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16. Abstract

Demand for better transit systems has grown over the years because of the continued urbanization of the cities, population growth and recent concerns of energy conservation. Evaluation procedures developed are primarily applicable for long range analysis and for user costs and benefits analysis. State and federal transportation officials have recognized the need for developing a procedure which can be used for short range transit evaluation, assessing both the user and nonuser impacts. As a result, the development of such a technique was authorized.

An extensive literature review was conducted. The findings of this review are presented in this report. Relevant short range transit alternatives and their user and nonuser impacts by city size are identified. Also, the three commonly adopted analytical approaches to evaluating impacts are presented. They include the economic efficiency approach, the cost-effectiveness approach and the scoring method.

Combining the strength of these methods, an improved approach specifically adapted for short range analysis, is outlined. This improved technique actually consists of all three evaluation methods, with one method assessing one particular impact category. The resulting full range of assessments should be helpful to transit officials in their decision-making processes. The findings of the report are not intended for implementation; instead, they should serve as references for future development.

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BACKGROUND DATA REQUIRED FOR DEVELOPING A GENERALIZED APPROACH TO EVALUATING IMPACTS OF SHORT RANGE TRANSIT ALTERNATIVES

by

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Improved Techniques for Impact Analysis
of Transit Alternatives

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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 due Dr. Pat Guseman for her assistance in conducting the survey and for her many comments, and Mr. Don Kitchen for his contribution in the literature search.

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ABSTRACT

Demand for better transit systems has grown over the years because of the continued urbanization of the cities, population growth and recent concerns of energy conservation. Evaluation procedures developed are primarily applicable for long range analysis and for user costs and benefits analysis. State and federal transportation officials have recognized the need for developing a procedure which can be used for short range transit evaluation, assessing both the user and nonuser impacts. As a result, the development of such a technique was authorized.

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SUMMARY

An extensive literature search was conducted on short run transit alternatives. According to types of services offered, short range transit alternatives were classified into conventional bus transit and the demand responsive transit categories. Six transit elements which are common to both categories were identified. The adjustments of the six, together with the demand responsive system adjustments, form seven categories of short range alternatives which were studied. Under each of these categories, transit submodes were identified.

The relation of city size characteristics to short range transit improvements was briefly examined. Cities were classified as large, medium and small with populations of 500,000 and above, between 200,000 and 500,000 and under 200,000 respectively. A survey of potential transit improvements expected in 1980 and 1981 by city size was conducted in seven Texas cities. It was found that improvements on routings ranked higher than others regardless of city sizes. On the other hand, all the priority treatments for high occupancy vehicles (HOV) were applicable only in large cities. Park-n-ride service, which ranked high in large cities in the survey was not available in small cities.

User and non-user impacts of short range alternatives identified in the study were grouped into three categories: the user costs, the system costs and the nonmonetary user and non-user costs. Under the first category, user impacts are travel time costs, fare costs, toll and parking fees, vehicle operating costs and accident costs. In the

system cost category, impacts include transit vehicle operating and accident costs, highway/road operating and maintenance costs, capital investment costs and ridership. Impacts on accessibility to jobs, passenger comforts, land use, business activity, energy consumption, and air and noise pollution were included in the last category. The relation of city size characteristics to these impacts was examined. It was found that most impacts are sensitive to population size and population density. The nonmonetary user impact category was found to be unrelated to any city size characteristics.

Three commonly used methods for impact assessments were studied. They are the economic efficiency analysis, the cost-effectiveness analysis and the scoring method. It is felt that these methods have served long range impact assessments rather extensively, but have played only a limited role in short range impact assessments. Therefore, an improved technique is proposed in outline form in this report. The recommended technique combines all three methods. The economic efficiency approach is used for user cost assessments; the cost-effectiveness method for system cost assessments; and the scoring method for the nonmonetary user and non-user cost assessments. The finalized form of this technique will be developed fully in the final report.

IMPLEMENTATION STATEMENT

This report identifies a full range of short-run transit alternatives and their impacts, and presents a generalized recommended approach to evaluating these impacts. The findings of the report are not intended for implementation. It is hoped these findings can serve as references to transit planners and officials and can assist them in their decision-making process when they are faced with choosing a short range transit alternative among many suggested.

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INTRODUCTION

Background of Study

The automobile has brought about the decentralization of the central business districts of our cities and given rise to suburban shopping centers and factories. Urban development is no longer located along fixed rail lines. Instead, complex radial and circumferential system of streets and freeways are constructed to serve the urban population. People commute in their automobile to and from work as far as 100 miles away.

Demand for transit has steadily increased mainly because of the continued urbanization. However, population growth and recent concerns of energy conservation are also determining factors. In the past, it has been demonstrated that people are reluctant to give up their automobiles and switch to mass transit modes. Transit demand has been estimated to have an income elasticity of -.9 while auto demand has a similar elasticity of -1.2 [47]. Hence, as income increases, less transit and more auto usage is demanded. With the drastic increase of gasoline price experienced this year, it is believed these measures are changing.

In comparison with the older cities of Eastern United States, Texas cities are more decentralized with respect to places of residence and places of employment. In addition, user as well as non-user costs, environmental impacts and fuel consumption are issues of great concern. Therefore, in Texas, concentration should be placed upon improvement strategies that increase the efficiency of the existing transportation system. Also there is a need to implement immediate action on short range transit system improvements.

Through the years, evaluation procedures that take into account all user and non-user costs and benefits, have evolved. They help decision-makers choose between alternative plans for improving the transportation system. However, these procedures are primarily applicable for evaluating long range and high cost alternatives, such as new freeway and fixed rail facilities. Also, most of the procedures developed thus far have been focused on analysis of user costs and benefits.

At the present time, the evaluation of short range transit alternatives is limited almost entirely to the estimation of system costs and revenues both of which can be obtained without much difficulty. Assessments of other user and non-user (community) impacts are more complex; nevertheless, they should be included in the evaluation, perhaps in a smaller scale. Therefore, state and federal transportation officials have recognized the need for the development of a procedure to evaluate the impact of alternative short run and low cost changes in the Texas transportation system.

Objective and Scope of Study

The objective of this study is to develop a generalized approach to impact evaluation of alternative short range transit system plans. The scope of the study is limited to areas defined by the objective. Since the present study is restricted to short run and low cost alternatives, major facility changes to accommodate rail or bus transit are automatically excluded from consideration. Those transit improvements that could be classified either short range or long range will also be included in this study.

Contents of Report

This report conveys the preliminary findings of the study. The major portion of the report contains the results of an extensive search of the literature and the results of a limited survey of city transit systems in Texas. The report also outlines a generalized approach to evaluating impacts resulting from the implementation of short range transit alternatives.

The major divisions of the body of the report are as follows: (1) determination of relevant alternatives, (2) determination of relevant impacts, (3) outline of generalized approach to impact evaluation, and (4) conclusions and recommendations.

RELEVANT SHORT RANGE TRANSIT ALTERNATIVES

Any transit improvement which requires a low level of capital investment [28] and a short time frame for implementation [24] is considered as a short range transit alternative. In this study, a period of two or less than two years is designated for this short time frame. With the time and budget constraints, alternatives under consideration involve mostly buses. The provision of bus service is many times less expensive than the rail system. Capital expenditures for buses are primarily limited to the purchases of equipments and the construction of garages and maintenance facilities.

Studies (39, 41) have indicated that, in the next five to ten years, buses will be the predominant means of transportation regardless of the size of a city, and variations and improvements of the bus system with respect to its types of services and its basic transit elements constitute the immediate and the near future transit considerations.

It is believed that the characteristics of the size of a city are related to transportation. For the short range transit considerations, the types of improvements of the bus system of a city should depend, to a great extent, on the city size characteristics. This aspect is explored in this section after the presentation of the classification of short range alternatives according to types of transit services and common transit elements.

Before further discussion of these alternatives, there are two things which should be stressed strongly. First, budget allowance is a very important factor. No matter how efficient an alternative is in the impact evaluation, it would not be feasible if it requires more budget than it is allocated. Second, it is important to incorporate short range alternatives into the long range comprehensive regional plans in order to form a consistent and effective overall transportation system for a region.

Types of Transit Services

Transit services can be provided by two fundamentally different types of transit systems: conventional bus systems and demand responsive systems.

Conventional Bus System

A conventional bus system has local or express buses which provide fixed route and fixed schedule services. Such a system is often referred to as fixed-route-fixed-schedule transit (FFT). Conventional buses run on either mixed-traffic lanes or on exclusive lanes reserved for them alone or with other high occupancy vehicles (HOV).

Demand Responsive System

A demand responsive system provides services at levels demanded by users. This system is often referred to as demand responsive transit (DRT). Demand responsive systems have been shown to better serve areas with low density where conventional bus systems are not economically feasible or operable.

There are three types of services to which DRT can make the most contribution [50]. It can offer:

- feeder service to major transits;
- services to the elderly, handicapped and disadvantaged who have difficulties in using the FFT;
- alternative to private auto.

DRT is still in its infancy period. Many of its projects have been demonstration projects either supported by UMTA, other federal, state, or local agencies. The general public is not as familiar with it as with the FFT. It is felt that a more detailed discussion of its wide spectrum of modes may provide a better understanding of its potentials.

According to the types of service, DRT can be classified into the fixed-route-fixed schedule DRT and the door-to-door DRT.

Fixed route-fixed-schedule DRT. Service is provided upon demand, along a fixed route and/or on a fixed schedule. This mode can better serve low density urban areas.

Door-to-door DRT. Door-to-door service is provided upon demand by users. There are no fixed routes and no fixed schedules for this mode. It can best serve rural areas where density is very low [33], or special interest groups, like the elderly, the handicapped and the disadvantaged [35].

There are seven common sub-modes of door-to-door DRT, some of which have been in existence longer than others.

1. Taxi. A privately operated DRT, familiar to most people, a taxi offers door-to-door service in big cities and in little towns. Since the source of revenues from the operation comes from fares, fares charged to users of this mode of transit are higher than other types of DRT which are heavily subsidized.
2. Shared Taxi. Instead of serving one sole party at one time, the taxi is offered to other party or parties at the same time. Fares are lower than the taxi but higher than the bus. They vary according to the number of passengers in the taxi and also according to the travel time.
3. Jitneys. This is a semi-DRT consisting of passenger cars or station wagons. Jitneys travel basically one route, cruising along until being flagged down by a customer [33]. Jitneys are

not allowed in many U.S. cities because of questionable safety involved and also for political reasons, like opposition from the taxi lobby. These also are the reasons that, even though jitneys incur lower fuel cost than buses and lower user-time, they have not emerged as a leading short-range alternative [7].

4. Dial-a-bus. This is a publicly funded transit alternative, but can be contracted to private sources for operation. Various types of vehicles, from the conventional bus, to minibus, to van, are used in this mode. A user dials and asks for bus service which offers door-to-door service (or fixed-route fixed-schedule depending on whichever is available or suitable to his needs).

5. Charter Service or Subscription Bus. Both of these two modes of DRT have common collection and dispersion points. Passengers are picked up from one common, or at most a few collection points, and transferred directly to their common destination by route that the operator sees best. Fares are high unless subsidized. The primary distinction between charter service and subscription bus is the following:

   - The charter service is on a one-time basis, operating out of requests by specific interest groups, like a tourist group on a tour or a group from one area attending some specific event in another area.
   - The subscription service operates on a regular basis. It generally involves work-trips. Workers from one area, with common employers, subscribe to the service getting to and from work.

Their fares may or may not be subsidized by their employers.

6. Shuttle Service. This service is offered to commuters as feeder to major transits, like trips between hotels and airports, train or bus terminals. It can also serve to connect transits at the peripheral of a congested area.
7. Carpooling. This mode includes vanpooling and buspooling as well. Arranged among riders who live in a common general area and work for the same employer, carpooling is a transit mode whereby riders share rides in a private automobile or a company-owned van or bus.
   - In general, carpooling involves work trips.
   - There are preferential treatments for carpoolers in some places, like exclusive lane usage, preemption advantage, and toll and parking discounts.
   - Carpooling is continually being encouraged.

Common Transit Elements

From discussions above, it is seen that services offered by the FFT and DRT systems differ. However, there are six transit elements which are common to both systems. Each system is involved with a fleet of vehicles, routes, schedules, facility construction, fare structure and marketing techniques. Each of these six transit elements is discussed below.

Transit Fleet

The fleet of a transit system is the basic element which offers physical services to transit users. Fleet size, composition and physical conditions should all reflect the demand of users.

Fleet Size. The size of a transit fleet should be one which can meet the demand. The bigger the demand, the larger the fleet should be. Any excess supply will create inefficiency, and any insufficient supply will prolong waiting time and rider's discomfort from over-crowding.

Fleet Composition. The composition of a fleet should reflect the variations in demand along routes and among hours. Along a highly demanded route, larger buses should be used to accomodate the larger number of users. Conversely, along a less popular route, or at off-peak hours, a smaller bus or van should be used.

Fleet Condition. The fleet should be kept in operable condition at all times, especially when user demand is approaching fleet capacity. Often this cannot be done due to lack of an adequate budget allowance or available mechanics. However, when a decision is needed for increasing the fleet size, upgrading or rehabilitating the old vehicles may prove to be a less expensive alternative.

Routings

Routes of the FFT and the fixed-route-fixed-schedule DRT should cover areas where demand is relatively high. Except on main arterials, they should be non-duplicated. They should be so designed that minimum walking time is required of the users. Travel time, expressed as walking time, has proved to be an important factor [43] influencing the success of these two transit modes.

Improvements of routes by adding new routes along areas where transit is in great demand, by eliminating old routes where demand is low, or simply by altering the existing routes to meet the segmentational demand, are the potential short range transit alternatives in this category.

Schedules

Schedules for the FFT and the fixed-route-fixed-schedule DRT should reflect the different levels of demand. During peak-hours, shorter headways should improve the over-crowdedness, although fleet size will have to be increased and more drivers hired, resulting in higher system costs. Interrelationship among alternatives such as this will be dealt with in the final report. Waiting time is an important ingredient in improving the quality of transit service [43].

When timings of demand change due to new working hours imposed on workers or for other reasons, schedulings of transit should change accordingly. Also, unnecessary delay caused by vehicular break-downs should be avoided. Reliability of a transit mode is crucial in attracting new ridership.

Thus, in this category, improvements of the frequency of service can be obtained by changing the headways, by changing the operating hours, and by improving the reliability of operations.

Facility Construction

Transit systems can be improved by construction or alteration of various types of facilities as discussed below.

Maintenance Facilities. A strong maintenance program can improve reliability of the operation. Any light construction or alteration of a maintenance facility to carry out the maintenance program is one of the short range transit alternatives.

Signs. Adding or altering signs concerning transit and traffic is another alternative in this category. The appropriate signs placed at critical points can facilitate traffic and avoid unnecessary mistakes made by transit users.

Park-n-Ride Facilities. Park-n-ride services have emerged in many cities. Parking spaces are provided for commuters who drive a short distance, park their vehicles and catch an express bus transit or some other mode of transit for a longer distance. In considering the park-n-ride alternative, it is important to know the following:

- A park-n-ride lot can be an existing parking lot of a church, a shopping center with low attendance during weekdays, or an open area that is not presently utilized. If local funds are used, even permanent construction of lots built to specifications within one year can be considered.
- Locations and passenger amenities are important factors for the success of park-n-ride facilities [43]. Lots should be far enough from the CBD in order to make transfer worthwhile. They should be located so that backtracking by users is minimal. They should have good access to transits and highways.
- Park-n-ride lots should be large enough to accommodate demand.
- Provisions of lightings, telephone facilities and shelters are desirable.

Shelters and Benches. Providing shelters and benches not only in the park-n-ride lots but also at bus terminals or stops, adds to passenger amenities which in turn will improve the quality of service, an important factor for the success of any transit improvement.

Downtown Terminal. A downtown terminal can lessen some of the usual traffic congestion in the CBD. It also revitalizes business activities in the generally decaying downtown area. If available funding is from other than local sources, the time from planning to implementation of such a facility may exceed the two year short range period required. Thus it could not be considered as a short range alternative.

Exclusive Treatments. Exclusive treatments for high occupancy vehicles (HOV) in ramps, lanes and signal preemption are effective alternatives where applicable, to speed up traffic and to save travel time. Again, when considering the alternatives, it is important to know the following:

- It is reported [22] that this transit mode is preferred by all three segments: the drive only, the less auto dominant, and the marginal auto dominant. However, it is much more so for the last segment group, the marginal auto dominant. Given the exclusive treatments, the marginal auto dominant group would switch from private driving more readily than the other two groups.
- High occupancy vehicles, like bus, vanpool and carpool, are allowed to travel on ramps, or lanes exclusively reserved for them, or they are given the signal preemption privilege.
- Because of the short time frame required, the only reserved lanes

considered here are those which can be converted from existing lanes, with little or no construction involved.

- These exclusive lanes are either separated from other lanes by some physical barriers, like plastic inserts, or not physically separated.
- The preferential lanes can be concurrent flow or contraflow as related to the direction of the traffic on other lanes.
- On arterial streets, special bus lanes allow buses to stop without being delayed as a result of queuing.
- The signal preemption treatment allows HOVs to travel on the exclusive lanes without stopping.

Auto Restricted Zone (ARZ). ARZ is an area created in a congested portion of the city, like the CBD or a shopping district, where automobiles are prohibited or restricted from entering during a specific period of the day or all the time [43].

- In general, the focal point of ARZ is a pedestrian and transit mall where a great deal of business or cultural activities are generated.

Fare Structure

Studies [34,47] have indicated that demand for transit is slightly sensitive to fares. Kraft [47] estimated the cost and service elasticities of transit demand in the forms of fare and line-haul time to be -.09 and -.39 respectively. For an increase of 10 percent in fare, transit demand decreases by .9%, whereas, a similar increase in line-haul time results in 3.9% decrease in transit demand. The following are fare options to be considered.

Fare Discrimination for Peak and Off-Peak Periods. This measure can discourage shoppers competing for transit use at peak hours with workers. As a result, overcrowdedness can be lessened.

Altering Fare Zones. Fare zones established may change transit demand. Some cities offer free fare transit in the CBD.

Road and Parking Pricing. Road and parking pricing should be considered on congested roads or for peak-hour parking so that congestion will be reduced and more parking spaces will be available for shoppers.

Marketing Techniques

Effectively providing information on available transit alternatives is a short range consideration. Marketing can be a powerful approach. Techniques used include distribution of free printed brochures on available transits, advertisement on television, radio or newspaper, display of posters at stations or bus-stops, installation of signs on highways or roads, and contact with employers.

From the above discussion, it is clear that each of the six transit elements have several options, each of which can be identified as a short range transit alternative for FFT and/or DRT. In addition to these six sets of alternatives a separate set is represented by some of DRT's unique services, such as charter service, subscription service, carpooling and shuttle service.

Table 1 presents information from the literature review concerning places where the seven sets of transit alternatives have been attempted or are still in use. Impacts identified from each source are also listed in the table.

City Size Characteristics

Based on the previous review of literature, it is observed that the size of a city plays an influential role in determining the availability or feasibility of certain transit alternatives in that city. A transit alternative which is applicable in a large city may not be economically feasible in a small city, and what is applicable in a small city may not be applicable in a large city.

In this study, cities are classified into three size categories according to population size. The large city has population of greater than 500,000, the medium sized city has 200,000 to 500,000, while the small city has less than 200,000.

Different sizes of cities possess different population and transit characteristics. Besides some local geographic, funding, or other factors, population characteristics actually dictate transit characteristics to a great extent. The two together, then, should form a good basis for transit considerations.

Table 1. Short-Range Transit Alternatives Demonstrated and Impacts Identified - Literature Review

Short-Range Alternatives	Place	Description a/	Impacts a/, b/	Lit. Cited
I. Transit Fleet Adjustments				
Changing Size of Fleet	Xenia, OH	Xenia bought 10 minibuses and 7 pass. taxis later.	Demand was met	31
Changing Composition of Fleet	Westport, CT	Acquired a fleet with diff.vehicle sizes	No change in level of services	31
Upgrading/Rehabilitating Fleet	Westport, CT	Had an effective maintenance program together with keeping a fleet of diff. sizes.	Resulted in high degree of vehicle reliability and availability.	31
	Zenia, OH	Hired full-time maintenance mechanic.	Cut down on vehicle "down time"	31
II. Route Adjustments	San Diego, CA	Improved routing together with coordinating in scheduling for all transit and paratransit operations and accepting transfer among systems.	System performance was improved; capital cost was negligible	35
	Denver, CO	Improved routing together with improved scheduling.	Service frequency ↑ by 26%	31
	New York State	Improved routing together with improved scheduling	Annual fuel savings of 350,000 to 400,000 gallons; Ridership ↑ of 39,865	7
Adding/Subtracting Routes	Xenia, OH	Cut all fixed routes and replaced by DRT	Ridership ↓ significantly, indicating riders may be more sensitive to fares than to service	28
Altering Existing Routes	Seattle, WA	Blue Streak Bus together with implementing reversible lanes and free parking at park-n-ride service.	Travel time ↓ from 30 to 40 min.before to 15 min. now	22
III. Frequency of Service Adjustments				
Changing Headways	Denver, CO	Together with improved routing.	System performance improved	31
Changing Operating Hr.				
Improving Reliability of Operation		(See Up/Rehab. Fleet in I)		
IV. Facility Adjustments				
Adding Shelters/Benches	Minneapolis, MN	Bus-metered freeway consisting of bus ramps, park-n-ride, shelters and bus signs.	Annual savings of $219,000 in travel costs, $665,000 in reduction of accident costs, $293,000 in travel time saving.	22
Adding Park-n-Ride Service	Dade County, FL	Park-n-Ride with exclusive lanes for HOV	Ridership ↑ tremendously	15
	Vancouver, B.C.	Park-n-Ride service with free parking	Ridership ↑ phenominally	8
	Ft.Worth, Garland, San Antonio, Austin, TX	All offered Park-n-Ride services		12
	San Diego, CA	Together with improved routing	Performance of transit system improved	35

a/ Blank represents no information available from sources cited.

b/ "↑" means "increase"; "↓" means "decrease".

Table 1. Short-Range Transit Alternatives Demonstrated and Impacts Identified - Literature Review (Continued)

Short-Range Alternatives	Place	Description a/	Impacts a/, b/	Lit. Cited
Providing Exclusive Treatments For HOV				
Ramps	I-45 Mockingbird Ramp, Dallas		Evaluation not available	22
	I-35 W. Minneap, MN		Estimated annual savings of $578,000 from accident reduction travel time and cost.	22
	Harbor Freeway, L.A.		Bus leaving freeways would not be delayed in queues at ramps.	22
	Hollywood Freeway, L.A.		Cut bus delaying time	22
	N.Central Express, Dallas			40
	Gulf Freeway, Houston			40
Lanes	I-95, Dade City, FL	Reversible lanes	Alleviate the peak-period traffic. Travel time cut 8-10 min. Violation high	15
	Banfield Freeway, Portland, OR	Use shoulder areas for exclusive lanes	Substantial improvement in speed in the peak hours. Carpooling ↑ from 3 to 5%. Violation relatively small	5
	Boston, MA	Contra Flow Lane	Travel time saved by HOV is upset by ↑ travel time for other lane users due to congestion as result of priority lanes	22
	I-45, Houston, TX	Contra-Flow Lane. Part of it was open late 1979.	Too early for evaluation	31
Signal Preemption	Los Angeles, CA	In downtown sections	Portal-to-portal reduced by 5-7%; riding time reduced by 15-20%	22
	Dallas, TX	Installed a bus-locator linked to computer, adjusting traffic signal timing favoring buses		40
	Washington, D.C.	A computerized traffic signal system with provisions for bus preemption installed in downtown.		22
Providing Auto Restricted Zone	Minneapolis, MN Washington, D.C. Atlanta, GA	Nicollet Mall, Minneapolis; "F" St. Mall, Washington, D.C; Broad St. Busway, Atlanta Streets closed to vehicles, except emergency vehicle or delivery service during off-peak hrs. Space developed as walkways, grassed malls		40
V. Fare Adjustments				
Fare Structure Changes				
Providing Peak/off-Peak Fare Differentials	Trenton, N.J. Denver, CO	Offered off-peak free fare	Level of service ↑ ; Ridership ↑ .	31
	Albany, N.Y.	Offered free fare in CBD		31
	Knoxville, TN	Offered free fare in CBD	Ridership ↑ from 2,500 to 6,000/mo	31
	Seattle, WA	Offered free fare in CBD	Ridership ↑ from 4,100 to 12,250/week day	31
	Portland, OR	Offered free fare in CBD	Ridership ↑ from 950 to 8,200/week day	31
Road/Parking Pricing	Madison, WI	Surcharge imposed on vehicle entering city-operated parking lots during morning peak	Encouraged shift to transit and carpools; spaces left for shoppers' use	31
	Santa Cruz, Hermosa Beach, CA, Seattle, WA	Required special permit for parking in residential and downtown. Purchased by visitors, but free to residents	Protecting residents from not having parking spaces	31

a/ Blank represents no information available from sources cited.

b/ "↑" means "increase"; "↓" means "decrease".

Table 1. Short-Range Transit Alternatives Demonstrated and Impacts Identified - Literature Review (Continued)

Short-Range Alternatives	Place	Description a/	Impacts a/, b/	Lit. Cited
VI. Marketing Adjustments	Austin, TX, Pheoniz, AZ	Big advertising effort to sell bus passes or ticket books	Sales of tickets ↑ tremendously	31
	Minneapolis, MN, Knoxville, TN	Marketing techniques aimed at contacting employers and distributing information to employees to form carpools or vanpools		28
VII. Demand Responsive System Adj.	Westport, CT	Fixed route DRT, vehicle publicly owned privately managed	Revenue/cost = .52	28
	Irondequoit, N.Y.	Fixed route DRT, hired unionized drivers	Revenue/cost = .02	28
	Xenia, N.Y.	DRT was installed to replace FFT	Ridership ↓ significantly, resulting an ↑ in oper. cost/pass., indicating commuters were sensitive to fares	31
	Santa Clara, CA	110 of 200 buses on fixed-route, others on door-to-door	Public favorable	35
	Lafayette, IN	Fixed route DRT for high density areas		35
Altering Charter Service	Madison, WI		Reduced congestion	29
	Golden Gate, CA		Reduced congestion	29
Stimulating Carpools/Vanpools	St. Paul, MN	3-M Co., Vans owned by company.	Vanpoolers ↑	37
	Knoxville, TN	UMTA - Service and Method Demonstration project, the Knoxville Commuter Pool matches potential carpoolers	Convenience was rated as the primary reason; cost reduction as result of carpooling was only secondary.	28
	Golden Gate, CA	Service and method Demonstration project Vanpool information distributed at toll booths and buses.		28
	Norfolk, VA	SMD project; vanpools and private haulers aimed at 5 Navy bases		28
Shuttle Service	Dayton Busway, OH	Served as DRT on flexible route with line-haul in arterials to core areas	Annual savings from carpoolers = $114,750 Annual savings from auto drivers = $450,000; merchants pleased	22
	Westwood Village, L.A.	Minibus served as shuttle to theater, restaurants on Fridays and Saturdays		31
	St.Bernarh Parish, LA	DRT served as shuttle to FFT		31
Adding Subscription Service	Reston, VA	Commuters self-organized subscription	Revenue/cost breaks even	10
	Southern, CA	COM-BUS, covered 3 counties in So.CA	Small project	11

a/ Blank represents no information available from sources cited.

b/ "↑" means "increase"; "↓" means "decrease".

Literature Survey

Some of the population and transit characteristics of a city stressed in the literature as being relevant to transit are as follows:

- population size
- population density
- percent of persons 65 years or older
- percent of ethnic minority
- percent of blue collar unskilled workers
- median family income
- percent using transit for work trips

Each of these characteristics will affect in different degrees the various transit alternatives which in turn will have different user and nonuser impacts.

For example, DRT can better serve a sparsely populated city than FFT, not only in the sense of economics but also in terms of level of service as well.

If a city has a high percentage of persons 65 years or older, better routings of FFT or fixed route DRT or equipping DRT with wheelchair lifts should receive priority considerations.

When a city has a high percentage of blue collar unskilled workers, it means there exist one or more large employers. Therefore, transit alternatives that favor a common working place should be considered, such as subscription bus, charter service, carpool, park-n-ride, and exclusive lane treatment.

The higher the family income, the less is the willingness for the switch from auto to public transit. As a result, transit considerations should gear more toward accommodating auto and facilitating the flow of auto traffic.

If a city has a high percentage of people using transit for work trips, improvements of scheduling of FFT or fixed-route DRT should be made to handle the peak hour demand.

Of course, what is described above is oversimplified, but the importance of the demographic factors on transit improvements is well illustrated. In reality, it is suggested [43] that the availability of funding plays a very significant role in the determination of any transit alteration by city officials rather than the population characteristics discussed above, or other factors. However, research in exploring transit innovations or improvements is by no means to be discouraged. It is research like this, or others, which will provide information to the funding agencies who in turn make decisions on funding based on information provided.

Telephone Survey

To determine relevant short range transit alternatives by city size, a telephone survey was conducted in early 1980. Seven cities in Texas were chosen for the survey, with two in each of the large and medium city-size categories, and three in the small size. In each of the selected cities, a minimum of one city staff member and a transit management representative were interviewed regarding the projected short-run transit alterations for individual systems. As related to actions for adding, deleting or altering system components, three sets of questions were directed to the representatives interviewed. They were:

1. What constitutes a short-range transit alternative?
2. What new or changed system components are anticipated within the next two years?
3. How are these planned alternatives ranked in terms of priorities?

Results

Results of the survey indicate a short-range alternative as defined to be changes or improvements which could be undertaken within two years. This short time frame is in accordance with what is defined in literature [24] and is the basis of this study for the designation of no more than two years as the time period of "short-range".

Table 2 summarizes the transit adjustments anticipated by the surveyed cities in the next two years, with rankings of priorities given within category and overall categories by city size. It is found that top priority projects seem to be focused on the first three categories of transit adjustments: fleet adjustments, route adjustments and frequency of service adjustments. Among the three, route adjustments appear to be the top prioritized short range alternative chosen by all three city sizes. However, there are other alternatives which are more sensitive to city size. Priority treatments for HOV are favored by large cities but are not available in either the medium or small cities. On the other hand, many of the

Table 2. Prioritized Projections of Texas Transit Alternatives by Size of Urbanized Area, 1981-1982

Projections of Transit Improvements in 1981-1982	Rankings by Category and Overall Rankings of Alternatives by Size of Urbanized Area					
	Large a/		Medium b/		Small c/	
	Category Rank	Overall Rank	Category Rank	Overall Rank	Category Rank	Overall Rank
I. Transit Fleet Adjustments						
Changing Size of Fleet	1	3	1	1	1	4
Changing Composition of Fleet	3	-	2	-	2	12
Upgrading/Rehabilitating Fleet	2	2	-	-	3	-
II. Route Adjustments						
Adding/Subtracting Routes	2	5	2	3	2	2
Altering Existing Routes	1	1	1	2	1	1
III. Frequency of Service Adjustments						
Changing Headways	1		2	-	2	6
Changing Operating Hours	3		1	-	3	
Improving Reliability of Operations	2	4	3		1	3
IV. Facility Adjustments						
Constructing/Altering Maintenance Facility			4	-	2	10
Adding/Altering Signs	3		1	3	3	-
Adding Shelters/Benches	2		3	5	4	11
Providing Downtown Terminal			2	4	1	9
Adding Park-n-Ride Facilities	1	6	5	6	N.A.	N.A.
Providing HOV Priority Treatment:			N.A.	N.A.	N.A.	N.A.
Exclusive Ramps	4	7				
Exclusive Lanes						
Signal Pre-emption	5	10				
V. Fare Adjustments						
Fare Structure Changes	1		2	-	1	-
Providing Pk./off-Pk. Fare Differentials	-		N.A.	N.A.	N.A.	N.A.
Fare Zone Alterations	2		1	4	N.A.	N.A.
VI. Marketing Adjustments						
Free Printed Brochures						
TV/Radio Advertising					1	
Newspaper Advertising					2	
Posters Display at Transit Stops	3				3	
Info. Signs on Main Roads or Highways	1					
Informing Employers of Avail. Facilities	2					
VII. Demand Responsive System Adjustments						
Adding Peak Hour Services	2	8	2		3	-
Adding off-Peak Hour Services	1	7	1	-	1	5
Altering Charter Operations	4	6	3	-	2	7
Stimulating Carpools/Vanpool	5	11	4		4	8
Shuttle Service	3	9	N.A.	N.A.	N.A.	N.A.
Adding Subscription Service	4		3	-	2	-

a/ Cities with population greater than 500,000. See Table 3 for specifics.
b/ Cities with population between 200,000 and 500,000. See Table 3 for specifics.
c/ Cities with population less than 200,000. See Table 3 for specifics.

Note: A blank indicates the existence of such alternative but there is no mentioning of it from officials interviewed.

A " - " indicates there is no change anticipated in the studied period.

N.A. represents alternative not available.

demand responsive system adjustments have higher overall ratings in the small cities than in the large cities.

The different population and transit characteristics of the seven surveyed cities are shown in Table 3. Midland depends solely on van with a mixed subscription and DRT. Operations began only in the early part of 1980. Port Arthur began its transit operation in May of 1979. Also among the population characteristics, percent of minority and percent of work trips were omitted in the table because of lack of available data source.

Table 3. Population and Transit Characteristics for Texas Cities in Sample Survey

Characteristics	Small Cities a/			Medium Cities b/		Large Cities c/	
	Midland	Port Arthur g/	Wichita Falls	Corpus Christi	El Paso	Houston	San Antonio
Population Characteristics							
Population Size d/	72,239	239,373	118,153	256,197	476,630	2,106,445	981,176
Population Density e/	70	259	197	282	340	1,011	667
% of Persons 65 or older d/	9.4%	11.0%	11.4%	8.1%	7.2%	5.8%	8.0%
% of Blue Collar Workers e/	16.3%	20.5%	15.9%	17.5%	14.4%	18.8%	15.0%
Median Family Income e/	$10,444	$ 9,013	$ 7,912	$ 8,165	$ 7,790	$ 10,346	$ 8,043
Transit Characteristics f/							
Average Headways		1 hr. h/	1 hr. h/	48 min i/	30 min. h/	22 min. h/	N.A.
Number of Passengers		150,986	273,697	1,749,217	8,440,702	44,302,068	33,113,209
Revenue/Vehicle Mile		$ .25	$ .42	$ .99	$ .72	$ .83	$ .51
Revenue/Passenger		$ .19	$ .42	$ .73	$ .36	$ .30	$ .22
No. Buses in Regular Service		4	8	26	69	363	336
No. Bus Routes		4	5	22 h/	26	56 h/	76
No. Vans for Elderly and Handicapped		0	0	3	0	326	25
No. of Elderly and Handicapped Passengers		N.A.	N.A.	N.A.	720,868 h/	2,256,312 h/	N.A.

a/ Cities of less than 200,000 population
b/ Cities of 200,000 to 500,000 population
c/ Cities of greater than 500,000 population
d/ Figures shown were the projected estimates of 1979, by the Texas Department of Human Resources, of the various counties in which the different cities lie. Midland - Midland; Port Arthur - Jefferson; Wichita Falls- Wichita; Corpus Christi - Nueces; El Paso - El Paso; Houston - Harris; San Antonio - Bexar.
e/ Data Source: U.S. Department of Commerce. County and City Data Book, 1972 (A Statistical Abstract Supplement). Bureau of the Census, Washington, D.C., 1973.
f/ Data were provided by official at the State Department of Highway and Public Transportation, Austin, Tx. for 1979. No data was available for Midland since operation started in 1980.
g/ Transit characteristics data provided were for the months of May to December of 1979 since operation began in May 1979.
h/ Data were provided by transit official in the relevant cities.
i/ Figure was obtained from averaging the peak and off-peak headways of all routes, appeared in Transit Development Program, 1976-80 prepared by Wilbur Smith and Associates, 1976.

DETERMINATION OF RELEVANT IMPACTS

Any of the short range alternatives previously discussed impacts both users as well as non-users of the transit. There are impacts which are common to many of the alternatives even though the degree of impact may be different. However, there are some impacts which are unique to a particular alternative simply because of the specific characteristics borne by the alternative.

Impacts identified through literature studies are classified into three groups:

- user cost
- system cost
- the non-monetary user and non-user cost.

In this section, the three impact groups, and their relation to city size characteristics are discussed.

User Costs

User costs are direct costs incurred to users of a transit mode for the usage of private and/or public vehicles required by that transit mode. They are measured in dollars ($). Five impacts are identified under the user category. They are: travel time costs, vehicle operating costs, accident costs, fare costs, and toll and parking fees. Each of these will be discussed more fully in this section.

Travel Time Costs

Travel time represents the total time a passenger or non-hired driver needs for transit in private and/or public vehicles. It includes walking time for users to get to and from the transit, waiting time for users to wait for the transit and in-vehicle time spent by users in private and/or public transit vehicles.

The travel time saved by transit users traveling to and from work can be multiplied by the local hourly wage, yielding the user cost in dollars. However, the user cost for travel time varies with savings in travel time, trip type, and users' incomes. Some studies have estimated each passenger hour to be worth $3.00 [29,2]. Of course, this value must be updated [12,38].

Walking time can be saved by better route planning, waiting time by improved scheduling, and in-vehicle time by more reliable service and by more efficient transit alternatives which improve traffic flow and decrease congestion.

Therefore, short range transit alternatives involving route, fleet size and frequency of service adjustments, strong mainentance programs, park-n-ride service, exclusive treatments for HOV and the demand responsive system, listed in Table 1, can all impact travel time.

The degree of travel time impact is estimated in Table 4 according to the relative effectiveness of each of the relevant alternatives in reducing walking time, waiting time and congestion time.

Travel time is considered to be one of the important impacts. Studies

Table 4. A Summary Illustration of User and System Impacts of Short-Range Transit Alternatives

Impacts / Short Range Transit Alternatives	User Costs - Monetary: Travel Time	Fare	Toll/ ParkingFee	Accidents	Vehicle Op. Costs	System Costs: Transit Vehicle Op. Costs	Hiway/Road Op.& Maint.Cost	Cap. Inv. Cost	Ridership
0. "Do Nothing" [a/]	$155	$50	$25	$30	$40	$65	$80	0	8,000,000
	—Mil.Dollars at Present Values in 1978 Dollars—					—Mil.Dollars in Present Values of 1978 & Discount Rate of 10%—			
I. Transit Fleet Adjustments		—							
Increasing Size of Fleet	--		-	--	--	+	+	+++	+
Changing Composition of Fleet	—		—	—	—	?	—	+++	—
Upgrading/Rehabilitating Fleet	---		--	---	---	--	—	++	+++
II. Route Adjustments		—							
Adding Routes	-		-	—	-	+	+	+	+
Altering Existing Routes to Suit Demand	-		-	—	-	—	+	+	+
III. Frequency of Service Adjustments		—							
Decreasing Headways	---		-	—	---	+	+	+++	+++
Changing Operating Hours to Meet Demand	-		—	—	-	—	—	—	+
Improving Reliability of Operations	---		--	---	---	--	—	++	+++
IV. Facility Adjustments		—							
Constructing/altering Maint.Fac.	—		—	—	—	-	—	++++	—
Adding/altering Signs	—		—	--	-	-	—	+	—
Adding Shelters/Benches	—		—	—	—	—	—	++	+
Providing Downtown Terminal	—		---	-	-	—	—	++++	++
Adding Park-n-Ride Facility	--		--	--	--	--	—	+++	+++
Providing Exclusive Treatment-HOV:	---		--	---	---	--			+++
Exclusive Ramps							—	++++	
Exclusive Lanes							-	+++	
Signal Preemption							—	+	
Providing Auto Restricted Zones	---		--	---	---	--	-	++++	+++
V. Fare Adjustments						—			
Decreasing Fare Structure	—	-	-	-	-		—	+	+
Providing Pk./Off-Pk. Fare Diff'tls.	—	?	-	-	-		—	+	+
Altering Fare Zones	—	?	--	-	-		—	+	+
Road/Parking Pricing	-	—	?	-	-		-	+	+
VI. Marketing Adjustments	—	—	—	-	-	—	—	+	+
VII. Demand Responsive System Adjustments									
Adding Peak Hour Service	--	—	--	-	--	+	—	++	++
Adding Off-Peak Hour Service	-	—	-	—	-	+	—	+	+
Altering Charter Operation	-	+++	-	-	--	+	—	++	++
Stimulating Carpool/Vanpools	-	—	-	-	-	—	—	+	?
Providing Shuttle Service	-	++	-	-	-	+	—	++	+
Adding Subscription Service	---	+	--	---	---	+	+	+++	+++

a/ A hypothetical case for the year 1978.

Note: The numbers of "+" or "-" in each space indicate the degrees of "how much more" or "how much less" as compared to the "Do Nothing" alternative.

" — " represents no change.

" ? " indicated impact could go either direction depending on other considerations.

have shown that level of service, best measured by travel time saved, is the leading factor for inducing people to switch from private auto driving to transit use [51].

Accident Costs

The impact on accidents measures the safety of the transit alternatives. It includes fatalities and non-fatalities injuries incurred by transit users while in private vehicle.

Costs per accident are difficult to be measured in monetary terms since many different variables are involved in each accident.

The degrees of severity in injuries, the make of automobile, the type of road, the wage rate difference among regions, and others, can all affect the cost of an accident.

Methods have been developed to take into account most of these variables, yielding an average cost in monetary terms for each severity class of accident [2].

Alternatives which improve the maintenance of transit vehicles or provide more relaxed driving conditions will decrease accident rates faster than other alternatives. The upgrading of vehicle fleets, the exclusive treatments of HOV, and the subscription service are alternatives which fit this description.

Vehicle Operating Costs

Vehicle operating costs are costs incurred by transit users while in private vehicles. They include fuel and oil consumption, tire wear and other maintenance costs [2]. Here congestion cost is manifested in the fuel and oil consumption. In some cases, depreciation of the vehicle is also included in this category.

The more attractive the transit alternative is, the more readily will people switch from driving alone to transit usage and the less will they spend in operating their vehicles. Therefore, most of the fleet adjustments, frequency of service adjustments, exclusive treatments for HOV and subscription service rank high in impacting vehicle operating costs.

Fare Costs

Fare is defined as fee charge to user for the transit service. Contrary to what is believed, the impact on fare cost is not as great as the impact on travel time saved [34,47]. However, it is still an influential impact on users when they are faced with alternatives offering comparable service.

Exceptions to the above observation are the budget-conscious groups, like the elderly and the low income.

Among the short range alternatives, only the fare adjustments and the demand responsive system have impact on fare cost. When fare is decreased, a negative impact on fare results. As to alternatives providing peak/off-peak fare differentials and changing fare zone, the impact in not clear. It depends on the hour when or the zone where the user uses the transit.

Among the demand responsive system adjustments, charter operation has the highest fare, followed by shuttle service and lastly by subscription service.

Toll and Parking Fees

Toll and parking fees are fees charged for using a road, or a segment of a road, and parking facilities. Fees may be different at different hours of the day or for different types of vehicle. Lower fees may be offered at off-peak hours and for HOV.

Any alternatives which encourage people to switch from private-auto driving to transit will decrease toll/parking fees paid by users who drove before.

The alternative that offers the most effective method in heavy activity areas, like the CBD or shopping areas, to alleviate private driving, will have the most impact on toll and parking fees.

System Costs

System costs represent all costs incurred by a transit system. They include transit vehicle operating costs, transit vehicle accident costs. highway and road operating and maintenance costs, capital investment cost and ridership that a system has. All except ridership are measured in dollars.

Transit Vehicle Operating Costs

Transit vehicle operating costs are analogous to the vehicle operating costs in the previous section, except that these costs are based on the transit system vehicles and not the transit riders' vehicles. Also drivers' wages account for nearly half of the total cost in this category.

Additional usage of transit vehicles will increase operating costs, whereas good maintenance programs and less stopping as a result of less congestion will decrease operating costs. Transit improvements and impacts should reflect this relationship.

Transit Vehicle Accident Costs

Transit vehicle accident costs include costs incurred as a result of an accident involving a bus, a van or other public transit vehicles used in short range transit consideration. Improvements in technology or up-keep of these transit vehicles can decrease fatalities and accident rates. Also reduction in congestion and traffic conflict is an important factor. Alternatives which improve the maintenance of transit vehicles or provide more relaxed driving conditions for transit vehicle operators will decrease accident costs in this category.

Highway/Road Operating and Maintenance Costs

Costs in the upkeep of highways or roads used for the transit mode are included in this category.

Increasing the number of buses on a road or highway tends to tear and wear the roads faster, and results in higher highway/road operating and maintenance costs.

The exclusive treatments allowing HOV to be on roads built intentionally for them will lessen costs in this category.

Capital Investment Costs

Capital investment costs are defined as capital costs in establishing the transit alternatives.

The degrees of involvement, the amount of purchase and the extent of construction for a transit alternative determine the amount of capital investment costs required.

Any improvements requiring construction, like constructing/altering maintenance facilities and providing downtown terminals, exclusive ramps or auto restricted zones, will need much higher capital investment costs.

Ridership

Ridership represents the number of people using the transit. It is affected by the level of service that a transit mode offers and also by the fare charged. Service in the form of time saving has been shown to be the most influential factor affecting ridership. Also, the reliability of a transit mode to provide a certain level of service is found to be a contributing factor in saving riders' time, which in turn influences ridership.

Other passenger amenities contributing to the comfort, convenience or attractiveness of the users' environment, like providing shelter, upgrading buses, etc., have shown to have small but positive effect on ridership [8].

Ridership is put under system cost for the convenience of assessment officials in the cost-effectiveness analysis of transit improvements discussed later.

Nonmonetary User and Non-user Costs

There are certain nonmonetary user and non-user costs (impacts) of transit alternatives which should be considered. The nonmonetary user impacts identified are accessibility to job opportunity and passenger comforts. The nonmonetary non-user costs include impacts on land use, air and noise pollution, energy use and business activity.

Accessibility to Job Opportunity

Routings and stops of transit vehicles are the two main aspects of most transit alternatives that impact users' accessibility to jobs. If routes and stops are designed to be away from job centers, users would have to look for other alternatives to get to work, or would even have to change jobs altogether.

Any alternative that favors work trips, like subscription service, adding peak hour service, or providing reliable services will impact accessibility to job opportunities, and so will those which decrease congestion time, like the priority treatments for HOV. The park-n-ride service and the downtown terminal generate more business activities around the park-n-ride lots and the downtown, creating more jobs as a result, and making the jobs accessible.

Passenger Comforts

Passenger comfort is one of the factors affecting ridership. Travel time, degree of crowding, temperature level, etc., determine the level of passenger comfort offered by a particular transit alternative.

A congested route, reflected by longer travel time, brings aggrevation and ill temper to passengers. An overcrowded bus, resulting from poor scheduling, certainly brings discomforts to passengers.

Land Use

Evaluation of land use is a complex matter because of the many aspects which are difficult to assess [10]. Impacts on land use are affected by changes in land values, business receipts and employment levels. Any, or all three of these, can occur not only along the transit improvements, but also in the general area as well.

Land value along or around a transit route (except rapid route) may be affected because of potential business generated or eliminated as a result of accessibility. Accurate prediction of price changes is reported to be almost impossible [1]. Therefore, caution is needed when making statements concerning changes in land value as related to transit improvements.

Employment gains or losses are described as transitory [1]. Unemployment resulting from business displacements caused by a transit improvement may be offset by the labor demand for the project.

Whether the changes in land use are good or bad depend greatly on the overall plans for the whole area. Procedures involving either manual or computerized techniques have been developed for the estimation of impacts on land use [17,10]. The manual technique involves judgment of planners to assess development potentials whereas the computer programs require data of travel time, costs, etc.

Business Activity

A transportation alternative can influence business activity in an area positively or negatively. Some of the influences have been discussed in the land use impact. However there are other aspects which are important to business activity.

When land is displaced and converted to transportation use, business activity on this piece of land changes. Economic stimulus arises as a result of construction activity evolved. Also accessibility changes, and negative spillovers such as air and noise pollution, brought about by the transportation improvement, indirectly affect an area's economy.

Energy Consumption

In recent years, energy conservation is becoming a more and more critical policy concern. The federal government attempts to encourage energy conservation by providing assistance and fundings to states for the development of programs which promote the use of carpools, vanpools and public transportation. Components of energy consumption by these modes include energy required for vehicle propulsion, upkeep of stations, maintenance, vehicle manufacture and guideway construction.

Alternatives which promote carpooling or transit usage can reduce energy consumption which otherwise is required if private automobiles are used.

Although most of the energy consumption costs have been covered in the vehicle operating costs or the transit vehicle operating costs, it is felt that energy consumption is such an important issue that it should be considered as a separate impact by itself. The measurement unit for this impact category is miles per gallon (mpg).

Air Pollution

There are three major pollutants related to transportation. They are hydrocarbons (HC), carbon monoxides (CO) and nitrogen oxides (NO_x) [38]. It is believed that among all the nitrogen oxides, only nitrogen dioxides (NO_2) has adverse effects on health at ambient air concentration [51].

Measurements of these pollutants can be made experimentally by placing a specific instrument at critical points of traffic, or theoretically by calculation of emission rate from models developed.

Factors affecting emission rate are:

- type, model and year of vehicle - pollutants emitted differ quantitatively according to these variables. Also EPA rulings on pollution control vary from year to year.

- speed of vehicle - Anderson and Curry [11, 18] report emission rates of HC and CO at uniform speeds and also at stopped position. NO_x emission rates are found to begin increasing with speed at about 25 mph, and approach .01 pound per vehicle-mile at 60 mph [53]. As speed increases, emission rates of HC and CO decrease [27].
- cold or hot engine - CO and HC emit in larger quantities with cold engine than with hot engine [53].
- other pollutants - These include lead and smoke particulants. Because of the strict EPA standards, emission rates of these particulates have been declining rapidly [51].

Based on factors listed above, transit alternatives which decrease congestion and increase speed will emit less CO and HC and more NO_x.

The measurement unit for air pollutants is grams per passenger mile.

Noise Pollution

Noise arising from traffic on roads or on highways is measured in decibals (dBA) by a precision sound level meter. The physical effects of noise are measured and not the loudness. Another way of measuring noise is by estimation, using models developed.

Factors influencing noise are: traffic density, speed and type of vehicle [58]. Also the basic design of freeways and the presence or absence of sound barriers affect noise level as well [18]. Land use activities along a freeway are found to be related to the noise level [58]. Based on factors discussed above, the various transit improvements will have different degrees of impact on noise level. They can be evaluated accordingly.

User and non-user impacts of short range transit alternatives identified vary in their importance for evaluation. Among them, travel time costs and accident costs are frequently quoted as user impacts resulting from transit adjustments on a specific system (Table 1).

Like the interrelationships among some alternatives, some of the impacts actually impact one another. For example, travel time strongly impacts passenger comfort, and passenger comfort in turn influences users' vehicle operating costs. Other less prominent interrelationships also exist among impacts. Problems of this nature will be attended to more fully in the final report. It is hoped that a new way may be developed to resolve them.

In Table 4 and 5, the various short range alternatives identified earlier are evaluated for each of the user and non-user impacts against a "Do Nothing" alternative constructed hypothetically, and against each other. No efforts are given to rate the impacts among themselves although equal considerations are given to the three most interrelated ones, namely travel time costs, vehicle operating costs and passenger comfort.

Table 5. A Summary Illustration of User and Nonuser Impacts of Short Range Transit alternatives - Nonmonetary

Impacts / Short Range Transit Alternatives	User Costs - Nonmonetary		Nonuser Costs				
	Accessibility to Job Opportunities	Passenger Comforts	Land Use	Air Pollutions CO	Air Pollutions HC	Air Pollutions NO_x	Noise Pollution
0. "Do Nothing" a/	Good b/	Fair c/	Very good d/	25.0	4.0	3.0	Bad
				— gram/passenger mile—			—dBA—
I. Transit Fleet Adjustments							
Increasing Size of Fleet	+	+ e/	—	-	-	-	+
Changing Composition of Fleet	—	—	—		—		—
Upgrading/Rehabilitating Fleet	++	+ f/	+ i/	--	--	-	-
II. Route Adjustments							
Adding Routes	+	+ e/	+ j/		—		—
Altering Existing Routes to Suit Demand	+	+ e/	-		—		—
III. Frequency of Service Adjustments							
Decreasing Headways	++	+ e/	—	--	--	--	+
Changing Operating Hours to Meet Demand	+	+ e/	—		—		—
Improving Reliability of Operations	++	—	+	-	-	-	—
IV. Facility Adjustments							
Constructing/altering Maint.Fac.	—	—	—		—		—
Adding/altering Signs	—	—	—		—		—
Adding Shelters/Benches	—	++	—		—		—
Providing Downtown Terminal	+++	++	++ k/	-	-	-	++
Adding Park-n-Ride Facility	+++	++ g/	+ l/	-	-	-	+
Providing Exclusive Treatment-HOV: Exclusive Ramps, Exclusive Lanes, Signal Preemption	+++	++ g/	-	--	--	-	+
Providing Auto Restricted Zones	+++	++	++	--	--	--	++
V. Fare Adjustments							
Decreasing Fare Structure	+	- h/	—	-	-	-	—
Providing Pk./Off-Pk. Fare Diff'tls.	+	- h/	—		—		—
Altering Fare Zones	+	?	—		—		—
Road/Parking Pricing	-	+	—	-	-	-	—
VI. Marketing Adjustments	+	-	+	-	-	-	—
VII. Demand Responsive System Adjustments							
Adding Peak Hour Service	+++	—	—	-	-	-	—
Adding Off-Peak Hour Service	+	—	—	-	-	-	—
Altering Charter Operation	—	—	—	-	-	-	+
Stimulating Carpool/Vanpools	++	++ g/	—	-	-	-	—
Providing Shuttle Service	+++	+	+	-	-	-	+
Adding Subscription Service	+++	+++	—	-	-	-	+

a/ A hypothetical case for the year 1978.
b/ Most major business centers are served. However several big plants on outer perimeter of city are not served by transit.
c/ Conditions are bad at peak hours: No air-conditioning, traffic congested.
d/ Business activities are established along transit routes. As a result, land values and employment opportunities are high.
e/ Less crowded at peak hour.
f/ Air-conditioning installed.
g/ More relaxed.
h/ More crowded.
i/ Business has increased because of ↑ in ridership.
j/ New business appears on new routes.
k/ More business at CBD.
l/ Business activities appear around parking lots.

Note: The numbers of "+" or "-" in each space indicate the degrees of "how much more" or "how much less" as compared to the "Do Nothing" alternative.

" — " represents no change.

" ? " indicated impact could go either direction depending on other considerations.

Relation of Impacts to City Characteristics

In consideration of the relationship of user and non-user impacts to city characteristics, it seems that population characteristics have more direct relevancy to the problem since transit characteristics are derived from the population characteristics discussed previously. Among the population characteristics, population and population density appear to be most directly related to transportation impacts. These two characteristics very well define the size of a city. Greater emphasis, therefore , is placed on the city size effects on the different impacts and brief discussions on the other population characteristics are presented.

Population and Population Density

Population density and population have been reported to be the most important city characteristics which explain transit demand. Chadder and Mulinazzi [15] developed a transit model for small cities of population 50,000. Population of 65 years old and over together with fare and median income were the independent variables. For medium sized cities of 100,000 to 500,000 population, Guseman, et al. [25] built a model which has population, headways and number of buses as the independent variables. It is reported that the transit system in a small city must be flexible and capable of handling expanded ridership because it cannot afford to spend much effort in demand forecasting [15] like larger cities.

Most of the impacts studied earlier can be influenced by the size of a city. Data available give support to the generalization that the larger the city, the greater the impacts. A thorough analysis identified the major underlying factor for this observation as congestion. In general, larger cities are more congested than smaller cities. Congestion caused by too many vehicles on too few roads, streets or highways occurs frequently in big cities, especially during peak hours. It slows traffic down to where motors remain idling, casuing an increase in stop-go movements for vehicles. The combined effects are higher fuel consumption [49], longer travel time, and greater air and noise pollution. Hence, it is seen that user and non-user impacts are directly related to city size. The relationship between city size and each of the impacts is discussed below.

Travel Time. The cost of travel time is a function of user's values of walking, waiting, transferring and in-vehicle time. In congested traffic, more time is required to travel the same distance than in less congested traffic, resulting in higher travel time cost. Since big cities tend to be more congested, it can be concluded that the user impact of travel time is sensitive to city size.

Vehicle Operating Costs. Among the components of vehicle operating costs, fuel and oil consumption is affected by congestion. Vehicles in idling position, as a result of traffic congestion, has lower fuel and oil efficiency. Also, as traffic congestion increases, the number of speed changes increases, requiring more fuel and oil consumption. Therefore, user impact of vehicle operating costs is city size related.

Accidents. Accident rates increase with traffic volume. Large cities have high traffic volumes, resulting in high accident rates. However, one study [2] has suggested that reduced speed caused by congestion in fact lowers accident rates, partially offsetting the higher rates resulting from increased traffic congestion. Higher accident insurance rates are being charged in most of the big cities, evidencing greater accident rates. There, it is apparent that the user impact of accidents varies with the size of a city.

Fare, Toll and Parking Fee. The category of user impacts of fare, toll and parking fees is found to be related to city size. Fares are generally higher in big cities, and the contributing factor is higher operating costs. Tolls are imposed for the purposes of generating revenues and lowering congestion on the tolled section. Rarely are tolls imposed in small cities. Because of high land costs, parking fees are often more expensive in the larger cities.

Transit Vehicle Operating Costs. Studies have shown that transit operating costs are higher for larger cities. Womack and Burke [57] defined transit operating costs as the summation of transit vehicle costs as defined in this text, plus administrative costs, vehicle maintenance costs and insurance costs. The last three items together contribute only a fourth of the total (20-25%). In 1977, they reported transit operating costs were $1.04, $.79 and $.72 (all in 1972 dollars), respectively, for large, medium and small systems under the same city size classification of this report. In this cost category, the single major cost item which is common to all three systems is the labor cost, as expressed in salaries, wages and fringe benefits. Labor costs per passenger are found to be $.12, $.066 and $.022 for large, medium and small systems, respectively, for the same year period. Because of the sensitivity of labor costs to city size, transit vehicle operating costs are different according to the size of a city.

Transit Accidents. The user impact of accidents has been found sensitive to city size as discussed above, the same conclusion can be drawn for the system impact of transit accidents since the underlying relationship between traffic volume and accident rates existing in the user impact category holds true for the transit system.

Highway/Road Operating and Maintenance Costs. Under the highway/road operating and maintenance costs category, the major cost item is, again, labor costs which have been found to be city size related. Hence, this cost category is also influenced by city size.

Capital Investment Costs. Major portions of capital investment costs for transportation needs in most cities, large or small, come from federal and state findings. The distribution of these fundings depends not so much on the size of a city, but more so on the specific needs of the city. Service and demonstration projects by UMTA, such as fare and routing improvements study in the small city of Xenia, Ohio [30] and the project of installing a high occupancy lane in the big city Boston [42], were undertaken with little regards to city size. The impact of capital investment costs, therefore, is indifferent to city size.

Ridership. Clearly ridership is city size related. The larger the city, the greater the number of passengers served by available transit modes in that city. The larger population automatically includes more workers, means more work trips, and results in larger ridership.

Non-monetary User Costs. Neither of the non-monetary user costs studied here seems to be city size related. How accessible to job opportunities a transit alternative is, or how comfortable the passengers are in a transit, depends on many variables, but city size seems not to be one of them.

Non-User Costs. Among non-user costs, land use and business activities do not appear to be affected by the size of a city, whereas impacts of air and noise pollutions and energy consumption do. In a big city, the basic fact that more vehicles are on the roads creates higher amounts of air and noise pollution and consumes greater amounts of energy. Besides, the by-product of high volume of vehicles on the roads is congestion, which has been shown to have similar effects.

Percentage of Population 65 or older

People who are 65 or older are mostly retired people. Work-trips made by this group are trimmed considerably from those made by the same people before they retire. Their non-work trips are generally made by way of transit. In fact, this group is found to be transit captives [47]. Auto usage for this group declines, leaving less automobiles on the roads. As a result, impacts of fuel consumption, accident and pollutions are affected while other impacts are left untouched. Each of the affected impacts is discussed in this section.

Fuel Consumption. Because of the less automobile usage but higher transit dependency by the group of 65 and over, any impact this is related to auto fuel consumption and pollutions will be lessened while impacts concerning transit operations will be increased as the percentage of this group becomes higher in a city. User impacts of vehicle operating costs and the non-user impacts of air and noise pollutions belong to the preceding impact category while impacts of system operating costs, such as transit vehicle operating costs and highway/roads O&M costs, belong to the latter category mentioned. It is believed that the decrease in auto fuel consumption by this group outweights the increase of transit fuel consumption resulting from the increased transit usage by the same group giving a net negative effect on the non-user impact of fuel consumption.

Accidents. People of 65 and over tend to have a higher accident rate, either because of slower reflexes or failing eyesights. A positive effect of transit accident by this group results because of the increase in ridership by this group and the greater number of transit vehicle-miles undertaken by the transit system. The greater the percentage of people 65 and over a city has, the higher the accident rates seem to result.

Ridership. As discussed above, the 65 and over age group is transit captives. Most of them depend on transit as their only means of transportation. Hence, the higher the percentage of this group in a city, the greater the ridership of transit.

Percentage of Blue Collar Workers

Blue collar workers are associated with work-trips. For a city having a high percentage of blue collar workers who tend to depend more on their automobiles than on transit [47], user impact of vehicle operating costs are higher, and non-user impacts of fuel consumption, and air and noise pollution levels climb. All other impacts are believed to be unrelated to this city characteristic.

Median Income

Studies have shown that people with higher median income tend to be less willing to switch from auto-driving to transit-taking [47]. Therefore, cities having higher median household incomes would experience similar user and non-user impacts of transit as those with a higher percentage of blue collar workers.

There is one non-user impact, which is uniquely and postively related to median income, and that is the impact of land use. If a city has a higher median income, its land values, a component of the impact of land use, are higher. As to the other impacts, this city characteristic has little influence on them.

Relationships of each of the various user and non-user impacts with each of the characteristics of cities have been identified. It is found that some city characteristics bear no relation to some of the impacts. For those which are related to impacts, the magnitudes of the relationships are difficult to establish. For example, both population and population density impact transit travel time. The more people a city has, or the more dense a city is, the greater travel time cost users have to pay. To compare the effects of these two characteristics on travel time seems to be rather meaningless. Each relationship is looked at independently.

Table 6 summarizes the respective relationships of user and non-user impacts with city characteristics just described. A positive or a negative relationship is represented by "+" or "-" respectively. "N.R." represents nonrelated. A double-negative, "--", is assigned to the relationship of the percentage of population 65 and over with user impact of vehicle operating costs to balance out the positive influence of this characteristic on transit vehicle operating costs, leaving a net negative relation with fuel consumption in the non-user impact category.

Table 6 Relationship of Impacts with City Characteristics

Impacts	City Characteristics				
	Population	Pop. Density	% of 65+	% Blue Collar	Median Income
User Costs - Monetary					
Travel Time	+	+	N.R.	N.R.	N.R.
Accident	+	+	+	N.R.	N.R.
Vehicle Operating Cost	+	+	- -	+	+
Fare	+	+	N.R.	N.R.	N.R.
Toll/Parking	+	+	N.R.	N.R.	N.R.
System Costs					
Transit Veh. Operating Cost	+	+	+	N.R.	N.R.
Transit Accidents	+	+	+	N.R.	N.R.
Highway/Road O&M Costs	+	+	+	N.R.	N.R.
Capital Investment Costs	N.R.	N.R.	N.R.	N.R.	N.R.
Ridership	+	+	+	N.R.	N.R.
User Costs - Non-Monetary					
Access. to Job Opportunity	N.R.	N.R.	N.R.	N.R.	N.R.
Passenger Comforts	N.R.	N.R.	N.R.	N.R.	N.R.
Non-User Costs					
Land Use	N.R.	N.R.	N.R.	N.R.	+
Business Activity	N.R.	N.R.	N.R.	N.R.	N.R.
Fuel Consumption	+	+	-	+	+
Air Pollution	+	+	-	+	+
Noise Pollution	+	+	-	+	+

Note: "+" represents a positive relationship.
"-" represents a negative relationship.
N.R. stands for "not related"

ALTERNATIVE ANALYTICAL TECHNIQUES FOR IMPACT EVALUATION

Efforts have been continually made over the years by analysts for the development of an effective analytical technique for transit impact evaluation. The three widely used approaches are: (1) the economic efficiency approach, (2) the cost effective approach, and (3) the scoring method. Each of these is discussed in this section together with the advantages and disadvantages of each presented.

Economic Efficiency Analysis

The economic efficiency analysis is often termed "investment appraisal methods". An improvement is appraised in the similar manner of an investment. The analysis seeks to satisfy the most general and universal criterion of maximizing user's net benefits for selecting the optimal alternative. In the process, explicit trade-offs between monetary costs and all other important impacts are provided.

The three methods used for this analysis are essentially equivalent. They are the benefit/cost ratio, the internal rate of return and the net present value methods.

Benefit/Cost Ratio

The benefit/cost ratio method is the most commonly used of the three methods, especially by public officials [3], and easily accepted by laypersons. It focuses on aggregate costs and aggregate benefits.

Assumption. The underlying assumption in this method is that marginal income or cost is weighted equally among all people who receive the benefits or who bear the costs [44].

Several attempts have been made to take into account the distributional effects by using weights. However, none of them has been very successful because judgments are involved [52, 32, 44]. Instead, Haefele [26] suggests listing all benefits and costs, in monetary terms if possible. For impacts which cannot be measured in dollars, a description of the respective incidences and timing of these benefits and costs is appropriate. Benefits and costs needed for the analysis are as follows:

Benefits.

- savings in user costs
- savings in system operating and maintenance costs and
- other benefits measured in dollars

Costs.

- additional engineering, right-of-way and construction costs
- relocation assistance costs, and
- other costs involved with improvements.

Optimal alternative. Every alternative is compared to a "Do Nothing" alternative and also to other alternatives. The best alternative is the one with the lowest capital cost and a benefit/cost ratio of greater than 1 when compared to other low capital cost alternatives.

Evaluation. Computationally this method is more complex. However, with the advance of computer technology, this aspect is no longer a problem. The Highway Economic Evaluation Model (HEEM), developed for the Texas State Department of Highways and Transportation in 1976, is a computerized benefit/cost model [46]. Florida Department of Transportation has recently attempted to computerize the 1977 AASHTO Procedures (American Association of State Highway and Transportation Officials) to facilitate the computation of the benefit/cost analysis [3].

Internal Rate of Return

Internal rate of return is defined as the discount rate at which benefits equate with costs.

Optimal alternative. The alternative with the highest rate of return is the optimal one and should coincide with the one picked from benefit/cost ratio method. Wohl [56] warns of using the internal rate of return as the sole effective indicator for making economic choice. He argues that it can lead to incorrect or ambiguous answers because multiple solutions may result from rolling stock replacements. Bergmann [5] and others [45,55] disagree.

Evaluation. Compared to the benefit/cost ratio method, the internal rate of return method is even more complex computationally. For this fact, the method has not been popular or used widely. However, with the availability of computer technology, computation can be easily made simple.

Net Present Value

Both costs and benefits, whether formerly incurred or expected in the future, are discounted to present values. A discount rate of 10% is commonly used to convert the annualized costs and benefits to present values. Net benefits are defined as the amount of benefits which is in excess of costs.

Optimal alternative. For an alternative to be economically justified, the net benefits should have a positive value [40]. The optimal alternative is the one with the highest positive value of net benefits.

Evaluation. The net present value method is simple to use. It avoids confusion of the dollar values which vary from year to year.

Cost Effectiveness Analysis

The cost effectiveness analysis is the comparison of the benefits and the required capital costs of one action with those of another action [40]. This technique was developed because some major impact measures are difficult to be put into monetary terms. Also, some evaluation factors can be better expressed or be more meaningful in quantitative or qualitative terms than in monetary terms.

Criteria

There are two criteria for this method:

- Minimizing the amount of resources required to achieve a given level of service or to meet some specific requirements.
- Maximizing the level of service or system performance, given level of operating cost.

"Level of service" which appears in both criteria has nonmonetary units.

Optimal Alternative

The alternative which best satisfies either of the above criteria is the optimal alternative. Colorado Department of Highways has developed the Hybero Program to perform cost-effectiveness calculations [40].

Typical Cost Effectiveness Measures

Some of the typical transit cost effective measures are:

- Increase in ridership/$ of capital investment
- Increase in ridership/$ of additional operating cost
- Decrease in total operating and capital cost/transit rider
- Decrease in average transit trip time/additional dollar of total additional cost
- Increase in transit accessibility of job/$ of additional cost
- Decrease in accidents/$ of capital investment
- Decrease in air pollution emission/$ capital investment

In practice, it is desirable to prepare several cost effective measures instead of one single measure since it would be quite impossible for one single criterion to summarize the cost effectiveness of quite different alternatives [17].

Disadvantages

The use of either criteria is more conducive to satisfying the purpose of comparing alternatives than to justifying an investment. In order for decision-makers to justify a prospective investment, the level of service has to be translated in terms of monetary benefits by the estimation of users benefits described by the economic efficiency method.

Scoring Methods

To avoid difficult measurement problems, unitless scores are used in the scoring methods for all alternatives by a panel of experts.

Criterion

The common criterion to all of the methods is to maximize a summary scoring function that incorporates evaluations of individual impact measures in relative weights determined by the scoring panel.

Disadvantages

The main drawback of this method is the inclusion of subjective judgment. Without the backing of data, this process is less valid. Also, scoring methods do not indicate justification of an investment.

Summary

Each of the three approaches discussed above has its unique characteristics, possesses its advantages, but also embraces some shortcomings. Facing the urgent needs of better transit alternatives, transit officials often have to depend on one of these techniques to make their choice among many alternatives. It is felt that an improved technique should be developed to facilitate their decision-making process. The next section is devoted to outlining such a technique.

OUTLINE OF A RECOMMENDED APPROACH TO IMPACT EVALUATION

The three approaches identified in the previous section have been used for both long run and short run impact assessments. Each of them has its strong and weak points. Attempts are made in this study to develop an improved technique adapted mainly for the short run impact evaluation. Exact details of the development of this technique require further studying. Here in the interim report, only the general outline of the technique is presented.

Procedures

The recommended method is composed of a blend of the economic efficiency approach, the cost effectiveness approach and the scoring methods, with each approach used for a different category of user and non-user benefits and costs.

Economic Efficiency Approach

The net present value method in economic efficiency analysis is used for the evaluation of user impacts which can be expressed in monetary terms. This step in the analysis enables planning or other public officials to recognize the justification of the investment in a specific alternative. User impacts under this category include travel time costs, fare, tolls and parking fees, vehicle operating costs and accident costs.

The summation of all these individual user costs for an alternative represents the total monetary user costs for this specific alternative. The one which offers the smaller total monetary user costs is prefered.

The net present value method is chosen instead of the cost/benefit ratio or the internal rate of return method because it is more easily applied and understood.

Details of estimating any of the costs in this category will require further investigation. They will be presented in the final report.

Cost Effectiveness Approach

For system analysis, cost effectiveness approach is used. It provides measures for system officials to see how cost effective a specific alternative is as related to ridership. Impacts included in this category are transit vehicle operating and accident costs, highway/road operating and maintenance costs, capital investment costs and ridership. Total system costs include the four types of costs just mentioned. Ridership per total system costs should yield information of the effectiveness of each dollar the system spends. Also, an analysis of the total system costs alone should be a very critical step in early transit planning, since it will determine the feasibility of undertaking any alternative given the allocated budget.

At present, estimation of impacts in this category appears to be rather straightforward. However, further study may reveal the existence of more complex but efficient methods of estimation.

Scoring Methods

Benefits or costs which are difficult to be measured in monetary terms are more efficiently estimated by means of scoring methods. Greater weights should be placed on objectives that are of greater importance to the pertinent area. An improved scoring method taking this into consideration, will be developed after further study.

Impacts in this category include accessibility to job, passenger comforts, land use, business activities, fuel consumption, air and noise pollutions and other social and environmental concerns.

Although scoring methods involve value judgments, it is believed that they fulfil the purpose of estimating nonmonetary impacts of the short run considerations. Methods have been developed for estimating more accurately these impacts, but few short run improvements can afford the time and funding to gether the necessary data.

The summation of the individually weighted scores of each of these impacts gives the total weighted score for an alternative in this category.

Optimal Solution

An overall evaluation of the results obtained in the above three impact categories should yield the optimal alternative among all alternatives studied. However, it is important to realize that in reality, there are almost always trade-offs that can be considered. Sometimes it may be necessary to forego the best alternative in one impact category in order to obtain an overall effective alternative in all three categories.

Conclusion

Instead of customarily using one single method, the proposed recommended technique uses all three commonly known methods for the full range of impact assessments in the short range transit alternatives. One method is specifically used for evaluating one particular category of user and non-user impacts. Although value judgments still appear in the scoring method used for assessing the social and environmental impact category, it is hoped that the use of an improved scoring method will lessen the effect of some of the subjectiveness.

Also double counting may appear in several places in the evaluation. For example, travel time affects accident rate, passenger comforts and vehicle operating cost. Ridership is impacted by all the monetary and nonmonetary user costs. However, it is believed that double counting of an interaction between impacts do not bias the outcome of the evaluation process because the common underlying factors which are congestion and money, are not included as separate impacts in the evaluation. As long as each of the impact categories is treated uniformly across alternatives, it is believed that the overall outcome of choosing an appropriate alternative is unaffected.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

After a long period of decline of almost twenty years, demand for mass transit has continued to rise steadily since 1973. The reasons for the rise in demand can be attributed to population growth, the continued urbanization of the cities and the increased cost and scarcity of fuel. Officials in transportation are constantly faced with making decisions on transit alternatives. Evaluation procedures developed primarily focus on long range analysis and are applicable for user costs and benefits studies. The need for developing a procedure for short range transit evaluations, including both user and non-user impact assessments, is recognized. The present study is to attempt to fill this need.

This interim report contains the findings of an extensive literature review of short range transit alternatives and their impacts. City size influences on both the alternatives and their impacts are summarized. The three commonly used evaluation methods are identified and a recommended approach for short range user and non-user impact assessments is outlined.

According to types of services offered, short range transit alternatives are classified into conventional bus transit and the demand responsive transit categories. Six transit elements which are common to both categories are identified. Variations and improvements of the six, together with unique demand responsive system adjustments, form the seven categories of short range alternatives to be considered. Under each of these categories, transit submodes are identified.

City size is found to be related to short range transit alternatives. Cities are classified into large, medium and small with populations of 500,000 and above, 200,000 to 500,000 and under 200,000 respectively. A survey on potential transit improvements expected in 1980-1981 by city size was conducted in seven Texas cities. Improvements on routings was found to be high in ranking regardless of city sizes. Each of the city size characteristics influences the various transit alternatives in different degrees.

User and non-user impacts of short range alternatives identified in the study are grouped into three categories: user costs, system costs, and nonmonetary user and non-user costs. The study of the relationship of city size characteristics to these impacts reveals that most impacts are sensitive to population size and population density. The non-monetary user impact category is believed to be unrelated to any city size characteristics.

The three commonly used methods for impact assessments identified are: economic efficiency analysis, cost-effectiveness analysis and scoring method. It is felt that these methods have served long range impact assessments rather extensively, but have limited roles in short range impact evaluations. Therefore, an improved technique is proposed in outline form in this interim report. The technique utilizes all three methods. The economic efficiency method is used for user cost assessments; the cost-effectiveness method for system cost assessments; and the scoring method for the nonmonetary user and non-user cost assessments. The finalized form of this technique will be developed fully in the final report.

The interrelationships among alternatives and double counting of impacts exist in transportation analysis. These problems will be dealt with in the final report.

Recommendations

Complex and sophisticated models have been built for estimating the various user and non-user costs. Further studies are needed for investigating the applicability of these models to the short range analysis, so that the recommended technique can be more easily implemented to perform future short range transit alternative evaluations.

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