresponding set of fuel consumption rate tables are shown in appendix tables A27-A33.

Ridership

Ridership represents the number of passengers on transit vehicles. Improvements of a transit mode can affect ridership favorably or unfavorably. Also most of the user and nonmonetary impacts impact directly or indirectly ridership to some extent. It is believed among all impacts, travel time exerts the greatest impact on ridership.

Procedure: Obtain the number of passengers directly from a transit system or from an on-board survey for currant ridership and project the ridership for each alternative over the analysis period from current or historical data.

Data Requirements: Records kept by transit systems or on-board survey such as those suggested in appendix tables A2-A3.

Estimation methods and data requirements for evaluating each of the relevant impacts have been presented. It is important to bear in mind that consistency in utilizing a unit cost or a specific procedure for an impact category across all proposed alternatives is necessary in order to obtain any meaningful comparison. Whichever unit value or procedure is used, it should be adopted uniformly for all alternatives under consideration.

A Hypothetical Case Study

To illustrate the methodology of the recommended impact evaluation approach just described, a hypothetical case study is presented. It is stressed here that the estimated impact values, in dollars, or other units may be far from reality and hence the outcome of the evaluation process may bear little resemblance to real world conditions. The main purpose of the presentation of this hypothetical case is to facilitate the understanding of the methodology presented in this report.

Problem and Suggested Shortrun Solutions

City X is faced with the problem of what to do about its major traffic route #13 which is plagued by congestion resulting from high volumes of automobiles. The route is divided into three segments according to road characteristics. Segment 1 (S1) is a 2-lane city street, segment 2 (S2), a 4-lane city street and segment 3 (S3) is a urban freeway. Four short range transit alternatives (A, B, C and D) are suggested and are evaluated against a "do-nothing" alternative (alternative "0"). Alternative A refers to a routing improvement, alternative B a scheduling improvement, alternative C a routing and scheduling combination improvement and alternative D a high occupancy vehicle (HOV) treatment.

Assumptions Used in the Analysis

The analysis period is defined to be ten years, residue values to be insignificant and the discount rate to be ten percent. During the whole analysis period, user costs, transit vehicle operation costs (netted out fare revenues) and nonmonetary costs are assumed to have a constant growth rate of 3 percent. O & M roads and highways costs are assumed to be a uniform annual series with equal amount of costs to be incurred each year. Further, all capital costs are assumed to be incurred at the beginning of year one. The hypothetically estimated segment values for the impacts are annual figures for study year one. Lastly, it is assumed that the relationship between the measured and estimated values of each impact and ratings is linear and continuous.

Categorical and Subcategorical Weights Assignments

A committee consisting of six members, four from the city planning and transportation divisions, and two from citizen groups, is formed. The two tasks which this committee has to perform are: 1) categorical weight assignments and 2) subcategorical weight assignments. The committee should take into consideration the local transportation needs and objectives determined in the preliminary investigation when assigning weights to the relevant impacts.

To assign categorical weights, each member of the committee is given 100 points to be distributed between the monetary and nonmonetary impact categories. The average points (categorical weights) are found to be 60 and 40, respectively, for the monetary and nonmonetary impact categories. Table 10 illustrates the point distribution from each member and the categorical weights obtained.

Subcategorical weights are assigned by the committee in similar fashion to the three nonmonetary impacts. The average weights obtained are shown in table 11 in percentages, with air pollution, noise pollution and land use sharing a percentage distribution of 27, 23, and 50, respectively.

Table 10. Categorical Weight Assignments of Monetary and Nonmonetary Impacts

Type of Impacts	Members						Average
	No.1	No.2	No.3	No.4	No.5	No.6	
Monetary	60	70	50	55	60	65	60
Nonmonetary	40	30	50	45	40	35	40

Table 11. Subcategorical Weight Assignments of Nonmonetary Impacts

Impacts	Members						Average (%)
	No.1	No.2	No.3	No.4	No.5	No.6	
Air Pollution	20	30	40	25	20	25	27
Noise Pollution	30	20	30	25	20	15	23
Land Use	50	50	30	50	60	60	50

Calculation of Impact Benefits and Costs

The estimated annual segment user costs, system costs and nonmonetary costs, hypothetically constructed, for the "do-nothing" and the four proposed alternatives are shown in table 12. These costs represent costs for all vehicle types, both peak and nonpeak periods and two-way traffic on each of the three segments of the route. Total route costs of each impact category for each alternative can be calculated by summing the three segment costs for the respective category; these total route costs are also included in table 12. Annual user benefits, nonmonetary benefits and changes in system costs of the alternatives are obtained by comparing the total route costs of each of the proposed alternatives to those of the "do-nothing" alternative.

Derivation of Total Scores for Alternatives

A present value factor of 7.1914[a] (for Ten years, at ten percent discount rate and three percent constant growth rate) is used to calculate the present value (PV) of ten years of user benefits and ten years of changes in net transit operating costs (defined as transit operating costs less fare revenues.) A factor of 6.1446[b] (for ten years, at ten percent

[a]The PV factor (f) is obtained by using the following formula in AASHTO [1]:

$$f = \frac{e^{(r-i)n}-1}{r-i}$$

where i = discount rate,
r = constant growth rate and
n = number of period.

[b]The number is obtained by using the following formula [23]:

$$A_{n/i} = \frac{1-(1+i)^{-n}}{i}$$

where A = present value of an annuity of $1,
n = number of period and
i = discount rate.

Table 12. Annual User Costs, System Costs and Nonmonetary Costs for All Vehicle Types, for Both Peak and Non-Peak Periods, and Two-Way Traffic by Alternative and by Segment of Route.

Impacts	Alternative "0"				Alternative A				Alternative B				Alternative C				Alternative D			
	S1	S2	S3	Total	S1	S2	S3	Total	S1	S2	S3	Total	S1	S2	S3	Total	S1	S2	S3	Total
User Costs	- 1,000 Dollars -				- 1,000 Dollars -				- 1,000 Dollars -				-1,000 Dollars				- 1,000 Dollars -			
Travel Time	1,500	1,200	800	3,500	1,200	1,000	800	3,000	1,180	970	750	2,900	500	400	600	1,500	1,000	800	200	2,000
Discomforts & Incon.	20	15	5	40	15	10	5	30	10	5	5	20	5	3	2	10	7	3	0	10
Vehicle Operating Costs	1,300	1,100	800	3,200	800	500	700	2,000	600	300	600	1,500	100	200	200	500	1,100	900	1,000	3,000
Accidents	350	250	600	1,200	300	200	500	1,000	250	150	400	800	250	200	450	900	300	200	200	700
Parking Fees	2	2	1	5	2	1	1	4	1	0.5	0.5	2	0.5	0	0.5	1	1	1	3	5
Fares & Toll	25	30	25	80	400	400	200	1,000	450	500	250	1,200	500	600	300	1,400	400	400	280	1,080
System Costs	- 1,000 Dollars -				- 1,000 Dollars -				- 1,000 Dollars -				- 1,000 Dollars -				- 1,000 Dollars -			
Transit Veh. Op Costs	500	300	200	1,000	900	700	300	1,900	1,000	850	300	2,150	1,200	1,000	400	2,600	500	700	900	2,100
Less: Fare Revenues	25	30	25	80	400	400	200	1,000	450	500	250	1,200	500	600	300	1,400	400	400	280	1,080
Net Transit Op. Costs	475	270	175	920	500	300	100	900	550	350	50	950	700	400	100	1,200	100	300	620	1,020
O & M Road/Hiway Costs	20	40	20	80	40	40	20	100	30	30	10	70	25	25	10	60	20	5	5	30
Capital Costs	0	0	0	0	500	500	500	1,500	800	700	300	1,800	800	700	500	2,000	0	1,000	1,200	2,200
Nonmonetary Costs																				
Air Pollution	- - 1,000 Grams - -				- - 1,000 Grams - -				- - 1,000 Grams - -				- - 1,000 Grams - -				- - 1,000 Grams - -			
CO	500	300	200	1,000	600	200	200	1,000	400	300	200	900	350	250	200	800	300	150	50	500
HC	70	50	30	150	75	45	30	150	60	50	30	140	60	40	30	130	60	30	10	100
NO_x	50	30	20	100	55	30	15	100	50	30	20	100	40	30	20	90	35	20	15	70
	- - dBA[a] - -				- - dBA[a] - -				- - dBA[a] - -				- - dBA[a] - -				- -dBa[a] - -			
Noise	55	0	0	55	50	0	0	50	45	0	0	45	60	0	0	60	40	0	0	40
Land Use	- - Acres - -				- - Acres - -				- - Acres - -				- - Acres - -				- - Acres - -			
Residential	100	60	40	200	100	60	40	200	100	65	40	205	100	70	50	220	100	70	60	230
Commercial & Ind.	5	3	2	10	5	5	2	12	5	3	2	10	5	6	4	15	5	3	2	10
Other	2	2	1	5	2	2	1	5	2	3	1	6	2	6	4	12	2	5	3	10

[a]Represents the average noise level of the route segments.

discount rate and for a uniform annual series) is used to arrive at the present value of ten years of changes in O & M road/highway costs. Alternative C is calculated to yield the highest total user benefits (PV) of 26,709,000 dollars and to incure a change in total system costs (PV) of 3,891,000 dollars (including capital costs) over the ten year period. Benefit-cost ratios are calculated by dividing the total user benefits (PV) by the change in total system costs (PV). Among the proposed alternatives, alternative C has the highest benefit-cost ratio of 6.86 while alternative D has the lowest with 3.36.

The next step in the analysis is to derive the total score for the user impacts of each alternative by rating the benefit-cost ratios. Rating of these ratios is done first by assigning the maximum rating of 3 to the largest benefit-cost ratio which is 6.86 from alternative C, thus setting up a proportionality factor of 0.437 (3 ÷ 6.86). Secondly, each of the remaining ratios is multiplied by this factor (0.437) to arrive at the respective rating. Alternative A comes out with a rating of 1.76 while alternatives B, C, and D have ratings of 2.58, 3.00, and 1.47, respectively. Each of these ratings of the benefit-cost ratios is then multiplied by 60, the categorical weight for monetary impacts as shown in table 10, to give the total scores of the alternatives. Alternative C scores highest with 180 while alternative D has the lowest score of 88.2. Table 13 shows annual user benefits and annual changes in system costs and the derivation of total scores for each of the proposed alternatives in the user impact category.

The next step is to derive the total score for the nonmonetary impact of each alternative. In order to obtain "pseudo" benefit-cost ratios for impacts in this category, dummy unit values, W, U, and V are assumed to

Table 13. Derivation of Total Scores for User Benefits from the Implementation of Transit Alternatives

Items	Alternatives			
	A	B	C	D
User Benefits	-1,000 Dollars -			
Travel Time	500	600	2,000	1,500
Discomforts & Inconviences	10	20	30	20
Vehicle Operating Costs	1,200	1,700	2,700	200
Accidents	200	400	300	500
Parking Fees	1	3	4	0
Fares & Tolls	-920	-1,120	-1,320	-1,000
Total Annual User Benefits	991	1,603	3,714	1,220
PV of Total Ten Years' User Benefits[a]	7,127	11,528	26,709	8,774
System Costs				
Annual Change in Net Transit Op. Costs	-20	30	280	100
PV of Total Ten Years' Change in Net Transit Op. Costs[a] (a)	144	216	2,014	719
Annual Change in O & M Road/Highway Costs	20	-10	-20	-50
PV of Total Ten Years' Change in O & M Road/Highway Costs[b] (b)	123	-61	-123	-307
Change in Capital Costs	1,500	1,800	2,000	2,200
PV of Total Ten Years' Change in Capital Costs (c)	1,500	1,800	2,000	2,200
PV of Total Ten Years' Change in System Costs (a+b+c)	1,767	1,955	3,891	2,612
Benefit-Cost Ratio	4.03	5.90	6.86	3.36
Rating of Ratio[c]	1.76	2.58	3.00	1.47
TOTAL SCORE (Rating x 60[d])	105.60	154.60	180.00	88.20

[a] A present value factor (f) of 7.1914 is used for a discount rate (i) of 10%, a constant growth rate (r) of 3%, over a period (n) of 10 years, as derived from the following equation suggested in AASHTO [1]:

$$f = \frac{e^{(r-i)n} - 1}{r-i} .$$

[b] A discount factor (f) of 6.1446 is used for a discount rate (i) of 10%, over a period (n) of 10 years, for a uniform annual series as obtained from the following equation from [23]:

$$f = \frac{1-(1+i)^{-n}}{i} .$$

[c] The maximum rating of 3 is assigned to the biggest benefit-cost ratio of 6.86. The proportionality factor becomes 0.437 (3÷6.86) and is used to multiply through all other ratios to arrive at their respective ratings.

[d] This is the categorical weight for the user cost category obtained from table 10.

represent dollar values for each thousand grams reduction of air pollution, for each decibal reduction of noise pollution and for each acre increase in land use, respectively. W, U and V are dummy unit values since they will be cancelled out in the rating process that is to be followed, and their dollar values need not be estimated as long as these "pseudo" benefit-cost ratios are not used to determine the economic desirability of alternatives. This report assumes that economic desirability is determined by the benefit-cost ratios obtained in the user impact category as discussed earlier. Whatever the unit values for the nonmonetary impacts are, the total impact scores for the nonmonetary impact subcategories are not affected; so are the total scores for the entire nonmonetary category, and finally the overall final scores for both monetary and nonmonetary categories. Therefore they are included here for illustrating the above point and is not included in the outline of the recommended impact evaluation approach.

Now, coming back to the hypothetical case, the annual nonmonetary benefits of air pollution, noise pollution and land use are transformed to annual benefits in terms of W, U and V, respectively. They are then discounted by adopting the same present value factor of 7.1914 used in the monetary category to arrive at the present values of the respective nonmonetary benefits (still in terms of W, U and V, respectively). Using the present values of changes in total system costs as the cost factor in each case, "pseudo" benefit-cost ratios are calculated for each impact within this nonmonetary category. Alternative D comes out to have the largest benefit-cost ratios of 15.97W, 4.13U and 9.65V for air pollution, noise pollution and land use impact subcategories, respectively.

These benefit-cost ratios are then rated within subcategory in the same manner as those described in the monetary category. Alternative D has the maximum rating of 3.00 in each of the three subcategories. The proportionality factors obtained for air pollution, noise pollution and land use are 0.188/W, 0.1726/U and 0.311/V, respectively. As each of these factors are multiplied through the ratios in the corresponding subcategory, the dummy unit values, W, U and V are cancelled out. Impact scores are obtained for the alternative by multiplying the appropriate subcategorical weights, shown in table 11, to each ratio rating. As expected, alternative D wins the highest impact scores in all three impact subcategories. Summation of all the impact scores across impact subcategories yields total impact score for each alternative. Alternative D has the highest total impact score of 3 while alternative A has the lowest of 0.46. Each of the total impact scores is further adjusted by multiplying to it the categorical weight of 40 obtained earlier to arrive at the total scores for the alternatives. Alternative D has the highest total score of 120 for the nonmonetary benefits while alternatives A, B, and C score 18.40, 46.40 and 39.60, respectively. Table 14 shows the annual nonmonetary benefits and derivation of total score for the nonmonetary benefits for the proposed alternatives.

Lastly, the total score for both the monetary and nonmonetary categories are summed together to give the final overall scores for the alternatives as shown in table 15. The overall evaluation process thus reveals the fact that alternative C with a final overall score of 219.60 is the optimal choice among all alternatives under consideration for city X.

Table 14. Derivation of Total Scores for Nonmonetary Benefits from the Implementation of Transit Alternatives

Items	Alternatives			
	A	B	C	D
Nonmonetary Benefits				
Air Pollution		- 1,000 Grams -		
CO	0	100	200	500
HC	0	10	20	50
NO_x	0	0	10	30
Total Annual Benefits	0	110	230	580
		- 1,000 Dollars -		
PV of Ten Years' Benefits[a]	0	7910W[b]	16540W	41710W
Benefit-Cost[c] Ratio	0	4.05W	4.25W	15.97W
Rating of Ratio	0	0.76	0.80	3.00
Impact Score (Rating x 0.27[d])	0	0.21	0.22	0.81
Noise		- dBA -		
Total Annual Benefits	5	10	-5	15
		- 1,000 Dollars -		
PV of Ten Years' Benefits[a]	3600U[e]	7200U	-3600U	10800U
Benefit-Cost[c] Ratio	2.04U	3.68U	-0.93U	4.13U
Rating of Ratio	1.48	2.67	- 0.68	3.00
Impact Score (Rating x 0.23[d])	0.34	0.61	- 0.16	0.69
Land Use		- Acres -		
Residential	0	5	20	30
Commercial & Industrial	2	0	5	0
Other	0	1	7	5
Total Annual Benefits	2	6	32	35
		- 1,000 Dollars -		
PV of Ten Years' Benefits[a]	1400V[f]	4300V	23000V	25200V
Benefit-Cost[c] Ratio	.79V	2.20V	5.96V	9.65V
Rating of Ratio	0.24	0.68	1.85	3.00
Impact Score(Rating x 0.50[d])	0.12	0.34	0.93	1.50
TOTAL IMPACT SCORE	0.46	1.16	0.99	3.00
TOTAL SCORE (TOTAL IMPACT SCORE X 40[g])	18.40	46.40	39.6	120.00

[a] A present value factor of 7.1914 as defined in footnote of table 13 is used.

[b] Pollutants are assumed to have a value of \$W x 10^4/1,000 grams. The exact value of W does not have to be known as long as this benefit-cost ratio analysis is not used to determine the economic desirability of alternatives.

[c] Cost factors used represent the PV of total ten years' change in system costs obtained in table 13.

[d] Figures are the percentages of the subcategorical weights obtained in table 11.

[e] Noise pollutant is assumed to have a value of \$U x 10^5/dBA.

[f] Land use is assumed to have a value of \$V x 10^5/acre.

[g] Figure represents the categorical weight obtained in table 10.

Table 15. Overall Scoring of Alternatives

Impacts	Alternatives			
	A	B	C	D
Monetary	105.60	154.80	180.00	88.20
Nonmonetary	18.40	46.40	39.60	120.00
Overall Final Score	124.00	201.20	219.60	208.20

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Traffic problems have a tendency to intensify in a growing city. Officials in transportation are constantly faced with challenges of providing adequate and dependable transportation to the public. Different transportation improvement impacts users and nonusers differently. The need for an efficient impact evaluation approach is, therefore, deeply felt. The present study limits its scope to short range considerations. The approach outlined in the interim report is fully developed in this report.

Before applying the recommended impact evaluation method, it is suggested that some aspects related to transportation should be considered and determined preliminarily. These considerations should serve as guidelines to decision-makers in transportation during the weight assignment process required in the recommended impact evaluation approach. They include identifications of: (1) relevant short range alternatives, (2) funding available for a specific improvement, (3) local needs and goals, (4) projected traffic and rider demand, (5) city size characteristics and (6) relevant impacts for evaluation.

The recommended impact evaluation method encompasses the three commonly used evaluation methods. The economic efficiency method is used for evaluating monetary impacts and the cost effectiveness method is applied in the nonmonetary impact evaluation. The common measurement used in both methods is the benefit-cost ratio. The scoring method is used to rate the estimated ratios within each impact subcategory. The ratings are then adjusted by the weights assigned to arrive at scores which can be summed up to yield the overall total scores of the alternatives. The overall ranking

of alternatives depends on the outcome of these total scores. The higher the score, the higher the ranking.

Estimation techniques used and data required for evaluating monetary and nonmonetary impacts are presented. Unit cost methods are chosen instead of other more complex estimation procedures because the present study is concerned primarily with short range transit considerations.

The problem of subjectiveness involved in the scoring method is believed to be kept to a minimum by the categorical and subcategorical weight assignment procedures suggested. Also the problem of double counting is avoided by the introduction of a separate impact category, the society impacts, which include business activity, accessibility, fuel consumption and ridership. The evaluation results of impacts in this category do not enter into the overall ranking of alternatives since each of them has been implicitly or explicitly accounted for in impacts of the other two categories which have undergone the overall evaluation. Because of the interests these society impacts are to city officials or special interest groups, it is hoped that by describing or listing the impacts in the evaluation, a more complete impact evaluation approach should result and better help decision-makers in their decision-making process.

Recommendations

Even though the evaluation method described in this report is considered to be simple compared to other methods, computation of the various impacts can be tedious. In the first place, impacts to be evaluated are many; and in the second place, variables affecting these impacts are multiple, ranging from the common ones which are borne by most of the impacts to the specific ones which influence specific impacts. Therefore, it is proposed here that the impact approach recommended in this study should be computerized. It is believed that efficiency and ease of utilizing this approach will be greatly enhanced; consequently, transportation officials can be better served.

REFERENCES

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

2. Babcock, Willard F. and Khasnabis, Snehamay, "A Study of Land Development and Traffic Generation on Controlled-Access Highways in North Carolina," Highway Research Record, 467, Highway Research Board, Washington, D. C., 1973.

3. Bain, J. S., "Criteria for Undertaking Water-Resource Developments," American Economic Review, May, 1960.

4. Buffington, Jesse L. and McFarland, William F., "Benefit-Cost Analysis: Updated Unit Costs and Procedures," Texas Transportation Institute, Texas A&M University, College Station, Texas, August 1975.

5. Buffington, Jesse L., McFarland, William F. and Rollins, John, "Texas Highway Economic Evaluation Model: A Critical Review of Assumptions and Unit Costs and Recommended Updating Procedures," Texas Transportation Institute, Texas A&M University, College Station, Texas, January 1979.

6. Cervero, Robert B., "Efficiency and Equity Impacts of Current Transit Fare Policies," Paper presented at the Annual Meeting of the Transportation Research Board, Washington, D. C., December 1980.

7. Chadda, H. S. and Mulinazzi, T. E., "A Transit Planning Methodology for Small Cities," Transit Journal, Vol. 3, No. 2, Spring 1977, pp.19-40.

8. Charles River Associates, "Economic Analysis of Policies for Controlling Automotive Air Pollution in the Los Angeles Region," Cambridge, Massachusetts, 1975.

9. Chui, Margaret K. and Buffington, Jesse L., "Background Data for Developing A Generalized Approach to Evaluating Impacts of Short Range Transit Alternatives," Texas Transportation Institute, Texas A&M University College Station, Texas, November 1980.

10. Cosby, Pamela J. and Buffington, Jesse L., "Land Use Impact of Improving West Vickery Boulavard in a Developing Area of Fort Worth, Texas," Texas Transportation Institute, Texas A&M University, College Station, Texas, August 1980.

11. Cosby, Pamela J., Herndon, Cary W., Jr. and Buffington, Jesse L., "Land Use Impact of Improving Gessner Road in a Developing Area in Houston, Texas," Texas Transportation Institute, Texas A&M University, College Station, Texas, March 1979.

12. Curry, David A. and Anderson, Duddly G., "Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects," National Cooperative Highway Research Program Report, 133, Highway Research Board Washington, D. C., 1972.

13. Guseman Patricia K., Hatfield, Nancy J. and Hall, Judith, "Critical Factors Influencing the Demand for Transit," Texas Transportation Institute Texas A&M University, College Station, Texas, June 1977.

14. Hibbard, Thomas H. and Miller, Fred, "Economic Analysis and the Environmental Overview: Suggestions for Project Recommendations by Local Governments," Transportation Research Record, 490, Transportation Research Board, Washington, D. C., 1974, pp.10-17.

15. McLeod, Douglas S. and Adair, Richard E., "Benefit-Cost Analysis Based on the AASHTO Procedures," Transportation Research Record, 747, Transportation Research Board, Washington, D. C., 1980, pp.43-49.

16. Memmott, Jeffery L. and Buffington, Jesse L., "Predicting Traffic Volume Growth Rates Resulting from Changes in Highway Capacity, and Land Development for Use in the HEEM," Texas Transportation Insitute, Texas A&M University, College Station, Texas, January 1981.

17. Pratt, Richard H., Pedersen, Neil J., and Mather, Joseph J., "Traveler Response to Transportation System Changes - A Handbook for Transportation Planners," Department of Transportation, Washington, D. C., February 1977.

18. Pucher, John and Rothenberg, Jerome, "Potential of Pricing Solutions for Urban Transportation Problems: An Empirical Assessment," Transportation Research Record, 731, Transportation Research Board, Washington, D. C., 1979, p.27.

19. Quinin, G. D., The Capital Expenditure Decision, Homewood: R. D. Irwin, 1967.

20. Ritch, Gene and Buffington, Jesse L., "The Freg 3CP Economic Package," Texas Transportation Institute, Texas A&M University, College Station, Texas, May 1980.

21. Schwab, Bernhard and Lusztig, Peter, "A Comparative Analysis of the Net Present Value and the Benefit-Cost Ratio as Meaures of the Economic Desirability of Investments," Journal of Finance, 24, June 1969, pp.507-16.

22. Wegmann, F. J., Bonilla, C. R., Bell, T. L., Dewhirst, D., Sovchen, C. A. and Heathington, K. W., "Market Opportunity Analysis for Short-Range Public Transportation Planning, Economic, Energy, and Environmental Impacts," National Cooperative Highway Research Program Report, 210, Transportation Research Board, Washington, D. C.. October, 1979.

23. Weston, J. Fred and Brigham, Eugene F., Managerial Finance, Sixth Edition, the Dryden Press, Hinsdale, Illinois, 1978, p. 1002.

24. Winfrey, R., Economic Analysis for Highways, International Textbook Company, Scranton, Pennsylvania, 1969.

25. Young, Murray F. and Woods, Donald L., "Threshold Noise Levels," Research Report No. 166-1, Texas Transportation Institute, Texas A&M University, College Station, Texas, 1970.

APPENDIX TABLES

Table A1. Basic Facility and Traffic Data Collected on Existing and Proposed Bus Routes and Used to Calculate Highway and Transit User Costs of Transit Alternatives by Segment and Type of Road[a]

Route Segment Data	City Street Segments[bc]					Freeway Segments[b]			
	1	2	3	4	5	1	2	3	4
Length of Segment (0.00 miles)									
Design Capacity Hourly (one-way)									
Number of Through Lanes (one-way)									
Average Hourly Traffic (one-way)									
Speed Limit (max. mph)									
Average Speed, Automobile (mph)									
Average Speed, Trucks and Buses (mph)									
Average Approach Speed, Automible (mph)									
Average Approach Speed, Trucks and Buses (mph)									
Average Speed Reductions, Automobiles (mph)									
Average Speed Reductions, Trucks and Buses (mph)									
Number of Speed Changes, Automobiles									
Number of Speed Changes, Trucks and Buses									
Number of Stops, Automobile									
Number of Stops, Trucks									
Number of Stops, Buses									
Number of Bus Stops									
Number of Intersections									
Time Stopped at Intersections, Auto (min)									
Time Stopped at Intersections, Truck (min)									

Table A1, Continued.

Route Segment Data	City Street Segments[bc]					Freeway Segments[b]			
	1	2	3	4	5	1	2	3	4
Time Stopped at Intersections, Buses (min)									
Time Stopped at Bus Stops, Buses (min)									
Time Stopped at Park-n-Ride Lots, Buses (min)									
Percent Automobiles and Pickups									
Percent Vans									
Percent Buses									
Percent Single Unit Trucks									
Percent Multiple Unit Trucks									
Average Occupancy per Auto and Pickup									
Average Occupancy per Van									
Average Occupancy per Bus									
Number of Fatal Accidents									
Number of Injury Accidents									
Number of Property Damage Accidents									

[a]Separate sheets must be used for peak and non-peak periods of each bus route and for each transit alternative.

[b]The last segment could cover the primary routes used by park-n-ride vehicles, and the number of segments will vary for each bus route.

[c]All streets or roads not classified as freeways.

Table A2 Transit User Survey of In-Vehicle and Out-of-Vehicle Travel Time, Trip Length, Trip Purpose, Bus Fares, Private Vehicle Tolls, and Parking Fees for Each Route, by Period.

Data Item	Amount by Period	
	Peak	Non-Peak
In-Vehicle Travel Time (one-way)	- - Average - -	
In Private Vehicle (part of trip)	________	________
In Bus (part of trip)	________	________
In Bus (whole trip)	________	________
Out-of-Vehicle Travel Time (one-way)	- - Actual - -	
Walking Time to and from Bus (min)	________	________
Waiting Time at Bus Stop (min)	________	________
Transfer Time from Car to Bus (min)	________	________
Transfer Time from Bus to Bus (min)	________	________
Trip Length (miles)	- - Average - -	
Single Mode (bus)	________	________
Multiple Mode (bus-car)	________	________
Trip Purpose (% of trips)	- - Average - -	
Work	________	________
Personal Business	________	________
Social-Recretational	________	________
Bus Fares	- - Actual - -	
Conventional Fixed Route (one-way ¢/person)	________	________
Conventional Fixed Route (prepaid one-way, ¢/person)	________	________
Express Fixed Bus Route (one-way, ¢/person)	________	________
Demand Responsive System (trip, ¢/person)	________	________
Tolls (private vehicles)	- - Actual - -	
Freeway ($/vehicle, trip)	________	________
Bridge ($/vehicle, trip)	________	________
Parking Fees (private vehicles)	- - Average - -	
On-Street (veh-hrs./day)	________	________
On-Street $/hour	________	________
Off-Street (veh-hrs./day)	________	________
Off-Street ($/hour)	________	________

Table A3. Bus Transit Operating Data Required from Transit Operator Files for Previous Year of Operation by Period.

Data Item	Amount by Period		
	Peak	Non-Peak	Both Periods
Average Number of Buses Operating			
Large	____	____	____
Small	____	____	____
Average Service Speed (mph)			
On Freeways	____	____	____
On Other Streets	____	____	____
Annual Miles of Travel per Bus	____	____	____
Annual Hours of Operation per Bus	____	____	____
Average Bus Trip Length (miles)	____	____	____
Average Daily Trips per Bus	____	____	____
Average Seats per Bus			
Large	____	____	____
Small	____	____	____
Average Number of Riders per Bus			
Large	____	____	____
Small	____	____	____
Annual Fare Revenues	____	____	____
Annual Operating Cost			
Buses Only	____	____	____
Total Transit System	____	____	____
Hourly Driver Wages ($)	____	____	____
Annual O & M Road Costs ($)	____	____	____

TableA4. Vehicle Occupancy Rates for Passenger Cars and Buses, by Location

Vehicle Type and Location	Occupancy Rate		
	Average	Peak Hour	Practical Maximum
	Persons per Vehicle		
Passenger Cars			
All trips[a]	2.2	1.6	3.5
Intercity trips	2.9	-	-
Buses			
Transit Buses[b]	9.0	18.0	25.0
Intercity Buses	20.0	-	30.0

[a]Includes work trips and intercity trips.

[b]Based on cities with populations of at least 300,000.

Source: Voorhees, Alan M., and associates, Inc.; Energy Efficiencies of Urban Transportation, technical study memorandum No. 9; Westgate Research Park, McLean, Virginia; May 1974.

Table A5. Excess Hours Consumed Per Speed Change-Cycle Above Continuing at Initial Speed for Passenger Cars and Pickups (Type 1)

(Hours per 1,000 speed change cycles)

Initial speed, mph	Speed reduced to and returned from, mph										
	Stop	5	10	15	20	25	30	35	40	45	50
5	1.02										
10	1.51	0.62									
15	2.00	1.12	0.46								
20	2.49	1.62	0.93	0.35							
25	2.98	2.11	1.40	0.80	0.28						
30	3.46	2.60	1.87	1.24	0.70	0.23					
35	3.94	3.09	2.34	1.69	1.11	0.60	0.19				
40	4.42	3.58	2.81	2.13	1.52	0.97	0.51	0.16			
45	4.90	4.06	3.28	2.57	1.93	1.34	0.83	0.42	0.13		
50	5.37	4.54	3.75	3.01	2.34	1.71	1.15	0.68	0.35	0.11	
55	5.84	5.02	4.21	3.45	2.74	2.08	1.47	0.94	0.57	0.28	0.09

SOURCE: Winfrey, Robley. Economic Analysis for Highways, International Textbook Company, Scranton, Pennsylvania, 1969.

Table A6. Excess Hours Consumed For Speed-Change Cycle Excess Hours Above Continuing at Initial Speed for Single-Unit Trucks and Buses (Type 2 & 4)

Vehicle: 12-kip single-unit truck
Unit: Hours per 1,000 cycles

Roadway surface: High type pavement in good condition

Initial Speed, mph	Speed Reduced to and Returned from, mph												
	Stop	5	10	15	20	25	30	35	40	45	50	55	60
5	0.73												
10	1.47	0.69											
15	2.20	1.35	0.62										
20	2.93	2.02	1.23	0.53									
25	3.67	2.70	1.86	1.12	0.45								
30	4.40	3.40	2.50	1.72	1.01	0.39							
35	5.13	4.11	3.16	2.33	1.59	0.91	0.36						
40	5.87	4.83	3.84	2.97	2.18	1.48	0.83	0.31					
45	6.60	5.57	4.54	3.64	2.81	2.07	1.37	0.76	0.28				
50	7.33	6.31	5.26	4.33	3.47	2.68	1.93	1.27	0.72	0.28			
55	8.07	7.06	6.02	5.07	4.17	3.35	2.56	1.84	1.23	0.71	0.32		
60	8.80	7.82	6.81	5.85	4.94	4.08	3.27	2.50	1.83	1.25	0.72	0.39	
65	9.53	8.58	7.64	6.71	5.80	4.92	4.09	3.30	2.57	1.90	1.30	0.77	0.33

* A speed-change cycle is reducing speed from and returning to an initial speed

Table A7. Excess Hours Consumed per Speed-Change Cycle Excess Hours Above Continuing at Initial Speed for Multiple-Unit Trucks (Type 3)

Vehicle: 50-kip 3-S2, diesel
Unit: Hours per 1,000 cycles

Roadway surface: High type pavement in good condition

Initial Speed, mph	Speed Reduced to and Returned from, mph											
	Stop	5	10	15	20	25	30	35	40	45	50	55
5	1.10											
10	2.27	0.95										
15	3.48	1.96	0.81									
20	4.76	3.05	1.71	0.69								
25	6.10	4.25	2.72	1.49	0.60							
30	7.56	5.59	3.90	2.45	1.36	0.54						
35	9.19	7.12	5.29	3.66	2.35	1.31	0.52					
40	11.09	8.94	6.99	5.20	3.66	2.40	1.36	0.58				
45	13.39	11.20	9.12	7.19	5.45	3.95	2.65	1.58	0.71			
50	16.37	14.13	11.95	9.88	7.95	6.19	4.60	3.18	1.95	0.89		
55	20.72	18.33	15.98	13.71	11.53	9.45	7.48	5.66	3.98	2.48	1.15	
60	27.94	24.99	22.10	19.28	16.55	13.93	11.44	9.10	6.92	4.92	3.10	1.46

* A speed-change cycle is reducing speed from and returning to an initial speed

Source: Winfrey, Robley. Economic Analysis for Highways, International Textbook Company, Scranton, Pennsylvania, 1969.

Table A8. Value of Time by Vehicle Type and Driving Mode[a]

Vehicle Type	In Moving Vehicle[a]		In Stopped Vehicle[b]	
	Driver	Passenger	Driver	Passenger
	- - - - - - - - - -Dollars Per Hour- - - - - - - - - -			
1	6.31	6.31	9.47	9.47
2	11.72	6.31	18.21	9.47
3	16.36	6.31	24.54	9.47
4	17.66	6.31	26.49	9.47

[a]Update of values of time reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2 to January 1980.

[b]Represents 1.5 times the in vehicle values of time, and is based on waiting data reported in the 1977 ASSHTO Redbook.

Source: Ritch, Gene and Buffington, Jesse L. "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A9 Freeway Volume to Capacity Ratios, by Number of Lanes and Level of Service

Number of Lanes	V/c Ratio Limits by Level of Service[a]					
	A	B	C	D	E	F[b]
4	0.0-0.35	0.36-0.50	0.51-0.75	0.75-0.90	0.91-1.00	1.00-0.0
6	0.0-0.40	0.41-0.58	0.59-0.80	0.81-0.90	0.91-1.00	1.00-0.0
8	0.0-0.42	0.43-0.63	0.64-0.83	0.84-0.90	0.91-1.00	1.00-0.0

[a]Volume to capacity ratios based on 70 miles per hour design speeds, ignoring the peak-hour factor. These v/c limits are assumed to be acceptable for other design speeds.

[b]In Level of Service F, the v/c is negative.

Source: Curry, David A. and Anderson, Dudley G., "Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects," National Cooperative Highway Research Program, Report 133, 1972.

Table A10. Unit Values for Levels of Discomforts & Inconveniences[a]

Level[b] of Discomforts & Inconveniences	Unit Value ($/veh-hour)
A	0
B	0
C	0
D	0.10
E	0.25
F	0.50

[a]These values are assumed to be applicable for both highways and city streets and for all vehicle types.

[b]Levels of discomforts and inconveniences are defined the same way as levels of service, referred as vehicle to capacity ratios by AASHTO [1].

Source: McLeod, Douglas S. and Adair, Richard E., "Benefit-Cost Analysis Based on the AASHTO Procedures," Transportation Research Record 747, Transportation Research Board, Washington, D. C., 1980, pp. 43-49.

Table A11. Running Costs on City Streets, by Vehicle Type and Uniform Speed[a]

Uniform Speed	Vehicle Type 1	Vehicle Type 2 & 4	Vehicle Type 3
Miles Per Hour[b]	- - - - - Cents Per Vehicle Mile[c] - - - - -		
5	19.202	36.497	66.960
10	14.556	28.608	46.590
15	12.866	25.627	39.346
20	12.022	24.275	36.051
25	11.534	23.834	34.718
30	11.292	23.969	34.581
35	11.276	24.528	35.273
40	11.345	25.357	36.896
45	11.544	26.458	39.073
50	11.858	27.829	41.951

[a]Update of Costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2 to January 1980.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from cents per mile to cents per kilometer, multiply by 0.6214.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

TableA12. Excess Running Costs of Speed Cycle Changes on City Streets for Vehicle Type 1, by Initial Speed[a]

Initial Speed	Speed Reduced to and Returned From (MPH)				
	Stop	10	20	30	40
Miles Per Hour[b]	- - - - - Cents Per Cycle Change - - - - - -				
5	0.250				
10	0.545				
15	0.956	0.353			
20	1.457	0.768			
25	2.031	1.355	0.516		
30	2.738	2.032	1.178		
35	3.580	2.886	2.017	0.794	
40	4.611	3.888	3.003	1.795	
45	5.864	5.125	4.211	3.001	1.191
50	7.453	6.627	5.681	4.442	2.616

[a]Update of Costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2 to January 1980.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A13. Excess Running Costs of Speed Cycle Changes on City Streets for Vehicle Type 2 & 4, by Initial Speed[a]

Initial Speed	Speed Reduced to and Returned From (MPH)				
	Stop	10	20	30	40
Miles Per Hour[b]	- - - - - Cents Per Cycle Change - - - - - -				
5	0.680				
10	1.668				
15	2.930	1.036			
20	4.420	2.440			
25	6.232	4.145	1.602		
30	8.369	6.232	3.627		
35	10.927	8.758	6.119	2.395	
40	14.051	11.833	9.098	5.358	
45	17.775	15.492	12.708	8.904	3.545
50	22.227	19.879	17.014	13.161	7.754

[a]Update of Costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2 to January 1980.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas May, 1980.

Table A14. Excess Running Costs of Speed Cycle Changes on City Streets for Vehicle Type 3, by Initial Speed

	Speed Reduced to and Returned From (MPH)				
Initial Speed	Stop	10	20	30	40
Miles Per Hour[b]	- - - - - Cents Per Cycle Change - - - - - -				
5	3.001				
10	6.822				
15	11.256	6.576			
20	17.151	11.601			
25	24.456	17.208	7.038		
30	33.491	26.075	15.789		
35	44.599	37.019	26.598	10.847	
40	65.305	50.630	39.955	24.129	
45	75.125	67.157	56.342	40.209	16.371
50	95.601	87.425	76.325	60.093	35.965

[a]Update of Costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2 to January 1980.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A15. Idling Costs, by Type of Vehicle[a]

Vehicle Type	Idling Costs
	Cents Per Hour[b]
1	37.540
2 & 4	78.214
3	80.218

[a]Update of Costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2 to January 1980.

[b]To convert from cents per mile to cents per kilometer multiply by 0.6214.

Source: Ritch, Gene and Buffington, Jesse L, "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas May 1980.

Table A16. Running Costs for Vehicle Type 1 on Freeways, by Level of Service and Average Speed[a]

Average Speed	Level of Service A	B	C	D	E	F
Miles Per Hour[b]	- - - - - Cents Per Vehicle Mile[c] - - - - -					
5						40.693
10						23.010
15						17.360
20						14.725
25						13.189
30					9.571	12.413
35				9.512	9.708	9.758
40			9.694	9.787	9.977	
45		9.713	10.033	10.200	10.537	
50	9.706	10.056	10.451	10.770		
55	10.647	10.504	11.007			
60	10.563	11.081				
65	11.268					

[a]Update of costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2 to January 1980.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from cents per mile to cents per kilometer, multiply by 0.6214.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University Texas, May 1980.

Table A17. Running Costs for Vehicle Types 2 and 4 on Freeways, by Level of Service and Average Speed[a]

Average Speed	Level of Service					
	A	B	C	D	E	F
Miles Per Hour[b]	- - - - - Cents Per Vehicle Mile[c] - - - - -					
5						113.307
10						57.891
15						41.223
20						33.982
25						30.653
30					21.362	28.945
35				22.413	22.970	23.652
40			23.208	23.512	24.359	
45		23.834	24.596	25.087	25.809	
50	24.956	25.239	26.238	27.067		
55	25.883	27.067	28.388			
60	27.812	29.065				
65	30.081					

[a]Update of costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2 to January 1980.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from cents per mile to cents per kilometer, multiply by 0.6214.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University Texas, May 1980.

Table A18. Running Costs for Vehicle Type 3 on Freeways, by Level of Service and Running Speed[a]

Average Speed	Level of Service					
	A	B	C	D	E	F
Miles Per Hour[b]	----- Cents Per Vehicle Mile[c] -----					
5						306.167
10						132.349
15						84.947
20						65.049
25						56.442
30					31.980	49.898
35				32.305	33.366	34.730
40			33.594	34.415	36.177	
45		35.301	36.668	37.685	38.185	
50	37.711	38.402	40.294	41.845		
55	40.299	42.651	45.283			
60	44.472	46.901				
65	49.283					

[a]Update of costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2 to January 1980.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from cents per mile to cents per kilometer, multiply by 0.6214.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Insitute, Texas A&M University, Texas, May 1980.

Table A19. Motor Vehicle Accident Rates, by Highway Type and Location Accident

Highway Type	Location of Accident		
	Rural	Urban	Urban Metered
	--Per Million Vehicle Miles--		
Freeways			
4-lane	1.4	2.8	2.5
6-lane	1.3	2.6	2.3
8-lane	1.2	2.4	2.2
10-lane	1.1	2.2	2.0
12-lane	1.0	2.0	1.8
14-lane	-	1.8	1.6
16-lane	-	1.6	1.4
Expressways			
2-lane	3.0	6.0	-
4-lane	2.8	5.6	-
6-lane	2.6	5.2	-
Conventional Highways			
Undivided			
2-lane	6.0	12.0	-
4-lane	5.6	11.2	-
6-lane	5.2	10.4	-
Divided			
4-lane	2.8	-	-
6-lane	2.6	-	-

Source: Texas Department of Highways and Public Transportation, Guide to the Highway Economic Evaluation Model, Austin, Texas, February 1976.

Table A20. Percentage Distribution by Accident Severity

Highway Type	Fatal	Injury	Fatal and Injury	Property Damage Only	Total
Rural					
2-lane	2.9	43.0	45.9	54.1	100.0
3-lane	3.4	38.7	42.1	57.9	100.0
4 or more lane undivided	1.7	39.7	41.4	58.6	100.0
4 or more lane divided	2.2	39,8	42.0	58.6	100.0
Divided expressway	3.2	42.0	45.2	54.8	100.0
Freeway	3.6	43.2	46.8	53.2	100.0
Urban					
2-lane	0.7	31.0	31.7	68.3	100.0
3-lane	0.9	28.4	29.3	70.7	100.0
4 or more lane undivided	0.6	33.8	34.4	65.6	100.0
4 or more lane divided	0.6	31.5	32.1	67.9	100.0
Divided expressway	1.3	35.6	36.9	63.1	100.0
Freeway	1.1	40.7	41.8	58.2	100.0

Source: Tamburri, T.N. and Smith, R.N., "The Safety Index: A Method of Evaluating and Rating Safety Benefits," Highway Research Record 332, Highway Research Board, Washington, D.C., 1970.

Table A21. Motor Vehicle Accident Unit Costs per Reported Accident by Severity and Location of Accident[a]

Severity of Accident	Location of Accident		
	Rural	Suburban	Urban
	- - - - - -Dollars Per Accident- - - - - -		
Fatal[b]	566,103	506,304	446,503
Injury[c]	27,709	24,630	21,551
Property Damage Only	1,264	1,084	904

[a]Based on NHTSA accident costs adjusted for location using CALTRANS accident cost data and then updated to January 1980.

[b]Includes direct accident costs and discounted gross future earnings which includes future maintenance costs of the decedent.

[c]Includes direct accident costs as well as costs for pain and suffering, loss of earnings, and loss of services to home and family in partial or total disability accidents.

Source: American Association of State Highway and Transportation Officials, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements (new Redbook), 444 North Capital Street, N.W. Suite 225, Washington, D.C., 1977.

Table A22. 1979 Unit Transit Operating Costs and Unit Transit Revenues by System Size[a]

System Size	Transit Operating Costs[b] ($/Vehicle-Mile)		Transit Revenues[b] ($/Vehicle-Mile)
	Including Adm. Costs	Excluding Adm. Costs[c]	
A	2.01	1.93	0.40
B	1.55	1.40	0.80
C	1.23	1.10	0.49

[a]System size is determined by city size. Systems A, B and C refer to transit systems in cities with population greater than 500,000, between 200,000 and 500,000, and less than 200,000 respectively. System A includes transit systems in Dallas, Houston and San Antonio; system B refers to transit systems in Austin Corpus Christi, El Paso and Fort Worth; and system C includes systems in Abilene, Amarillo, Beaumont, Brownsville, Galveston Laredo, Lubbock, San Angelo, Waco and Wichita Falls.

[b]These unit values represent the average unit values from transit systems in cities included in a system size as specified in the above footnote.

[c]According to Womack and Burke [13], administrative costs represent 4%, 9.5% and 10.7% of the total transit operation costs for system A, B, and C, respectively.

Source: State Department of Highways and Public Transportation, "1979 Texas Transit Statistics", Transportation Planning Division, December 1980.

Table A23. Pollution Emission Rates of Vehicle Type 1, by Type of Pollutant and Average Speed[a]

Average Speed	Type of Pollutant		
	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxides
Miles Per Hour[b]	-------- Grams Per Mile[c] ---------		
5	176.37	12.07	4.46
10	95.29	7.07	4.06
15	59.96	5.35	3.80
20	46.40	4.38	3.95
25	36.84	3.69	4.10
30	30.35	3.21	4.25
35	25.80	2.86	4.41
40	22.62	2.63	4.57
45	20.46	2.48	4.72
50	19.10	2.42	4.77
55	18.40	2.42	5.02
60	18.23	2.49	5.18

[a]Derived from pollution emission and speed correction factors published in U.S. Environmental Protection Agency, Supplement No. 5 for Compilation of Air Pollutant Emission Factors, Second Edition, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, December 1975. Light duty gasoline automobiles and trucks are combined in .97 and .03 proportions, respectively.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from grams per mile to grams per kilometer, multiply by 0.6214.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A24. Pollution Emission Rates of Vehicle Types 2 and 4, by Type of Pollutant and Average Speed[a]

Average Speed	Type of Pollutant		
	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxides
Miles Per Hour[b]	-------- Grams Per Mile[c] --------		
5	571.82	54.35	11.49
10	328.02	29.63	11.03
15	237.16	24.30	10.64
20	191.42	19.65	11.00
25	159.16	16.37	11.35
30	136.32	14.05	11.70
35	120.28	12.42	12.06
40	109.32	11.31	12.41
45	102.36	10.61	12.76
50	98.72	10.25	13.11
55	98.07	10.20	13.47
60	100.37	10.45	13.82

[a]Derived from pollution emission and speed correction factors published in U.S. Environmental Protection Agency, Supplement No. 5 for Compilation of Air Pollutant Emission Factors, Second Edition, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, December 1975. Represents heavy duty gasoline single-unit trucks and buses.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from grams per mile to grams per kilometer, multiply by 0.6214.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A25. Pollution Emission Rates of Vehicle Type 3, by Type of Pollutant and Average Speed[a]

Average Speed	Type of Pollutant		
	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxides
Miles Per Hour[b]	------- Grams Per Mile[c] -----------		
5	34.25	7.37	29.83
10	30.41	5.45	23.65
15	29.13	4.81	21.59
20	25.37	4.26	21.92
25	19.38	3.66	23.85
30	15.39	3.26	25.14
35	12.53	2.97	26.03
40	10.40	2.76	26.70
45	8.73	2.59	27.23
50	7.40	2.45	27.66
55	6.31	2.34	28.00
60	5.40	2.25	28.30

[a]Derived from pollution emission and speed correction factors published in U.S. Environmental Protection Agency, Supplement No. 5 for Compilation of Air Pollutant Emission Factors, Second Edition, Office of Air Quality Planning and Standards, Research Triangle Parks, North Carolina, December 1975. Represents heavy duty diesel trucks and buses.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from grams per mile to grams per kilometer, multiply by 0.6214.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A26. Idling Pollution Rates, by Vehicle Type and Type of Pollutant[a]

Vehicle Type	Type of Pollutant		
	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxides
	Grams Per Minute		
1[b]	14.74	0.83	0.12
2[c]	61.72	3.68	0.33
3[d]	00.64	0.32	1.03

[a]Derived from pollution emission factors published in U.S. Environmental Protection Agency, Supplement No. 5 for Compilation of Air Pollutant Emission Factors, Second Edition, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, December 1975.

[b]Based on light duty vehicles and light duty gasoline trucks combined in proportions of .97 and .03, respectively.

[c]Represents heavy duty gasoline trucks and buses and is based on the ratio of Vehicle Type 2 to Vehicle Type 1 moving vehicle emission rates.

[d]Represents heavy duty diesel trucks and buses.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A27. Fuel Consumption Rates on City Streets, by Vehicle Type and Uniform Speed

Uniform Speed	Vehicle Type		
	Type 1	Types 2&4	Type 3
Miles Per Hour[a]	------Gallons Per Mile[bc]-----		
5	.1025	.1906	.5099
10	.0634	.1273	.2648
15	.0511	.1075	.1861
20	.0460	.0988	.1558
25	.0436	.0947	.1300
30	.0429	.0932	.1205
35	.0434	.0936	.1125
40	.0449	.0954	.1195
45	.0460	.0988	.1271
50	.0499	.1040	.1452

[a] To convert miles per hour to kilometers per hour, multiply by 1.609344.

[b] To convert gallons per mile to liters per kilometer, multiply by 2.351.

[c] Fuel consumption rates are based on those reported in Winfrey, Robley, Economic Analysis for Highways, Internation Textbook Co., Scranton, Pennsylvania, 1969. Passenger cars and commercial vehicles, in proportions of .97 and .03 respectively, make up Type 1 vehicles. The 2-S2 gasoline trucks and 3-S2 diesel trucks, in proportions of .26 and .74 respectively, make up Type 3 vehicles.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A28. Excess Fuel Consumption Rates for Speed Cycle Changes of Vehicle Type 1 on City Streets, by Initial Speed

	Speed Reduced to and Returned from (MPH)				
Initial Speed	Stop	10	20	30	40
Miles Per Hour[a]	Gallons Per Cycle Change[bc]				
5	.00025				
10	.00101				
15	.00268	.00078			
20	.00438	.00202			
25	.00613	.00378	.00135		
30	.00792	.00565	.00311		
35	.00980	.00766	.00524	.00198	
40	.01180	.00986	.00753	.00474	
45	.01399	.01228	.01005	.00750	.00277
50	.01647	.01511	.01287	.01046	.00601

[a] To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[b] To convert from gallons per cycle to liters per cycle, multiply by 3.7854.

[c] Fuel consumption rates are based on those reported in Winfrey, Robley, Economic Analysis for Highways, International Textbook Co., Scranton, Pennsylvania, 1969. Passenger cars and commercial vehicles, in proportions of .97 and .03 respectively make up Type 1 vehicles.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A29 Excess Fuel Consumption Rates for Speed Cycle Changes of Vehicle Types 2 and 4 on City Streets, by Initial Speed

Initial Speed	Speed Reduced to and Returned from (MPH)				
	Stop	10	20	30	40
Miles Per Hour[a]	------- Gallons Per Cycle Change[bc] --------				
5	-				
10	.00333				
15	.00756	.00206			
20	.01179	.00554			
25	.01602	.00972	.00333		
30	.02025	.01389	.00750		
35	.02448	.01805	.01170	.00447	
40	.02871	.02220	.01587	.00887	
45	.03294	.02635	.01989	.01300	.00508
50	.03717	.03050	.02389	.01697	.00945

[a]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[b]To convert from gallons per cycle to liters per cycle, multiply by 3.7854.

[c]Fuel consumption rates are those reported 12-kip single unit trucks in Winfrey, Robley, Economic Analysis for Highways, International Textbook Co., Scranton, Pennsylvania, 1969.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A30. Excess Fuel Consumption Rates for Speed Cycle Changes of Vehicle Type 3 on City Streets, by Initial Speed

Initial Speed	Speed Reduced to and Returned from (MPH)				
	Stop	10	20	30	40
Miles Per Hour[a]	------- Gallons Per Cycle Change[bc] --------				
5	.00112				
10	.00708				
15	.01735	.00722			
20	.02866	.01820			
25	.04097	.03094	.01360		
30	.05430	.04440	.02843		
35	.06860	.05865	.04349	.01929	
40	.08381	.07301	.05839	.03694	
45	.09990	.08821	.07341	.05336	.02376
50	.11682	.10429	.08867	.06916	.04312

[a]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[b]To convert from gallons per cycle to liters per cycle, multiply by 3.7854.

[c]Fuel consumption rates are based on those reported in Winfrey, Robley, Economic Analysis of Highways, International Textbook Co., Scranton, Pennsylvania, 1969. Vehicle Type 3 rates represent 2-S2 gasoline trucks and 3-S2 diesel trucks combined in .26 and .74 proportions, respectively.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A31. Idling Fuel Consumption, by Vehicle Type

Vehicle Type	Idling Fuel Consumption Rate
	Gallons Per Hour[a]
1	.370
2 & 4	.650
3	.400

[a]To convert gallons per hour to liters per hour, multiply by 3.7854.

Source: Winfrey, Robley, Economic Analysis for Highways, International Textbook Co., Scranton, Pennsylvania, 1969.

Table A32. Fuel Consumption Rates for Vehicle Type 1 on Freeways, by Level of Service and Average Speed[a]

Average Speed	Level of Service					
	A	B	C	D	E	F
Miles Per Hour[b]	Gallons Per Vehicle Mile[c]					
5						.3555
10						.1435
15						.0894
20						.0672
25						.0558
30					.0385	.0499
35				.0373	.0381	.0383
40			.0378	.0382	.0390	
45		.0381	.0394	.0400	.0413	
50	.0389	.0403	.0419	.0432		
55	.0416	.0435	.0455			
60	.0439	.0461				
65	.0504					

[a]Based on Fuel Consumption rates and fuel costs as a proportion of total costs as reported in the 1977 ASSHTO Redbook and on total costs reported by Buffington and McFarland In Texas Transportation Research Report 202-2 after combining vehicle Types 1 and 2 in .97 and .03 proportions, respectively.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from gallons per mile to liters per kilometer, multiply by 2.351.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economics Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A33. Fuel Consumption Rates for Vehicle Types 2 & 4 on Freeways, by Level of Service and Average Speed[a]

Average Speed	Level of Service					
	A	B	C	D	E	F
Miles Per Hour[b]	Gallons Per Vehicle Mile[c]					
5						.5887
10						.3037
15						.1957
20						.1542
25						.1423
30					.1013	.1372
35				.1111	.1139	.1172
40			.1181	.1197	.1240	
45		.1281	.1295	.1321	.1359	
50	.1321	.1371	.1425	.1470		
55	.1434	.1500	.1573			
60	.1584	.1655				
65						

[a]Based on Fuel Consumption rates and fuel costs as a proportion of total costs as reported in the 1977 ASSHTO Redbook and on total costs reported by Buffington and McFarland in Texas Transportation Research Report 202-2 for Vehicle Types 3 and 6.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from gallons per mile to liters per kilometer, multiply by 2.351.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

Table A34. Fuel Consumption Rates for Vehicle Type 3 on Freeways, by Level of Service and Average Speed[a]

Average Speed	Level of Service					
	A	B	C	D	E	F
Miles Per Hour[b]	Gallons Per Vehicle Mile[c]					
5						2.8036
10						.9434
15						.5062
20						.3385
25						.2651
30					.1401	.2187
35				.1344	.1388	.1445
40			.1367	.1401	.1472	
45		.1443	.1499	.1541	.1561	
50	.1590	.1663	.1745	.1812		
55	.1725	.1825	.1938			
60	.1804	.1903				
65						

[a]Based on Fuel Consumption rates and fuel costs as a proportion of total costs as reported in the 1977 ASSHTO Redbook and on total costs reported by Buffington and McFarland in Texas Transportation Research Report 202-2 after combining vehicle types 4 and 5 in .26 and .74 proportions, respectively.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from gallons per mile to liters per kilometer, multiply by 2.351.

Source: Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Texas Transportation Institute, Texas A&M University, Texas, May 1980.

APPENDIX FIGURES

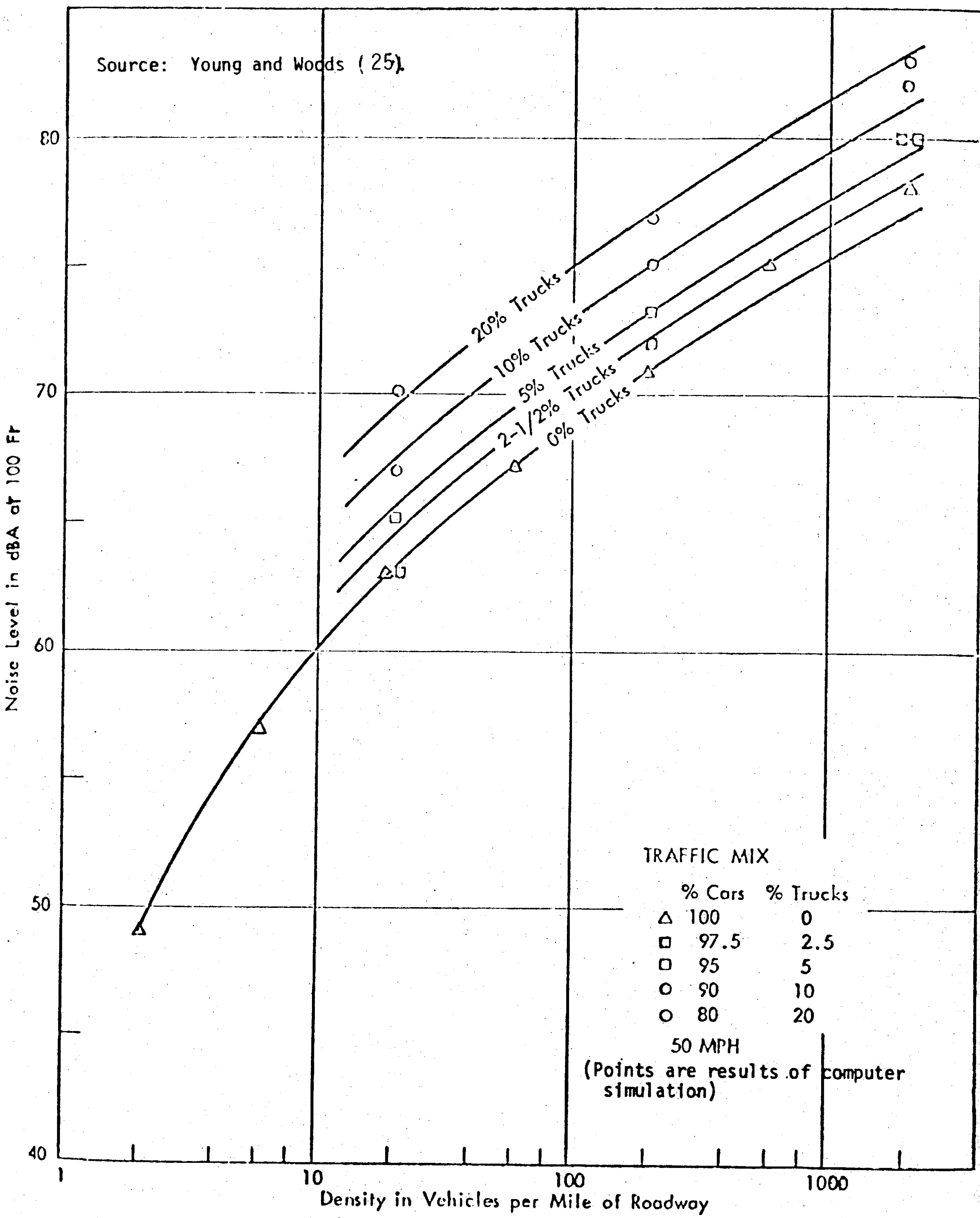

Figure A1 Curves for Estimation of Mean Noise Level in dBA at 100 Feet Distance From a Lane (or Single-Lane-Equivalent) of Mixed Car and Diesel Truck Traffic.

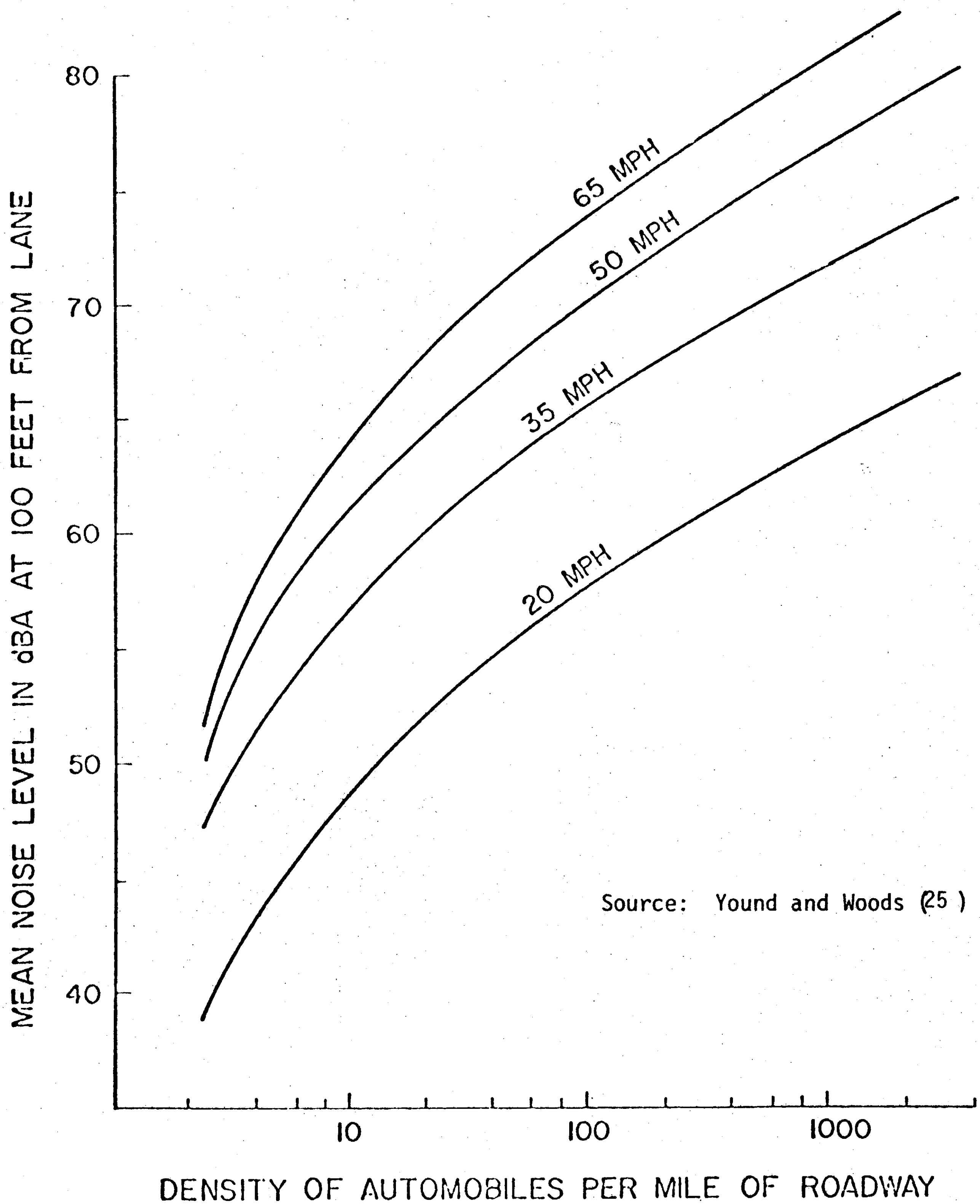

Figure A2 Mean Noise Level at 100 Feet from a Lane, by Density of Automobiles per Mile of Roadway for Selected Speeds.

BIBLIOGRAPHY

Transit Alternatives

Generalized

Abt Associates of Cambridge, "Qualitative Aspects of Urban Personal Demand," UMTA - NSS - 1, August, 1968.

Alan M. Voorhees & Associates, "Basic Characteristics of the Transit System in Houston," U. S. Department of Transportation, Urban Mass Transit Administration, Washington, D. C., October 1971.

Alan M. Voorhees & Associates Inc., "Eugene - Springfield Transit Study Report," UMTA - ORE - T9-1, December 1969.

Alan M. Voorhees & Associates, Inc., "Short-Range Transit Planning," Final Report, U. S. Department of Transportation, Washington, D. C., July, 1973.

Daniel, Mann, Johnson and Mendenall, "Mass Transit Program for the St. Louis Metropolitan Area," UMTA - IT - 09 - 0067 - 79 - 7, October 1978.

General Motor Research Lab, "New System Implementation Study - Vol. III: Case Studies," UMTA - NSS - 7, February 1968.

Gilman, W. C. and Company Inc., "A Transit Improvement Plan for the City of Meridian, Mississippi," UMTA - MS - 09 - 0005 - 74 - 1.

GM Transportation Systems Division, "Texas Transportation Development Program, Final Report, Midland Chanber of Commerce and the City of Midland, February 1978.

Hedges, Charles A., "Let's Attack the Real Urban Transportation Problem," Transportation Research Record, 519, Transportation Research Board, Washington, D. C., 1974, p. 11.

Mix, Charles V. S. and Dickey, John W., "Rural Public Transportation in Virginia," Transportation Research Record, 519, Transportation Research Board, Washington, D. C., 1974, p. 56

Nupp, Byron, "Trends and Choices for Intercity Passenger Transportation in an Era of Resource Stringency - A Problem Posed," Transit Journal, Vol. 19, No. 4, Summer 1980, p. 50.

Ott, Marian T. and Abkowitz, Mark D., "A Review of Recent Demonstration Experiences with Paratransit Services," Paper Presented at the Annual Meeting of the Transportation Research Board, Washington, D. C., January 1980, pp. 12, 25-27

R. H. Pratt Associates, "Low Cost Urban Transportation Alternatives: A Study of Ways to Increased the Effectiveness of Existing Transportation Facilities," January 1973.

Salt Lake City Corporation, "A Transit Improvement Program for the Utah Transit Authority," NTIS PB 204 076, March 1971.

Simpson and Curtin Inc., "Erie: Short-Range Transit Technical Study," Philadelphia, Pennsylvania, January 1977.

Spear, Bruce D., et al. "Services and Methods Demonstration Program," Annual Report, U. S. Department of Transportation, Washington, D. C., August 1979.

Stevens, Robert D. and Bacalis, George J., "Transportation for A New Town," Highway Research Record, 367, Highway Research Board, Washington, D. C., 1971, p.9.

Texas Transportation Institute, Reference Manual, Public and Mass Transportation, Texas A&M University, College Station, Texas, July 1975, pp. 111, B-1.

U. S. Department of Transportation, "Notebook 1 Identification of Transportation Alternatives," Washington, D. C., 1975.

U. S. Department of Transportation, "Transit Actions," October 1979, pp. 31 and 131.

U. S. Department of Transportation, "UMTA/TSC Service and Methods Demonstration Program Publications," edit. Elizabeth Page, Cambridge, Massachusetts, April 1979.

Warner, S. L. Stochastic Choice of Mode in Urban Travel: A Study in Binary Choice, Northwestern University Press, Chicago, 1962.

Wilbur Smith and Associate, "State of Texas Public Transportation Development Manual," Texas Mass Transportation Commission, 1971.

Wilbur Smith and Associates, "Transit Development Program 1976-80," U. S. Department of Transportation, July 1976.

Demand Responsive & Fixed Route

Archer, E. and Shortreed, J. H., "Potential Demands for Demand-Scheduled Bus Services," Highway Research Record, 367, Highway Research Board, Washington, D. C., 1971.

Atkinson, W. G., Coutumier, R. P., and Ling, Suen Ma, "Regina Telebus Study: The Impact of Telebus," Regina Transit System, Canada, March 1973.

Bauer, H. J., "Case Study of A Demand-Responsive Transportation System" Highway Research Board Special Reports, 124, Transportation Research Board, Washington, D. C., 1971, pp. 14-39.

Boyle, Daniel K., "Note on Bus Route Extensions," Transportation Research Record, 746, Transportation Research Board, Washington, D. C., 1980, pp. 56-59.

CACI, Inc., "COM-Bus: A Southern California Subscription Bus Service, UMTA/TSC Project Evaluation Series," Report No. UMTA - MA - 06 - 0049 - 77 - 4, May 1977.

CACI, Inc., "Evaluation and Operations of the Reston, Virginia, Commuter Bus Service, UMTA/TSC Project Evaluation Series," Report No. UMTA - MA - 06 - 0049 - 77 - 7, July, 1977.

Gustafson, R. L., Curd, H. N. and Golob, T. F., "User Preferences for A Demand Responsive Transportation System: A Case Study Report," Highway Research Record, 367, Highway Research Board, Washington, D. C. 1971.

Hobeika, A. G. and Satterby, G. T., "Operational Planning of Fixed Route and Demand-Responsive Bus Systems in Greater Lafayette, Indiana Area," Transportation Research Record, 563, Transportation Research Board, Washington, D. C., 1976, pp. 92-95.

Levinson, Herbert S., Adams, Crosby L. and Hoey, William F., "Bus Use of Highways Planning and Design Guidelines," National Cooperative Highway Research Program, Report 155, Transportation Research Board, Washington, D. C., 1975.

Levinson, Herbert S., Hoey, William F., Sanders, David B. and Wynn, F. Houston, "Bus Use of Highways," National Cooperative Highway Research Program, Report 143, Highway Research Board, Washington, D. C., 1973.

Neufville, Richard de, Koller, Frank and Skinner, Robert, "A Survey of the New York City Airport Limousine Service: A Demand Analysis," Highway Research Record, 348, Highway Research Boarc, Washington, D. C., 1971, p. 197.

O'Leary, K., "Planning for New and Integrated Demand Responsive Systems," Transportation Research Board Special Reports, Transportation Research Board, Washington, D. C., November 1974, pp. 14-20.

Peat Marwick,Mitchell & Company, "Evaluation of A Bus Transit System in A Selected Urban Area," Final Report, June 1969, pp. XV and 142.

Potts, J. T. and Helsing, R. G., Wedding the New to the Traditional in Bus Transit: Door-to Door- and Fixed-Route Systems Combined in California Traffic Engineering and Control, Printerhall Limited, London, England, April 1975, pp. 182-184.

Roos, D., "Dial-A-Bus System Feasibility," Highway Research Board Special Reports 124, Transportation Research Board, Washington, D. C., 1971, pp.40-49.

Stevens, R. D. and Smith, R. L., "Demand Bus for A New Town," Highway Research Board Special Reports, 124, Transportation Research Board, Washington, D. C., 1971, pp. 6-13.

Highway Occupancy Vehicle Treatments

Bothman, Robert W., "Banfield Freeway High-Occupancy Vehicle Lanes," Oregon Department of Transportation, January 1976.

Boyd, J. Hayden, Asher, Norman J. and Wetzler, Elliot S., "Evaluation of Rail Rapid Transit & Express Bus Service in the Urban Commuter Market," U. S. Department of Transportation, Washington, D. C., October 1973, p. 33.

Crain, John L., "Evaluation of A National Experiment in Bus Rapid Transit," Transportation Research Record, 546, Transportation Research Board, Washington, D. C., 1975, pp. 22-26.

Deuser, Bob, "Interstate 95 Exclusive Bus/Car Pool Lane Demonstration Project. Dade County, Florida," U. S. Department of Transportation, Florida Department of Transportation and Metropolitan Dade County, January 1976, p. 8.

Levinson, Herbert S. and David B. Sanders, "Reserved Bus Lanes on Urban Freeways: A Macromodel," Transportation Research Record, 513, Transportation Research Board, Washington, D. C., 1974.

Meier, Robert C., Vederoff, Gregory E. and Porter, Dennis, "Macroplanning Approach to the Assessment of Regional Bus Rapid Transit Systems," Transportation Research Record, 513 Transportation Research Board, Washington, D. C. 1974.

Morion, Donald A., "Status of Carpooling in the Highway Program," Paper Presented at the Annual Meeting of the Western Association of State Highway Officials, Portland, Oregon, June 1974.

Morris, Howard J., "Analysis of Transportation Impacts of Massachusetts Third-Party Vanpool Program," Paper Presented at the Annual Meeting of the Transportation Research Board, January, 1981.

Simkowitz, Howard, "Southeast Expressway High Occupancy Vehicle Lane Evaluation Report," U. S. Deaprtment of Transportation, Washington, D. C., May 1978.

Sweet, Charles P., "Los Angeles and San Francisco High-Occupancy Vehicle Lanes," California Department of Transportation, Sacramento, California, 1976.

U. S. Department of Transportation, Federal Highway Administration and Urban Mass Transit Administration, "Urban Corridor Demonstration Program North Central Expressway Corridor Bus Priority System Evaluation Report," Washington, D. C., April 1979.

Zahavi, Yacov and Roth, Gabriel, "Measuring the Effectiveness of High-Occupancy Vehicles Priority Schemes," Paper Presented at the Annual Meeting of Transportation Research Board, Washington, D. C., January 1980.

Park-and-Ride

Brown, Gerald R., "Influence of Park-and-Ride Factors in Modal Shift Planning," Transportation Research Record, 557, Transportation Research Board, Washington, D. C., 1975, pp. 12-20.

Christiansen, D. L., Grady, Douglas S. and Holder, Ronald, "Park-n-Ride Facilities: Preliminary Planning Guidelines," Texas Transportation Institute, Texas A&M University, College Station, Texas, August 1975.

Fare Structure

Bates, John W., "Effect of Fare Reduction on Transit Ridership in the Atlanta Region: Summary of Transit Passenger Data," Transportation Research Record, 499, Transportation Research Board, Washington, D. C., 1974.

Billingsley, Randall S., Guseman, Patricia K. and McFarland, William F., "Fare Box and Public Revenue: How to Finance Public Transportation," Texas Transportation Institute, Texas A&M University, College Station, Texas, February 1980.

Cervo, Robert B., "Efficiency and Equity Impacts of Current Transit Fare Policies," Paper presented at the 60th Annual Meeting of the Transportation Research Board, Washington, D. C., December 1980.

Pucher, John and Rothenberg, Jerome, "Potential of Pricing Solutions for Urban Transportation Problems: An Empirical Assessment," Transportation Research Record, 731, Transportation Research Board, Washington, D. C., 1979, p. 27.

Marketing

Gensch, Dennis H. and Torres, Patrick T., "A Perceived Difference Segmentation Model for Mass Transit Marketing," Paper Presented at the Annual Meeting of the Transportation Research Board, Washington, D. C., January 1980.

Generalized

Abdus-Samad, Usamah and Grecco, William L., "Sensitivity Analysis of Community Savings Due to Change-of-Mode Operations," Transportation Research Record, 557, Transportation Research Board, Washington, D. C., 1975.

Barton-Aschman Associates Inc., "An Evaluation of Alternative Transit Equipment Systems for Milwaukee County," UMTA - WISC - T9-1, May 1969.

Cherwony, Walter & Mundle, Subhash R, "Peak-base Cost Allocation Models," Transportation Research Record 663, Transportation Research Board, Washington, D. C., 1978, pp. 52-56.

Cohen, Harry S., Stowers, Joseph R. and Petersilia, Michael P., "Evaluating Urban Transportation System Alternatives," U. S. Department of Transportation, Washington, D. C., November, 1978.

H. B. Rouse and Company, "Transit Needs Analysis Vol. I: Transit Needs Assessment," Chicago, Illinois, November 1977.

Kessoff, Harold and Gendell, David S., "An approach to Multiregional Urban Transportation Policy Planning," Highway Research Record, 348, Highway Research Board, Washington, D. C., 1971, p. 89.

Lane, Johnathan S., Grenzeback, Lance R., Martin, Thomas J. and Lockwood, Stephen C., "Impact Assessment Guidelines," National Cooperative Highway Research Program, Transportation Research Board, Washington, D. C., 1978. pp 1 and 69.

Mera, L., "An Empirical Determination of a Dynamic Utility Function," Review of Economics and Statistics, Vol. 50, February 1968, pp. 117-122.

O'Leary, Timothy, "Evaluating the Expected Return - As Well as the Risk - of a proposed Transit Investment," Transit Journal, Fall 1979, pp. 19-28.

Peat Marwich, Mitchell & Co., "Analyzing Transit Options for Small Urban Communities Vol. Two: Analysis Methods," U. S. Department of Transportation, Washington, D. C., January 1978.

Peat Marwick, Mitchell & Co., "Simplified Aids for Transportation Analysis: Annotated Bibliography," UMTA - IT - 06 - 9020 - 79 - 1, January 1979.

Ruth, Art, "Cost-Effectiveness Analysis: The Program of the Colorado Department of Highways," Transportation Research Record, 747, Transportation Research Board, Washington, D. C., 1980.

Taggart, Robert E., Jr., Walker, Nancy S. and Stein, Martin M., "Estimating Socioeconomic Impacts of Transportation Systems," Transportation Research Record, 716, Transportation Research Board, Washington, D. C. 1979, pp. 9-10.

Wegmann, F. J., Bonilla, C. R., Bell, T. L., Dewhirst D., Sovchen, C. A. and Heathington, K. W., "Market Opportunity Analysis for Short-Range Public Transportation Planning, Economic, Energy and Environmental Impacts," National Cooperative Highway Research Program, Report 210, Transportation Research Board, Washington, D. C., October 1979.

Transit Demand

Brown, Gerald R., "Correlation of Socioeconomic Factors with Corridor Travel Demand," Transportation Research Record, 499, Transportation Research Board, Washington, D. C., 1974.

Carstens, R. L. and Csanyl, L. H., "A Model for Estimating Transit Usage In Cities in Iowa," Highway Research Record, 213, Highway Research Board, Washington, D. C., 1968.

Chadda, H. S. and Mulinazzi, T. E., "A Transit Planning Methodology for Small Cities," Transit Journal, Vol. 3, No. 2, Spring 1977, pp. 19-40.

Guseman, Patrick K., Harfield, Nancy J. and Hall, Judith, "Critical Factors Influencing the Demand for Transit," Texas Transportation Institute, Texas A&M University, College Station, Texas, June 1977.

Hartgen David T., "Forecasting Demand for Improved - Quality Transit Service with Small Sample Surveys," Planning and Research Bureau, New York State Department of Transportation, Albany, New York, November 1973.

Methodology & Applications

Bergmann, D. R., "Evaluating Mutually Exclusive Investment Alternatives: Rate-of-Return Methodology Reconciled with Net Present Worth," Highway Research Record, 437, Highway Research Board, 1973, pp.75-82.

Buffington, Jesse L. and McFarland, William F., "Benefit-Cost Analysis: Updated Unit Costs and Procedures," Texas Transportation Institute, Texas A&M University, College Station, Texas, 1975.

Buffington, Jesse L., McFarland, William F. and Rollings, John, "Texas Highway Economic Evaluation Model: A Critical Review of Assumptions and Unit Costs and Recommended Updating Procedures," Texas Transportation Institute, Texas A&M University, College Station, Texas, January 1979.

Haefele, E. T., "Social and Income Effects in the Analysis of Transportation Projects," in Colloquium on Investment Planning for Ports and Airports, University of British Columbia, Vancouver, B. C., 1970.

Hibbard, Thomas H. and Miller, Fred, "Applications of Benefit-Cost Analysis: The Selection of 'Nonconstruction' Projects," Transportation Research Record, 490, Transportation Research Board, Washington, D. C., 1974.

McLeod, Douglas S. and Adair, Richard E., "Benefit-Cost Analysis Based on the AASHTO Procedures," Transportation Research Record 747, Transportation Research Board, Washington, D. C., 1980, pp. 43-49.

Prest, A. R. and Turvey, R., "Benefit-Cost Analysis: A Survey," Surveys of Economic Theory, Vol. III, MacMillan and Co., London, 1966, pp.155-207.

Quinn, G. D., The Capital Expenditure Decision, Homewood: R. D. Irwin, 1967.

Schwab, Bernhard and Lusztig, Peter, "A Comparative Analysis of the Net Present Value and the Benefit-Cost Ratio As Measures of the Economic Desirability of Investments," Journal of Finance, Vol. 24, June 1969, pp. 507-16.

Steinberg, Eleanor B., "Benefit-Cost Analysis and the Location of Urban Highways," Highway Research Record, 348, Highway Research Board, Washington, D. C., 1971, p.40.

Steiner, H. M., Discussion of Paper, "Common Misunderstandings About the Internal-Rate-of-Return and Net Present Value Economic Analysis Methods," Transportation Research Record, 731, Transportation Research Board, Washington, D. C., 1979, pp. 1-16

Texas Department of Highways and Public Transportation, "Guide to the Highway Economic Evaluation Model," (developed by McKinsey and Co. of Dallas, Texas), Austin, Texas, February 1976.

Weisbrod, B., "Income Redistribution Effects and Benefit-Cost Analysis," in Problems in Public Expenditure Analysis (Chase, S. B., ed), Brookings Institute, 1968.

Weston, J. Fred and Brigham, Eugene F., Managerial Finance, Sixth Edition, the Dryden Press, Hinsdale, Illinois, 1978, p. 1002.

Winfrey, Robley, Discussion of Paper, "Common Misunderstandings About the Internal-Rate-of-Return and Net Present Value Economic Analysis Methods," Transportation Research Record, 731, Transportation Research Board, Washington, D. C., 1979, pp. 1-16.

Wohl, Martin, "Common Misunderstanding of the Internal-Rate-or-Return and Net Present Value Economic Analysis Methods," Transportation Research Record, 731, Transportation Research Board, Washington, D. C., 1979, pp. 1-16.

Bus Costs & User Costs

American Association of State Highway and Transportation Officials, A Manuel on User Benefit Analysis of Highway and Bus-Transit Improvements 1977, Washington, D. C., 1977.

American Transit Association, "Transit Operating Report - 1970," 1970.

Arthur Anderson & Company, "Bus Route Costing for Planning Purposes," Supplementary Report 108 UC, UK Department of the Environment Transport and Road Research Laboratory U. K., 1974.

Chapman, R. G., "Accidents on Urban Artierial Roads," Laboratory Report 838, Transport and Road Research Laboratory, U. K., 1978.

Collins, P. H. and Lindsay, J. F., "On a Crew Cost Model for Buses," Operational Research Unit Report R178, London Transport Executive, London, UK, 1971.

Curry, D. and Anderson, D., "Procedures for Estimating Highway User Costs, Air Pollution and Noise Effects," National Cooperative Highway Research Program, Report No. 133, Highway Research Board, Washington, D. C., 1972.

Dunbar, Frederick C., "Relative Accuracy of User-Benefit Measures," Transportation Research Record, 747, Transportation Research Board, Washington, D. C., 1980.

Gruver, James E., "Highway User Investment Study," Transportation Research Record, 490, Transportation Research Board, Washington, D. C., 1974.

Hibbard, Thomas H. and Miller, Fred, "Economic Analysis and the Environmental Overview: Suggestions for Project Recommendations by Local Governments," Transportation Research Record 490, Transportation Research Board, Washington, D. C., 1974, pp. 10-17.

Kemp, Michael A., Beesley, Michael E. and McGillivary, Robert G., "Bus Costing Information in Short-Range Planning: A Survey of Principles and Practice," The Urban Institute, Washington, D. C., December 1980.

Louviere, Jordan and Locur, George, "Analysis of User Cost and Service Tradeoffs in Transit and Paratransit Services," U. S. Department of Transportation, Washington, D. C., August 1979.

McFarland, W. F., Griffin, L. I., Rollins, J. B., and Phillips, D. T., "Multiple Criteria/Multiple Attribute Methods for Evaluating Highway Accident Countermeasures," Texas Transportation Institution, Texas A&M University, College Station, Texas, June 1977, p. 13.

Ritch, Gene and Buffington, Jesse L., "The Freq 3CP Economic Package," Research Report 210-5, Texas Transportation Institute, Texas A&M University, College Station, Texas, May 1980.

Roess, Roger P., "Operating Cost Models for Urban Public Transportation Systems and their Use in Analysis," Transportation Research Record, 490, Transportation Research Board, Washington, D. C., 1974, pp. 40-51.

Rollins, J. B., McFarland, .W F., Dudek, C. L., Stockton, W. R., Griffin, L. I. and Phillips, D. T., "Cost-Effectiveness and Safety: Current Practices and Needed Improvements," Texas Transportation Instutite, Texas A&M University, College Station, Texas, September, 1977.

UK Transport and Road Research Laboratory, "Symposium on the Costing of Bus Operations," Supplementary Report 180 UC, UK Department of the Environment Transport and Road Research Laboratory, UK, 1975.

Winfrey, Robley, Economic Analysis for Highways, International Textbook Company, Scranton, Pennsylvania, 1969.

Womack, Katie N. and Burke, Dock, "Costs of Public Transportation in Texas, 1973-1977," Texas Transportation Institute, Texas A&M University, College Station, Texas, September 1979.

Environmental & Land Use Impacts

Allan, Gary R., "Incorporating Economic Considerations in the Preparation of Environmental Impact Statements," Virginia Highway and Transportation Research Council.

Arbogost, Ronald G., Khasnabis, Snehamay and Opiela Kenneth S., "Establishing Priorities for the Location of Transit Stations for Development Purposes," Transportation Research Record, 747, Transportation Research Board, Washington, D. C., 1980.

Babcock, Willard F. and Khasnabis, Snehamay, "A Study of Land Development and Traffic Generation on Control-Access Highways in North Carolina," Highway Research Record, 467, Highway Research Board, Washington, D. C., 1973.

Bain, J. S., "Criteria for Undertaking Water-Source Developments," American Economic Review, May 1960.

Beaton, John L. and Bougart, Louis, "Can Noise Radiation from Highways be Reduced by Design?" Highway Research Record, 232, Highway Research Board, Washington, D. C., 1968.

Blair, Christopher N. and Lutwak, Susan D., "Simplied Traffic Noise Prediction Model for Transportation and Land Use Planning," Cambridge Collaborative, Inc., Cambridge, Massechusette.

Boyle, Daniel K., "The Effect of Small-Scale Transit Improvements on Saving Energy," New York State Department of Transportation, Albany, New York, June, 1979, P. 5.

Charles River Associates, "Economic Analysis of Policies for Controlling Automotive Air Pollution in the Los Angeles Regions," Cambridge, Massachusetts, 1975.

Cosby, Pamela J. and Buffington, Jesse L., "Land Use Impact of Improving West Vickery Boulevard in a Developing Area of Fort Worth, Texas," Texas Transportation Institute, Texas A&M University, College Station, Texas, August 1980.

Cosby, Pamela J., Herndon, Cary W., Jr. and Buffington, Jesse L., "Land Use Impact of Improving Gessner Road in a Developing Area in Houston, Texas," Texas Transportation Institute, Texas A&M University, College Station, Texas, March 1979.

Dale, Charles W., "Procedures for Estimating Highway, Fuel Consumption and Air Pollution," U. S. Department of Transportation, Washington, D. C., May, 1980.

Doctor, David A., "A Manual Model to Predict Highway Related Carbon Monoxides Concentrations," Southeast Michigan Council of Governments, Detroit, Michigan, April, 1975.

Dorfman, Jacoby, Thomas et al., Models for Regional Water Management, Harvard University Press.

Environmental Protection Agency, Supplemental No. 5 to AP - 42: Compilation of Air Pollutant Emission Factors, Washington, D. C., December 1975.

Erlbaum, Nathan S., Cohen, Gerald S. and Hartgen, David T., "Automotive Energy Forecasts: Impact of Carpooling, Trip Chaining and Auto Ownership," New York State Department of Transportation, Albany, New York, December 1977.

Kugler, B. A., Anderson, G. S., Commins, D. E. and Piesol, A. G., "Highway Noise Propagation and Traffic Noise Model," Establishment of Standards for Highway Noise Levels, Transportation Research Board, Vol. III, 1974.

U. S. Department of Transportation, U. S. Department of Housing and Urban Development, "Transportation and the Urban Environment," October 1978, pp. 56-59.

U. S. Environmental Protection Agency, "Air Quality Criteria for Nitrogen Oxides," Washington, D. C., January 1971.

Wendell, R. E., Norco, J. E. and Crobe, "Emission Prediction and Control Strategy: Evaluation of Pollution from Transportation System," Journal of the Air Pollution Control Association, Vol. 23, No 2, February, 1973.

Young, Murray F. and Woods, Donald L. "Threshold Noise Levels," Research Report No. 166-1 Texas Transportation Institute, Texas A&M University, College Station, Texas, 1970.