handbook of manual analysis techniques for transit strategies

SSTP

dallas - fort worth

Technical Report Documentation Page

1. Report No. TX-09-0045-81-1	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
Transportation System Management: Handbook of Manual Analysis Techniques for Transit Strategies (Dallas-Fort Worth)

5. Report Date

6. Performing Organization Code

7. Author(s)
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8. Performing Organization Report No.

9. Performing Organization Name and Address
Alan M. Voorhees and Associates for
North Central Texas Council of Governments

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
TX-09-0045

13. Type of Report and Period Covered

12. Sponsoring Agency Name and Address
U.S. Department of Transportation
Urban Mass Transportation Administration
400 Seventh Street, S.W.
Washington, D. C. 20590

14. Sponsoring Agency Code

15. Supplementary Notes
Prepared as a part of a TSM Prototype Planning Study at NCTCOG--as a part of the UMTA TSM Prototype Study Program, Richard P. Steinmann, UPM-13, UMTA Program Manager

16. Abstract

Transportation System Management (TSM) is a philosophy about planning, designing, implentining and operating transportation system improvements in a way which attempts to make best use of exisiting resources, which addresses movement of people and goods and which attempts to manage both transportation supply and demand. When first introduced in 1975, TSM represented a major change in the direction of transportation planning. Thus UMTA initiated a program of Prototype Studies designed to demonstrate how TSM considerations could be effectively integrated into the existing planning process. Studies were undertaken in Dallas-Ft. Worth, Seattle, Portland (Oregon), Kansas City and Middlesex County (NJ).

As a part of the study conducted in Dallas-Ft. Worth, North Central Texas Council of Governments undertook to develop a set of planning manuals which could be used in the ongoing process of developing strategies to improve the operation of the existing trasnportation system. Volume Two of this set of manuals was devoted to easy-to-apply manual techniques for analyzing the effect of a variety of transit oriented operations strategies. This document reproduces that manual in order that other interested agencies may apply these methods.

17. Key Words Transportation System Management, Transit, Analysis Methods	18. Distribution Statement Available to the Public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	201	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TRANSPORTATION SYSTEM MANAGEMENT:

HANDBOOK OF MANUAL ANALYSIS

TECHNIQUES FOR TRANSIT STRATEGIES

An Analytical Approach
to the Development and Evaluation of
Transit-Related TSM Projects and Alternatives

Prepared for the

NORTH CENTRAL TEXAS COUNCIL OF GOVERNMENTS

by

ALAN M. VOORHEES & ASSOCIATES, INC.

as a part of the

UMTA TSM PLANNING PROTOTYPE STUDIES PROGRAM

sponsored by

PLANNING RESEARCH AND EVALUATION DIVISION
OFFICE OF PLANNING ASSITANCE
URBAN MASS TRANSPORTATION ADMINISTRATION
US DEPARTMENT OF TRANSPORTATION
WASHINGTON, DC 20590

reprinted:
May 1981

FORWARD

When it was introduced in 1975, Transportation System Management (TSM) represented a change in the direction of the urban transportaiton planning process. In order to demonstrate the integration of TSM considerations into the process, UMTA initiated a set of Prototype Planning Studies. These studies were conducted in Dallas-Ft. Worth, Seattle, Portland (Oregon), Kansas City and Middlesex County (New Jersey). Each study addressed this overall goal in a slightly different way.

The focus of the TSM Prototype Study conducted in Dallas-Ft. Worth by the North Central Texas Council of Government (NCTCOG) was on the development of analytical techniques for the development of TSM strategies. A three volume set of planning manuals was developed by a contractor, PRC Voorhees. These manuals laid out a comprehensive analysis process for TSM for the Dallas-Ft. Worth area. Volume Two of this set of manuals was devoted to easy-to-apply analysis methods for transit related strategies. Because it includes methods not dependent on the data and analytical resources available to NCTCOG, it has the most relevance to other agencies. We are therefore reprinting Volume Two only.

We believe that this report should provide organizations analyzing the impacts of TSM strategies with a useful tool. The methods included here should be readily applicable in areas of all sizes and with a variety of analytical capabilities. We believe that these methods should enable a much more systematic assessment of the impact of a variety of transit-oriented strategies than was possible using other approaches.

Additional copies of this report are available from the National Technical Information Service, Springfield, Virginia 22161. Please refer to UMTA-TX-09-0045-81-1 in your request.

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CHAPTER ONE: INTRODUCTION

The analytical tools for the evaluation of individual TSM actions are covered in this handbook in the next two chapters:

- IMPACT: In Chapter 2, techniques for the evaluation of the consequences of implementation of specific transit TSM actions are prescribed as a variety of analytical procedures, and their sub-routines labelled analytical methods.

- PRIORITY PROGRAMMING: Chapter 3 provides a technique for setting priorities through the calculation and display of impact characteristics and the estimation of a weighted cost-effectiveness measure for each proposed project.

Once the TSM planner has decided that analysis of impacts is needed, a large number of techniques are available for use. Some impacts will be most suitable for study using manual methodologies. Others may involve the exclusive use of computer techniques. Still other techniques will be operable either at the manual or automated level, depending on what is appropriate in each situation. For example, the analysis of a simple bus route change (say, a re-routing for a few blocks) would be undertaken using standard travel time and distance calculations. On the other hand, study of an entire bus network would likely require the use of computer programs such as UTPS.

This handbook, is designed for the analysis of the less complex TSM actions, and therefore includes only non-automated techniques. Action evaluation using computer techniques is discussed in Volume 1 and Volume 3. However, even the users of the more sophisticated methodologies will find the procedures in this handbook helpful when preparing input data such as changes in link speed that might result from the implementation of priority lanes or similar improvements.

USING THE HANDBOOK

This handbook has been written for use by engineers, planners and analysts who are sufficiently experienced in transportation planning and operations to be able to judge the reasonableness of calculated values and to modify or substitute analytical techniques when necessary. The handbook will permit transit planners to consider traffic engineering impacts of transit actions, and traffic engineers to generate transit actions. Both, of course, are encouraged to consult and coordinate frequently with their opposite number.

The first-time user of the handbook should read the entire text, scan through the analytical procedures (the yellow pages) and the analytical methods (the blue pages), become familiar with the indexing for the procedures, and review the appendices. Sample calculations have been included in Appendix D.

When using the handbook in the non-automated mode, the only aid needed is a desk or hand calculator with the basic functions.

Handbook Limitations

The handbook is subject to several limitations that the user should be aware of as he follows through the process steps. First, as stated before, the handbook emphasizes transit.

Second, not all TSM actions can be analyzed in an objective manner. Five of the analytical procedures cover such subjects as transit management improvements and passenger amenities. These five procedures call for a subjective estimate of impact from the analyst.

Finally, there are factors of accuracy and validity. The accuracy of data developed by following the procedures and methods in the handbook will be largely a function of the accuracy of the input data. If numerous assumptions are made, then the answers must be used with caution. If factual data is applied, the results should be more reliable. Since formulas are used in many calculations, answers will be just as accurate as are the input data to the formula.

In some cases, however, the analyst will be limited by the number of significant figures available in his results. For example, the calculated impact of a minor transit action on the whole multi-modal system might be expressed in tens or hundreds of units. If the total system attributes are expressed in thousands of units, the transit impact can only be classed as "negligible," not as a numerical change.

Some analytical methods include simplifications of methodologies presented in detail elsewhere. One example is the use of generalized highway capacity tables in the handbook where more detailed versions can be found in the Highway Capacity Manual. References in such cases are included as Appendix E.

A program of field testing was conducted to check the steps, formulas, and curves included in the handbook. Numerous improvements resulted. However, there were several cases where a proposed analytical method could not be validated. In such cases, it was concluded that there were advantages to leaving these unverified methodologies in the handbook so that they could at least be used to suggest alternative approaches to problem-solving. Therefore, seven of the analytical procedures and seven of the analytical methods have been classified as wholly or partially experimental, and have been so-labelled.

As an aid in budgeting analysis time, it was noted during the field testing that the effort required to use the analytical procedures and methods varied from 2.0 to 14.4 man-hours per problem.

CHAPTER TWO: ANALYSIS OF TSM ACTION IMPACT

INTRODUCTION

This chapter contains procedures and methods which can be used to estimate the impacts of various TSM actions on the present performance of the transportation system. Because many actions impact both transit and the total vehicle flow, several techniques have been included for estimating the impact of transit actions on highways. Also, analysts in non-transit areas will find useful material in this chapter when contemplating the development of new transit service.

Handbook users will undoubtedly develop their own approach to impact estimation after using the overall TSM process a few times. It is likely that they will find favorities among the analytical methods in the handbook and will probably develop some new ones on their own.

Glossary

The following expressions have a particular meaning in this chapter:

- Analytical Procedure — A series of steps by which the quantification of the various impacts of an action is carried out.

- Analytical Method — A specific analytical technique or set of techniques by which a particular impact can be quantified. Various steps of an "analytical procedure" (above) will call for the application of an analytical method.

Updating

Ongoing research into the effects of transportation actions constantly advances the state-of-the-art of transportation planning. It is hoped that the planning techniques outlined in this handbook will form a permanent base upon which short-range TSM planning can be built. However, some of the methods used in the handbook are experimental, and others could change substantially over time and as experience is gained.

It is suggested that each handbook user keep marginal notes and develop inserts of new material as he finds better ways to carry out the analyses. It is also suggested that a specific agency (probably the MPO) be charged with the responsibility of collecting new methods and disseminating to the users of the handbook any necessary or desirable changes. A continuing exchange of new ideas and techniques between users and the MPO will enhance the updating effort.

PERFORMANCE MEASURES

An analytical approach to TSM planning requires that system performance be quantified in some manner so that problems and opportunities can be identified and the action impact predictions can be cast in a form suitable for before-and-after consideration. Two terms are introduced at this point:

- Performance Measure (PM) — A ratio or number of which a particular aspect of current system performance can be quantified; for example, "Passengers per Vehicle-Mile." Such a "PM" could be used to describe a route or the whole system. The impact of a TSM action could be forecasted as a change in the ratio. The monitoring and surveillance of system performance before-and-after project implementation could be in terms of the ratio before and the ratio after. Finally, system performance standards could be set in performance measure format so that actual performance could be compared to a desired level.

- Performance Measure Factor — A whole number which forms a component part of those performance measures that are expressed as ratios or percentages, or which is equivalent to a PM when that measure is already in whole-number form. In the example above, "Passengers" and "Vehicle-miles" are the factors of the performance measure.

The number and type of performance measures chosen for use can vary depending upon which measures are in current use, the availability of data for calculation of the measures, the depth of the analyst's interest, and the number and variety of problems expected. The selection of PM's may well change through time as the level of inquiry becomes more sophisticated, or as new or different data become available, or as priorities change.

For diagnostic purposes, the assessment of a transit system's operations may require that a relatively large number of performance measures be utilized. The number of items appearing on a typical transit operating cost statement is an example of this. On the other hand, the diagnosis of the regional multi-modal transportation system might call for only a few key items at the sub-area level. For example, system performance might be described only in terms of vehicle-miles or vehicle-hours of travel.

Choosing performance measures can be done in several different ways. On one hand, performance measures could be chosen on the basis of present practices or personal knowledge of the situation. From a contrasting standpoint, each performance measure on the list could be explicity connected to particular goals and objectives that are valid for the area which the analyst is studying. This approach will help ensure that impact analysis is directed towards relevant issues, assuming that the goals and objectives for an area truly represent community aspirations[1].

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[1] See the discussion of supply-demand equilibrium in Volume 1 for background on relating TSM actions to objectives and priorities.

It is the performance measures (actually performance measure factors) that are used as the basis for impact estimation. The analytical procedures and methods have been designed to predict changes in a variety of performance measure factors as actions are implemented. Also, the priority ranking of projects (discussed in Chapter three) is based upon the before-and-after values of PM's.

Appendix C contains additional comments about performance measures.

Worksheets

Figure 2-1 is an example of a worksheet that the analyst might find helpful in organizing his calculations. The worksheet is designed to include the list of PM factors, the "before" value of each factor used, the estimated change in each factor (from the analytical procedures), and the predicted final value.

PRELIMINARY DESIGN AND COST ESTIMATE

A preliminary design and an estimate of cost must be prepared for each of the actions to be carried through the process. The preliminary design must describe all the characteristics of the transportation system which are to be altered by the project such as route changes, frequency, speed, and so forth.

A design may remain valid throughout the evaluation process. Often, however, impact calculation or program evaluation will require changes in the design. If so, the action must be recycled.

It is important that the action be described explicitly. For example, if a proposed TSM project calls for an increase of bus frequency and an extension of service hours, both impacts must be evaluated.

Cost estimates will generally be limited to the cost of installing the project. Since TSM is basically a low-capital cost program, these installation costs should not be large. They would typically include such things as the cost of signal modification, lane markings, sign installation, shelter construction, vehicle modification, parking lot construction, feasibility studies, data processing equipment, garage improvements, vehicle purchase, minor street widening, channelization, and similar items. Transit operating costs would generally not be included. However, there may be special operating costs that should be identified, such as the daily cost of deploying and picking up cones used to mark reversible lanes, or similar costs not usually accounted for in transit or auto operating costs.

FIGURE 2-1. ACTION IMPACT WORKSHEET

Problem Number:	Analytical Procedure:
Action:	

Performance Measure Factor	Level of Impact	Initial Value	Estimated Change	Revised Value

The process of preparing preliminary designs for many of the TSM actions is straightforward and follows steps that should be familiar to experienced engineers and planners. No particular difficulty should be encountered in specifying a fare change, laying out new routes, selecting bus frequencies, describing routine signal and street improvements, and planning organizational and administrative changes. Standard methods exist for those sorts of actions. However, there may be many TSM actions that go beyond normal experience of the analyst or are relatively new concepts. To assist in defining some of the more specialized actions, Appendix A has been prepared. In Appendix A, design notes, rules-of-thumb, and guidelines have been collected. References are included to sources of design information.

SELECTION OF ANALYTICAL PROCEDURES

An analytical procedure is a set of instructions by which the impacts of an action can be quantified in an organized manner. A procedure may contain simple formulas or may refer to analytical methods, which can be thought of as sub-routines called up by the procedure.

The following process is used to select procedures:

a. Match the action described in the worksheet (Figure 2-1) to an action listed in the Index of Analytical Procedures (Figure 2-2).

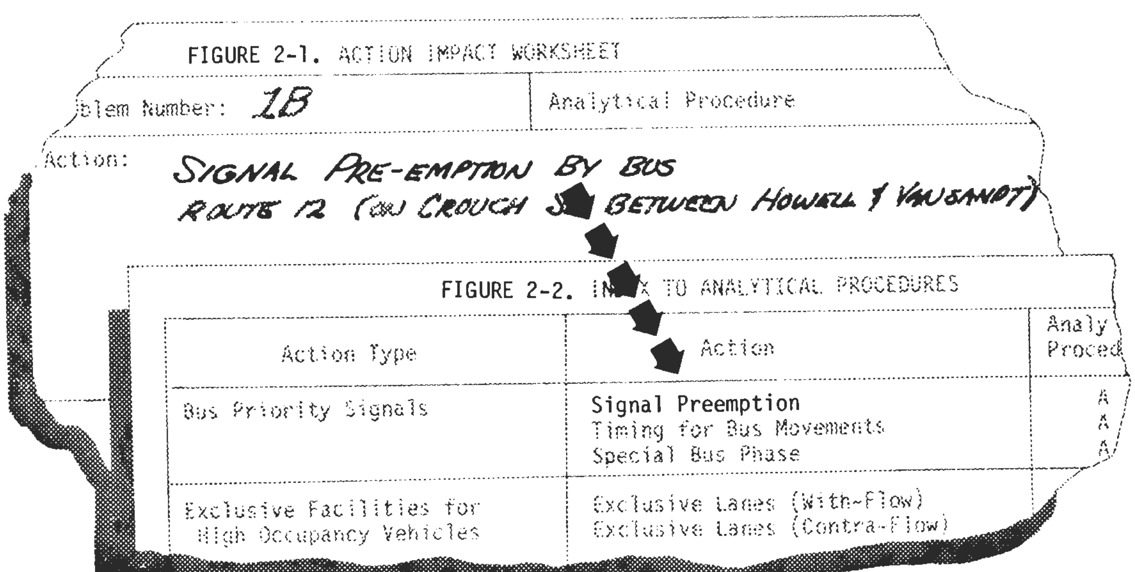


FIGURE 2-2. INDEX TO ANALYTICAL PROCEDURES

Action Type	Action	Analytical Procedure
Bus Priority Signals	Signal Preemption Timing for Bus Movements Special Bus Phase	A A A
Exclusive Facilities for High Occupancy Vehicles (HOV)	Exclusive Lanes (With-Flow) Exclusive Lanes (Contra-Flow) Exclusive Ramp Lane Metering By-Pass	A A A A
Improved Bus Stop Operations	Relocation Lengthening Bus Bays Pavement Strengthening Parking & Stopping Restrictions Off-Street Stations Freeway Stop Development	A A A A A A D
Bus Stop Amenities	Bus Stop Signs Benches Shelter Light Heat Phone Vending Services Information Display	I I I I I I I I
Changes in Fare Structure	General Reduction General Increase Peak-Base Differentials Commuter Discounts Special Fares (Elderly, etc.) Reduced Cost Transfers	B B B B B B
Increase Loading Efficiency	Wider Doors Multiple Door Loading Conductor Fare Collection "No-Barrier" Collection In-Station Collection Passes Tokens Minimize Zones	A A A A A A A A

FIGURE 2-2. INDEX TO ANALYTICAL PROCEDURES (Continued)

Action Type	Action	Analytical Procedure
Route Modifications	Change Path	D
	Extend Existing Route	D
	Shorten Existing Route	D
	Interline	G
	Turnbacks	C
	Line Haul-Feeder	C
	New Route	D
Schedule Modifications	Trippers	C
	Increase Frequency	C
	Decrease Frequency	C
	Change Arrival Times	C
	Change Recovery Times	C
Service Modifications	Increase Service Hours	E
	Reduce Service Hours	E
	Reduce Loading Standard	C
	Set/Change Policy Headways	C
Fleet Modifications	Disposal of Surplus Vehicles	J
	Replace Older Vehicles	K
	Use Various Bus Sizes	L
	Standardize Vehicle Types	J
	Modify Seating	L
	Kneeling Buses	M
	Air Conditioning	I
Inter-Modal Integration	Park-Ride	F
	Fringe Parking With Shuttle	F
	Common Routes & Schedules	N
	Transfer Facilities	N
	Common Stations	N
	Reduced Cost Transfers	O
Marketing Improvements	Information Booths	I
	Media Campaigns	I
	Info on Buses	I
	Phone Info Center	I
	Destination Signing	I
	Market Analysis	I
	Travel Counseling	I
Programming Improvements	Automated Run-Cutting	J
	Improved Data Handling	J
	Automated Data Handling	J

FIGURE 2-2. INDEX TO ANALYTICAL PROCEDURES (Continued)

Action Type	Action	Analytical Procedure
Management Improvements	Delegate Authority	J
	Assign Responsibilities	J
	Establish Mgmt. Objectives	J
	Improve Reporting	J
	Improve Budgeting	J
	Improve Accounting	J
	Personnel Relations	J
	Internal Communications	J
	Short-Range Planning	J
	Improved Purchasing	J
	Improved Cash Handling	J
	In-House Energy Conservation	J
Supervision of Operations	Automatic Veh. Detection	K
	Roving Supervisors	K
	Checkers	K
	Radios	K
	Digital Communications	K
Maintenance Improvements	Improved Records	J
	Programmed Maintenance	J
	Programmed Inspection	J
	Washing Facilities	J
	Cleaning Facilities	J
	Improved Garages	J
	Improved Shops	J
	Parts Inventory	J
Engine Modifications	Pollution Control	P
	Energy Conservation	P
	Noise Control	P
Security Improvements	Silent Alarms	J
	Phones at Stops	J
	Surveillance	J
	Lighting	J
	Exact Change Policy	J
	Strong Boxes	J
Safety Improvements	Training	Q
	Rails and Stanchions	Q
	Boarding Area & Door Improvements	Q
	Vehicle Lighting	Q
	Seat Belts & Modifications	Q
	Standee Restrictions	Q
	In-Vehicle Hazard Removal	Q
	Personnel Safety Measures	J

FIGURE 2-2. INDEX TO ANALYTICAL PROCEDURES (Continued)

Action Type	Action	Analytical Procedure
Special Transit Services	Shuttle Service in High Activity Centers (HAC) Subscription Service Express Service Elderly & Handicapped	R D A M
Common Carrier (CC) Para-Transit	Substitute D-R for Fixed Route New Demand-Responsive Bus Bus-Pool Matching Para-Transit Info (CC)	H H S S
Modify Demand	Staggered Hours Short Work Week Flex-Time Extended Hours (Shopping)	T T T T

b. In Figure 2-2, read across the row corresponding to the action being investigated to the column marked "Analytical Procedure." The letter there identifies the applicable procedure.

FIGURE 2-2. INDEX TO ANALYTICAL PROCEDURES

Action Type	Action	Analytical Procedure
Priority Signals	**Signal Preemption**	A
	Timing for Bus Movements	A
	Special Bus Phase	A
Exclusive Facilities for High Occupancy Vehicles (HOV)	Exclusive Lanes (With-Flow)	A
	Exclusive Lanes (Contra-Flow)	A
	Exclusive Ramp Lane	A
	Metering By-Pass	A
Bus Facilities	Exclusive Lane (With-Flow)	A

IMPACT CALCULATION

To calculate impact, the following process is followed:

a. Turn to the table of contents at the beginning of the analytical procedures section. A page-edge index has been provided to help locate the chosen procedure. After turning to the first page of the procedure, it would be convenient to make a copy of the whole procedure. Although a copy is not required, it will reduce the need to flip around between the procedure and any methods called by that procedure. The margin of the copy can also serve as a scratch-sheet for the simpler calculations and notes.

b. Follow through the steps of the procedure, using scratch sheets to maintain a record of all calculations. Since it may be necessary to refer back to these calculations at a later date, they should be clear and comprehensive. All assumptions should be clearly marked and described.

c. If a step in the procedure calls for the use of an analytical method, turn to the front of the methods section, which follows right after the analytical procedures. The table of contents at the front is indexed along the margin to aid in locating the desired method. When using a method, be sure to document all calculations on the scratch-sheets for later reference.

Not all of the steps in each analytical procedure need be followed. The steps listed have been included to provide for a calculation related to each possible performance measure. Therefore, only the steps for the performance measures actually chosen need to be executed (unless there is a particular impact not covered by a selected performance measure that the analyst wishes to investigate). Also, it will be helpful to involve others, such as experienced co-workers, in the analysis. Discussions of actions and which impacts will be significant is very useful to arrive at realistic answers. The analyst may want to call upon outside specialists for certain types of problems.

Further, it will be useful to pass through the analysis steps twice: the first time perhaps in a discussion with co-workers, making preliminary calculations; and the second time to make numerical checks and review assumptions.

In some cases, it might be necessary to calculate imaginary values. For example, the number of vehicles actually assigned to a bus route might be much larger than theoretical calculations would show due to the use of one or two trips by buses from other routes. In such a case, the theoretical number of vehicles might be calculated, then used to estimate another factor (such as cost), and then discarded in favor of the actual number assigned. Also, when there is a serious doubt about any input factor, a variety of values for that factor should be assumed and the sensitivity of results tested. Then, even if the final answer cannot be completely trusted, at least a range of possible results will be established.

A good practice when making impact estimates is to compare theoretical results to similar situations from actual operations. For example, when O-D data is not available, calculations of park-ride patronage can still be completed, but they should be compared to an actual park-ride operation elsewhere if at all possible.

ASSESS THE REASONABLENESS OF RESULTS

When calculations are furnished, the analyst should pause for a moment, look at his work, and ask himself "Does it make any sense?" When working dilligently on analysis steps that require many decisions and lots of calculations, it is easy for the analyst to get too close to the subject so that the reasonableness of results and other aspects of evaluation are not apparent. It is useful at such a time to have an independent review of the estimates by someone who has not been directly involved. Such independent review can quickly spot results that are out-of-line. At the very least, the analyst should clear his mind of details and look at the predicted impacts in relationship to present performance, estimates from other sources, and the relationship among action impacts. It is always appropriate to apply judgment to shade values up or down, although that step should be carefully recorded along with the other calculations.

Table of Contents
Analytical Procedures

- SIGNAL PREEMPTION BY BUS
- TIMING FOR BUS MOVEMENTS
- SPECIAL BUS PHASE

1. Calculate Speed Change Using Method 1.

- EXCLUSIVE LANES FOR H.O.V. (WITH FLOW)
- EXCLUSIVE LANES FOR H.O.V. (CONTRA)

Calculate Speed Change Using Method 2.

- STOP RELOCATION
- STOP LENGTHENING
- BUS BAYS
- PAVEMENT STRENGTHENING
- PARKING AND STOPPING RESTRICTIONS
- OFF-STREET STATIONS

Calculate Speed Change Using Method 3.

- EXCLUSIVE RAMP FOR H.O.V.
- EXCLUSIVE RAMP FOR BUSES
- METERING BYPASS FOR H.O.V.
- METERING BYPASS FOR BUSES
- EXPRESS BUS SERVICE

Calculate Speed Change Using Method 4.

- KNEELING BUSES
- WIDER DOORS
- MULTIPLE DOOR LOADING
- CONDUCTOR FARE COLLECTION
- NO-BARRIER FARE COLLECTION
- IN-STATION FARE COLLECTION
- PASSES
- TOKENS
- MINIMIZE ZONES

Calculate Speed Change Using Method 5.

- TRUCK CONTROLS (4 ACTIONS)
- GENERAL SIGNAL IMPROVEMENTS (7 ACTIONS)
- GENERAL STREET IMPROVEMENTS (16 ACTIONS)

Calculate Speed Change Using Method 6.

2. Compare before-and-after travel times, and evaluate the impact of the improvement on vehicle assignments, service frequency, and the schedule:

   A. Convert "before" and "after" speeds to travel time (if necessary):

   $$\text{Time in Mins.} = \frac{(\text{Distance in Miles})(60)}{(\text{Speed})}$$

   B. Hold frequency constant and check for significance of change in vehicle requirements:

   $$\text{Vehicle} = \frac{(\text{Frequency})(\text{Distance})}{(\text{Speed})}$$

   C. Hold vehicles constant and check for significance of change in frequency:

   $$\text{Frequency} = \frac{(\text{Vehicles})(\text{Speed})}{(\text{Distance})}$$

   D. Depending upon the magnitude of the changes tested above, make appropriate modifications to vehicle assignments or the service schedule.

(Continued)

3. Using the revised frequency and/or speed data, calculate the change in patronage using Method 6 or, if "before" mode split is available, Method 7.

4. Calculate new revenue:

$$\text{Fare Revenue} = (\text{Passengers})(\text{Average Fare})$$

or

$$\text{Fare Revenue} = \sum[(\text{Passengers A})(\text{Fare A}) + \text{---}$$
$$\text{---}(\text{Passengers J})(\text{Fare J})]$$

when different fares exist.

5. Check for impact on vehicle occupancy. (Refer to Method 9, if necessary):

$$\text{Max. Occupancy After} = \frac{(\text{Max. Occupancy Before})(\text{Passengers After})}{(\text{Passengers Before})}$$

6. Calculate passenger-miles:

$$\text{Pass-Miles} = (\text{Average Occupancy})(\text{Vehicle-Miles})$$

or

$$\text{Pass-Miles} = (\text{Number Passengers})(\text{Trip Length in Miles})$$

(Refer to Method 9).

7. Holding vehicle-miles constant, calculate new vehicle-hours:

$$\text{Vehicle-Hours} = \frac{\text{Vehicle-Miles}}{\text{Speed}}$$

Alternatively, hold vehicle-hours constant and calculate new vehicle-miles:

$$\text{Vehicle-Miles} = \frac{\text{Speed}}{\text{Vehicle-Hours}}$$

8. Calculate new number of vehicles (if necessary):

$$\text{Vehicles} = \frac{(\text{Frequency})(\text{Miles of Route})}{(\text{Speed})}$$

Note: At this point it may be necessary to round the number of vehicles to an integer and re-compute vehicle-miles and vehicle-hours.

9. Calculate new number of drivers:

$$\text{Drivers After} = \frac{(\text{Drivers Before})(\text{Vehicles After})}{(\text{Vehicles Before})}$$

(Continued)

10. Estimate new costs using Method 10. Calculate operating ratio, if desired; as $\frac{\text{Revenue}}{\text{Cost}}$

11. Estimate new fuel consumption using Method 12.

12. Calculate capacity-miles:

$$\text{Capacity-miles} = \sum[(\text{Vehicle-Miles A})(\text{Capacity A}) + \text{---}(\text{Vehicle-Miles J})(\text{Capacity J})]$$

13. Estimate air pollutant emissions using Method 13.

14. Estimate noise emissions using Method 14.

15. Estimate multi-modal impacts using Procedure X.

- GENERAL REDUCTION IN FARES
- GENERAL INCREASE
- PEAK-BASE DIFFERENTIALS
- COMMUNTER DISCOUNTS
- SPECIAL FARES
- REDUCED COST TRANSFERS

1. Assume a new average fare that would result from the candidate action. When determining average fare, give consideration to any special fares for elderly, handicapped, students or commuters.

2. Using the new fare, calculate the change in patronage using Method 6 or, if "before" mode split is available, Method 7. Cross-check results with Method 8.

3. Calculate new revenue:

   Fare Revenue = (Passengers) (Average Fare)
   or
   Fare Revenue = $\sum$[(Passengers A)(Fare A)+...(Passengers J)(Fare J)]

   Calculate revised operating ratio, if desired, as $\frac{\text{Revenue}}{\text{Cost}}$

4. Calculate new occupancy (refer to Method 9 if necessary):

   $$\text{Maximum Occupancy After} = \frac{(\text{Max. Occupancy Before})(\text{Passengers After})}{(\text{Passengers Before})}$$

5. Calculate passenger-miles:

   Pass-Miles = (Average Occupancy)(Vehicle-Miles)
   or
   Pass-Miles = (Number of Passengers)(Trip Length in Miles)
   (Refer to Method 9).

6. Estimate multi-modal impacts using Procedure X.

ANALYTICAL PROCEDURE C

- INCREASE FREQUENCY
- DECREASE FREQUENCY
- POLICY HEADWAYS

Assume the new frequency that would result from the action.

- REDUCE LOADING STANDARD
- TRIPPERS
- TURNBACKS

Using the new occupancy desired from the action, calculate the new frequency:

$$\text{Frequency} = \frac{\text{Passengers}}{\text{Occupancy}}$$

- CHANGE RECOVERY TIMES

Calculate the new route trip time (the time before + or - the change in recovery time) and calculate the new frequency:

$$\text{Frequency} = \frac{(\text{Route Minutes})(\text{Vehicles})}{\text{Trip Time}}$$

Note: Also check Analytical Procedure K (Schedule Adherence).

- CHANGE ARRIVAL TIMES

Assume the new frequency that would result if only a portion of runs are altered (a reduction on one side and an increase on the other). If all runs are altered the same amount, check Analytical Procedure G (Transfers).

- LINE HAUL - FEEDER CONVERSION

The action represents a split of one route into two or more. Measure the route distance of the new components and assume the new frequency. If occupancy is specified:

$$\text{Frequency} = \frac{\text{Passengers}}{\text{Occupancy}}$$

1. Calculate new patronage:

   A. Convert frequency to headway:

   $$\text{Headway} = \frac{\text{60 minutes}}{\text{Frequency}}$$

   B. Take waiting time as one-half of headway and calculate new partonage using Method 6 or, if "Before" mode split is available, Method 7.

2. Check new occupancy:

$$\text{Max. Occupancy After} = \frac{(\text{Max. Occ. Before})(\text{Pass. After})}{(\text{Pass. Before})}$$

3. Calculate new revenue:

$$\text{Fare Revenue} = (\text{Passengers})(\text{Avg. Fare})$$

or

$$\text{Fare Revenue} = \sum[(\text{Pass A})(\text{Fare A}) + \ldots.(\text{Pass J})(\text{Fare J})]$$

4. Calculate new vehicle-miles:

$$\text{Vehicle-miles} = (\text{Route Miles})(\text{Daily Frequency})$$

(Continued)

5. Calculate new passenger-miles:

Passenger-miles = (Occupancy)(Vehicle-miles)
or
Passenger-Miles = (Passengers)(Trip Length in Miles)
(Refer to Method 9)

6. Calculate new vehicle-hours:

$$\text{Vehicle-hours} - \frac{\text{Vehicle-miles}}{\text{Speed}}$$

7. Calculate new number of vehicles:

$$\text{Vehicles} = \frac{(\text{Frequency})(\text{Route miles})}{(\text{Speed})}$$

8. Calculate new number of drivers:

$$\text{Drivers After} = \frac{(\text{Drivers Before})(\text{Vehicles After})}{(\text{Vehicles Before})}$$

9. Estimate new costs using Method 10.

   Calculate operating ratio, if desired, as $\frac{\text{Revenue}}{\text{Cost}}$

10. Calculate capacity-miles:

$$\text{Capacity-miles} = \sum[(\text{Veh-miles A})(\text{Capacity A}) + \ldots (\text{Veh-miles H})(\text{Capacity J})]$$

11. Estimate noise generation using Method 13.

12. Estimate air pollutant emissions using Method 14.

13. Estimate multi-modal impacts using Procedure X.

- CHANGE PATH OF ROUTE
- EXTEND EXISTING ROUTE
- SHORTEN EXISTING ROUTE
- NEW ROUTE

- SUBSCRIPTION SERVICE

Steps for analysis of subscription service are the same as for bus routes but usually covering peak period only, and serving specific origins and destinations.

- JITNEYS

Steps for analysis of jitney routes are the same as for bus routes but vehicle capacity is less, costs will be different, and schedules may not be applicable (in which case use average frequency).

- AUTO RESTRICTED ZONES (ARZ)
- THROUGH TRAFFIC RESTRICTIONS

Determine the route modifications required by the traffic restrictions.

1. Plot the new or revised route on a scaled map.

2. Measure the new or revised length.

3. Assume a reasonable average speed and calculate new route round-trip travel time:

$$\text{Route-Mins} = \frac{(\text{Route Miles})(60\ \text{Mins/Hr})}{(\text{Speed})}$$

4. Estimate service frequency:

   A. Use existing frequency where applicable.

   B. Assume a reasonable wait time for subscription service (up to 15 mins.) and for jitneys (1 to 5 minutes).

   C. Check new frequency for shortened or lengthened routes if number of vehicles is not to change (otherwise use existing frequency and revise vehicle total):

$$\text{Frequency} = \frac{(\text{Vehicles})(\text{Speed})}{(\text{Route Miles})}$$

5. Estimate patronage using one of the methods below (Note that there are alternative techniques for some actions):

   A. Use the existing value for passengers per vehicle-mile for shortened routes or changes in route path:

$$\text{Passengers} = (\text{Pass Per Vehicle-mile})(\text{Vehicle-miles})$$

(Continued)

Note: When one of the more sophisticated methods (below) is selected, it is a good idea to calculate the resulting passenger per vehicle-mile ratio as a check of reasonableness. In fact, it is best to use several alternative methods of patronage estimation and then select the most reasonable total.

B. Layout the new area covered (See Method 15). Estimate population and new vehicle-mileage. Estimate patronage using Method 16 when a new route or an extended route is under study.

C. If adequate trip data is available or can be estimated, calculate patronage using general Method 6 when dealing with a new route, an extended route, or subscription service.

D. Apply existing mode split (based on corridor volumes) to the new coverage area for an extended route.

E. Calculate the change in mode split using Method 7 if frequency, speed, or access time is changed and an existing mode split percentage is available.

6. Calculate occupancy:

A. For existing operations:

$$\text{Maximum Occupancy} = \frac{(\text{Max. Occ. Before})(\text{Pass. After})}{(\text{Pass. Before})}$$

B. For new routes:

$$\text{Occupancy} = \frac{\text{Passengers}}{\text{Vehicle Trips}}$$

(1) To obtain maximum occupancy, assume a loading profile for a route, for example:

Maximum Load = (2)(Average Load)

(2) Assume a 90% or 100% loading for jitneys and subscription services.

7. Calculate revenue:

Fare Revenue = (Passengers)(Average Fare)
or
Fare Revenue = $\sum$[(Pass A)(Fare A)+....+(Pass J)(Fare J)]

8. Calculate new vehicle-miles using assumed frequency from step 4:

Vehicle-Miles = (Route Miles)(Daily Frequency)

9. Calculate passenger-miles:

Pass-Miles = (Average Occupancy)(Vehicle-Miles)
or
Pass-Miles = (Passengers)(Trip Length or Miles)
(Refer to Method 9)

(Continued)

10. Calculate vehicle-hours:

$$\text{Vehicle-hours} = \frac{\text{Vehicle-Miles}}{\text{Speed}}$$

11. Calculate vehicles:

$$\text{Vehicles} = \frac{(\text{Frequency})(\text{Route Miles})}{(\text{Speed})}$$

Note: At this point it may be necessary to round-off the number of vehicles to an intesev and re-calculate vehicle-miles and vehicle-hours.

12. Calculate number of drivers:

$$\text{Drivers After} = \frac{(\text{Drivers Before})(\text{Vehicles After})}{(\text{Vehicles Before})}$$

13. Estimate costs using Method 10.

Calculate operative ratio, if desired, as $\frac{\text{Revenue}}{\text{Cost}}$

A. Cost units for jitneys (1974):

(1) $0.09 per pass.

(2) $0.17 per veh-mls.

(3) $3.15 per veh-hr.

14. Calculate capacity-miles:

$$\text{Capacity-miles} = \sum[(\text{Veh-miles A})(\text{Capacity A})+\ldots (\text{Veh-miles J})(\text{Capacity J})]$$

15. Estimate fuel consumption using Method 12.

Estimate air pollutant emissions using Method 13.

16. Estimate noise generation using Method 14.

17. Updata coverage using Method 15.

18. Update demand compatibility using method 17.

19. Calculate multi-modal impacts using Procedure X.

- INCREASE SERVICE HOURS
- DECREASE SERVICE HOURS

1. Select new service hours.

   Note: The following steps apply generally to extending service hours, although they could be used for a reduction in hours in a negative sense. However, when a shortening of the service period is contemplated, the characteristics of the service to be deleted will generally be known.

2. Estimate change in patronage using Method 18.

3. Estimate change in revenue:

   Fare Revenue = (Passengers)(Average Fare)
   or
   Fare Revenue = $\sum$[(Pass A)(Fare A+....(Pass J)(Fare J)]

4. Estimate occupancy. Assume a frequency and passenger loading profile during changed hours:

   $$\text{Occupancy} = \frac{\text{Passengers}}{\text{Number of Bus Trips}}$$

5. Calculate vehicle-miles during changed hours:

   Vehicle-miles = (Route Miles)(Daily Frequency)

6. Calculate passenger-miles:

   Passenger-miles = (Average Occupancy)(Vehicle-miles)
   or
   Passenger-miles = (Passengers)(Trip length in Miles)
   (Refer to Method 9)

7. Calculate vehicle-hours:

   $$\text{Vehicle-hours} = \frac{\text{Vehicle-miles}}{\text{Speed}}$$

8. Estimate number of vehicles required:

   $$\text{Vehicles} = \frac{\text{(Frequency)(Route Miles)}}{\text{(Speed)}}$$

   Note: It may be necessary at this point to round-off vehicles to an intesev and re-calculate vehicle-miles and vehicle-hours.

(Continued)

9. Estimate drivers required:

$$\text{Drivers After} = \frac{(\text{Drivers Before})(\text{Vehicles After})}{(\text{Vehicles Before})}$$

10. Calculate capacity-miles:

$$\text{Capacity-miles} = \sum[(\text{Veh-miles A})(\text{Capacity A}) + \ldots. (\text{Veh-miles J})(\text{Cap. J})]$$

11. Estimate costs using Method 10.

Calculate operating ratio, if desired, as $\frac{\text{Revenue}}{\text{Cost}}$

12. Estimate fuel consumption using Method 12.

13. Estimate air pollutant emissions using Method 13.

14. Estimate noise generation using Method 14.

• PARK-RIDE

Assume a logical location for the park-ride lot.

• FRINGE PARKING WITH SHUTTLE BUS

Estimate the number of daily person-trips susceptible to diversion by selecting highway and street facilities that will have reasonable access to the future fringe parking, totaling the vehicle count on these facilities and calculating total person-trips:

Total Person-trips = (Vehicles)(Occupancy)

1. Layout the park-ride market area using Method 19, and obtain O-D trips or use alternative steps. (Skip for "Fringe parking")

2. With the total person trip volume estimated, estimate the modal split using Method 6. The modal split will be based upon marginal disutility from the parking facility in to the destination. Values in the equations can be developed as follows:

   A. Ta: Calculate using walking distance in the lot and at the destination at 4 feet per second.

   B. Tw: Use half of the headway planned for the park-ride or shuttle bus service.

   C. Tr: Calculate using a reasonable speed for bus service, possibly express service from the park-ride lot, and the distance from the lot to the destination area controlled.

   D. F: Use the fare planned for the park-ride or shuttle service.

   E. At: Use the walking distance from original destination (usually CBD parking) at 4 feet per second.

   F. Ar: Calculate using a reasonable speed from the area of the park-ride or fringe lot to the original destination (usually CBD parking).

(Continued)

Note: If the park-ride or fringe lot is not on the original auto route, add auto running time between the original route and the lot to the transit running time (Tr).

G. P: Use parking cost at the original destination.

Note: If there will be a parking cost at the park-ride or fringe lot, that cost must be added to transit fare (F).

H. D: Use the highway distance via the original route and current out-of-pocket cost units.

Note: Driving cost from the original auto route to the park-ride or fringe lot must be added to transit fare (F).

3. When patronage is estimated, check vehicle occupancy using assumed frequencies of park-ride or shuttle service. Modify schedule if necessary.

4. Calculate transit vehicle-miles for the planned park-ride or shuttle service:

   Vehicle-miles = (Route Miles)(Daily Frequency)

5. Calculate revenue:

   Revenue = (Passengers)(Fare) + (Vehicles in Lot)(Parking Cost)

6. Estimate occupancy:

   $$\text{Occupancy} = \frac{\text{Passengers in Time Period A}}{\text{Buses in Time Period A}}$$

   (See step 2)

7. Calculate passenger-miles:

   Passenger-miles = (Occupancy)(Vehicle-miles)
   or
   Passenger-miles = (Passengers)(Trip Length in Miles)
   (Refer to Method 9)

8. Calculate vehicle-hours:

   $$\text{Vehicle-hours} = \frac{\text{Vehicle-miles}}{\text{Speed}}$$

9. Estimate vehicles:

   $$\text{Number Vehicles} = \frac{(\text{Frequency})(\text{Route Miles})}{(\text{Speed})}$$

   Note: At this point it may be necessary to round-off number of vehicles to an integer and recalculate vehicle-miles and vehicle-hours.

(Continued)

10. Estimate number of drivers using a system-wide factor:

    Drivers = (Vehicles)(Drivers Per Vehicle Factor)

11. Estimate costs using system-wide units from Method 10, or units from a similar service if the park-ride service is new. (Refer to Method 11).

12. Estimate fuel consumption using Method 12.

13. Calculate capacity-miles:

    $$\text{Capacity-miles} = \sum[(\text{Veh-miles A})(\text{Capacity A}) + \ldots. (\text{Veh-miles J})(\text{Capacity J})]$$

14. Estimate air pollution emissions using Method 13.

15. Estimate noise generation using Method 14.

16. Update coverage using Method 15.

17. Update demand compatibility using Method 17.

18. Estimate multi-modal impacts using Procedure X.

• INTERLINE ROUTES

1. Obtain the actual number of transfers between the routes to be interlined (or the best available estimate) and calculate a system-wide total after interlining occurs.

2. Estimate the change in patronage:

   A. Estimate or obtain the actual average wait time when transferring.

   B. Estimate or obtain the actual average wait time at the originating stops.

   C. Calculate the percent negative change in the wait time factor:

   $$\text{Change in wait time} = \frac{\text{(Transfer Wait Time)}}{\text{(Transfer Wait)+(Original Wait)}}$$

   D. Estimate the change in mode split using Method 7. Apply to mode split in the corridor where the interlined routes operate and revise patronage by the ratio of Before-and-after mode splits.

      (1) Alternatively, calculate the entire mode split function using Method 6.

   Note: Applies to both routes as a single new unit.

3. Calculate revenue:

   Fare Revenue = (Passengers)(Average fare)
   or
   Fare Revenue = $\sum$ [(Pass A)(Fare A)+....(Pass J)(Fare J)]

4. Calculate occupancy:

   $$\text{Max. Occupancy} = \frac{\text{(Max. Occ. Before)(Pass After)}}{\text{(Passengers Before)}}$$

5. Calculate passenger-miles:

   Passenger-Miles = (Occupancy)(Vehicle-Miles)
   or
   Passenger-Miles = (Passengers)(Trip Length in Miles)
   (Refer to Method 9)

(Continued)

6. Estimate new demand compatibility using Method 17.

7. Estimate multi-modal impacts using Procedure X.

- NEW DEMAND-RESPONSIVE BUS
- SUBSTITUTE DEMAND-RESPONSIVE FOR FIXED ROUTE

1. Layout the demand-responsive (D-R) service area:

   A. Equivalent to the fixed-route coverage area (unless revision is desired) when substitution occurs.

   B. Most D-R service areas have varied from 3 to 10 square miles, with 13,000 to 44,000 population. As a rule of thumb, the ratio of one vehicle per 3,000 persons can be used.

2. Assume a level of service delivery for the proposed new D-R service in terms of the number of vehicles and the seats per vehicle.

   A. Vehicle size varies from 5 seats to full-size, with an average of 18 seats.

   B. Most D-R fleets fall in the range of 1 or 2 to 20.

3. Calculate patronage and vehicle-hours using Method 21:

   Passengers = (Pass. per 1,000)(Pop. in 1,000's)
   and
   Veh-hours = (Veh-hrs per 1,000)(Pop. in 1,000's)

   Note: When a substitution of demand-responsive service for fixed-route is being investigated, check patronage, vehicle, and vehicle-hows estimates against the existing operation and shade values up or down if there is a wide divergence.

4. Calculate revenue:

   Fare Revenue = (Passengers)(Average Fare)

5. Calculate vehicle-miles:

   Vehicle-miles = (Veh-Miles per 1000)(Pop in 1,000's)(Speed)

   Note: Demand-responsive speeds are generally the same as fixed route, with a reasonable range from 7 MPH to 14 MPH. Assume a value with consideration for vehicle size, street width and configuration, and area density.

(Continued)

6. Calculate passenger-miles:

   Passenger-Miles = (Average Occupancy)(Vehicle-Miles)
   or
   Passenger-Miles = (Passengers)(Trip Length in Miles)
   (Refer to Method 9)

   Note: Trip distance in the demand responsive system ranges from 1.0 to 3.4 miles on existing systems, with an average of 2.2 miles.

7. Estimate occupancy:

   $$\text{Occupancy} = \frac{\text{Passenger-Miles}}{\text{Vehicle-Miles}}$$

   (Refer to Method 9)

8. Estimate number of drivers:

   Drivers = (Vehicles)(Drivers per Vehicle)

   Note: Select a ratio of drivers per vehicle based upon present system operations or planned operating hours for the service.

9. Estimate costs using Method 10 when system-wide cost units are available, plus 20% to 25% for costs of dispatching. When system costs are not available, base costs on an updated value per vehicle-hour. In 1974, costs averaged between $13.39 and $17.95 per vehicle hour.

10. Calculate fuel consumption using Method 12.

11. Calculate capacity-miles:

    Capacity-miles = (Vehicle-miles)(Capacity)

    Note: For demand responsive service, seated capacity would be most suitable since standees are usually rare.

12. Estimate air pollutant emissions using Method 13.

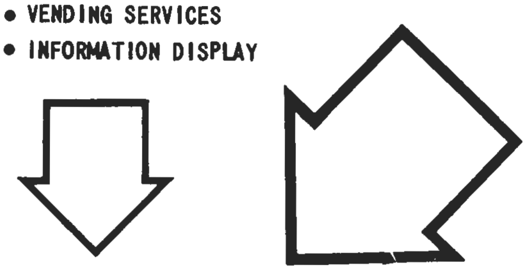
13. Estimate noise generation using Method 14.

14. Estimate multi-modal impacts using Procedure X.

- **BUS STOP SIGNS**
- **BENCHES**
- **SHELTERS**
- **LIGHT**
- **HEAT**
- **PHONE**
- **VENDING SERVICES**
- **INFORMATION DISPLAY**

- **AIR CONDITIONING**

- **INFORMATION BOOTHS**
- **MEDIA CAMPAIGNS**
- **INFO ON BUSES**
- **PHONE INFO CENTER**
- **DESTINATION SIGNING**
- **MARKET ANALYSIS**
- **TRAVEL COUNSELING**



1. These actions all create essentially non-quantifiable impacts. Further, they generally impact upon present users of transit rather than potential users. Impact can perhaps be estimated by experienced analysts in terms of patronage increases. These increases could occur in terms of patrons diverted from another mode to be regular transit users, patrons diverted who already are occasional users, or increased travel by present users. Increased patronage might fall in the following ranges:

   A. Improved bus stops: 0% to 1%

   B. Air conditioning of buses: 0% to 2%

   C. Marketing programs: 0% to 2%

   D. Field testing of Transbus, with surveys of riders, indicated that Transbus amenities might increase the number of rides per day by 18%.

   E. Programs designated as "marketing improvements" have produced increases up to 25%, but always with fare incentive programs as a part of the project.

   F. One characteristic of successful programs where patronage was sharply increased was that information about using the system was easily available and there were strong advertising promotions.

2. The larger increases would be encountered when substantial improvements are made starting from a poor or non-existant beginning point. Lesser or no increase would result when marginal improvements are made to higher levels of performance.

3. Calculate new revenue:

   Fare Revenue = (Passengers)(Average Fare)

(Continued)

4. Calculate new passenger-miles:

   Passenger-Miles = (Occupancy)(Vehicle-Miles)
   or
   Passenger-Miles = (Passengers)(Trip Length in Miles)
   (Refer to Method 9).

5. Calculate new occupancy:

$$\text{Max. Occupancy} = \frac{\text{(Max. Occ. Before)(Pass. After)}}{\text{(Passengers Before)}}$$

- DISPOSE OF OLDER VEHICLES
- STANDARDIZE BUS TYPES

- AUTOMATED RUN CUTTING
- IMPROVED DATA HANDLING
- AUTOMATED DATA HANDLING

- DELEGATE AUTHORITY
- ASSIGN RESPONSIBILITIES
- ESTABLISH OBJECTIVES
- IMPROVE REPORTING
- IMPROVE BUDGETING
- IMPROVE ACCOUNTING
- PERSONNEL RELATIONS
- INTERNAL COMMUNICATIONS
- SHORT RANGE PLANNING
- IMPROVED PURCHASING
- IMPROVED CASH HANDLING
- IN-HOUSE ENERGY CONSERVATION
- PERSONNEL SAFETY MEASURES

- IMPROVED RECORDS
- PROGRAMMED MAINTENANCE
- PROGRAMMED INSPECTION
- WASHING FACILITIES
- CLEANING FACILITIES
- IMPROVED GARAGES
- IMPROVED STOPS
- PARTS INVENTORY

- SILENT ALARMS
- PHONES AT STOPS
- SURVEILANCE
- LIGHTING
- EXACT CHANGE
- STRONG BOXES

1. These actions all create essentially non-quantifiable impacts. However, they all are directed towards cost reductions (at least in a secondary sense) and often cost reduction is the primary objective. Therefore, to estimate the impact of this group of actions, first prepare a cost breakdown using Method 20.

2. Determine independently the modification in costs, man-hours, or cost per man-hour that would likely result from the implementation of any of the actions listed above. Few guidelines exist:

   A. RUCUS (automated run-cutting) has reduced driver costs 1% to 2%, has allowed a 3% increase in service at only a 1% increase in wages, and has produced up to 5% savings in vehicles.

   B. Substitution of automated fare collection for attendents has produced up to 30% decrease in fare collection costs.

   C. Sound industrial engineering has increased maintenance productivity by 30%.

   D. A comprehensive maintenance program has increased available extra buses from 2 or 3 to 17.

   E. Gains in garage efficiency may be up to 13%.

   F. Silent alarms might reduce assaults 0% to 20%.

(Continued)

Note: The greatest gains will occur where initial performance is poor. Lesser or no gains would occur when starting conditions are better.

3. Apply the ratios or percentages of changes determined in step 2 to the cost allocations and cost units determined in Method 20. For example:

   A. Reduce the cost of depreciation to reflect disposal of surplus vehicles.

   B. Reduce the cost of maintenance (or maintenance cost per man-hour, or maintenance man-hours) to reflect the benefits from standardization of vehicles.

   C. Reduce transportation costs (or transportation costs per man-hour, or transportation man-hours) to reflect savings from automated run-cutting.

   D. Reduce administrative costs (or administrative costs per man-hour, or administrative man-hours) to reflect savings from

      (1) Improved or automated data handling

      (2) Management improvements in general

   E. Reduce light, heat, and power expense to reflect in-house energy conservation.

   F. Reduce injury and damage expense, insurance, and/or safety expenses to reflect the impacts of in-house personnel safety programs.

   G. Reduce maintenance costs (or maintenance costs per man-hour, or maintenance man-hours) to reflect savings from general maintenance management improvements.

   H. Reduce injury and claims expense, and insurance expense, to reflect benefits of increased security.

4. After appropriate modifications are made, re-total costs. Then, determine new unit costs for the estimation of cost changes resulting from system operating revisions using Method 10.

- RADIOS
- DIGITAL COMMUNICATIONS

1. Independently estimate:

   A. Improvement in on-time performance.

   B. Reduction in road calls.

- AUTOMATIC VEHICLE DETECTION
- ROVING SUPERVISORS
- CHECKERS

1. Independently estimate improvement in on-time performance.

- REPLACE OLDER VEHICLES

1. Independently estimate:

   A. Reduction in maintenance costs (or man-hours, or cost per man-hour) as produced by Method 20.

   B. Independently estimate improvement in road calls (mechanical). Use historical data for age catagories.

- USE VARIOUS BUS SIZES

1. Using present patronage on routes where the new size buses will be deployed and the new vehicle capacities, calculate:

   A. New occupancy standard or allowable load factor.

   B. New occupancy rates for routes using the different sized vehicles.

   C. Go to Procedure C.

2. If operating costs are significantly different for the various vehicle sizes, revise costs using Method 20. Alter cost units used in Method 10.

   A. Cost experience with small buses varies widely. Costs have been reported between 50% and 300% of full-sized bus cost per vehicle-mile. Generally, mini-buses are considered to have short (5 year, 100,000 miles) lives.

- MODIFY SEATING

1. Using present patronage on routes where modified buses will be ployed and the revised seat configuration (fewer seats and more room for standers, for example), calculate:

   A. New occupancy standard or allowable load factor, and go to Procedure C.

   B. New occupancy rates for routes using reconfigured vehicles, and go to Procedure C.

   C. If loading efficiency is changed, go to Procedure A.

• SPECIAL ELDERLY AND HANDICAPPED SERVICE

1. For a demand responsive type special service, use a modification of analytical Procedure H.

   A. First, calculate the number of mobility handicapped. A rate of 30 to 40 per 1,000 persons is typical.

   B. Estimate the number of daily trips. Assume a trips per person rate of between 0.5 and 1.0 daily trips per mobility-impaired person. Typically, somewhere around half of these trips can be made on regular transit service so that the trip rate for specialized service would be between 0.25 and 0.50.

   C. Cross-check results with Method 21.

2. Estimate the vehicle-hours required using a productivity of between 4 and 10 passengers per vehicle-hour. For example, productivity for elderly will fall into normal ranges (say, 6 to 17), but productivity for handicapped may be as low as 1 or 2. (See Method 21).

3. Estimate number of vehicles required:

• KNEELING BUSES

1. For routes where special equipment such as kneeling buses are used, calculate the share of patronage that is mobility-impaired. Typical percentages are 2.5% of those 5 to 64 years and 16.5% of those 65 and up. Of that total, about 12% will benefit from boarding and alighting improvements. Typical data are:

$$(0.12)(0.025)(0.85) = 0.0025$$
$$(0.12)(0.165)(0.06) = \underline{0.0011}$$
$$0.0036$$

or a 0.4% increase in patronage (and revenue). Allowing for induced trips, the actual increase might be 0% to 0.8%.

2. Go to Steps 5, 6, and 7.

$$\text{Vehicles} = \frac{(\text{Vehicle-Hours})(\text{Peak to Base Ratio})}{(\text{Service Hours})}$$

The length of the service day can vary from 10 to 16 hours and the peak-base ratio between 1.0 and 2.0 is probably suitable.

(Continued)

4. Calculate vehicle-miles:

$$\text{Vehicle-Miles} = (\text{Vehicle-Hours})(\text{Speed})$$

5. Calculate revenue:

$$\text{Fare Revenue} + (\text{Passengers})(\text{Average Fare})$$

6. Calculate passenger-miles:

$$\text{Passenger-Miles} = (\text{Passengers})(\text{Trip Lenghth in Miles})$$

Trip length will probably fall near the transit average for the urban area.

7. Estimate occupancy:

$$\text{Average Occupancy} = \frac{\text{Passenger-Miles}}{\text{Vehicle Miles}}$$

(Refer to Method 9)

8. Estimate number of drivers:

$$\text{Drivers} = (\text{Vehicle})(\text{Drivers per Vehicle})$$

9. Estimate costs using Method 10 when system-wide cost units are applicable, plus a 20% to 25% surcharge for dispatching.

10. Calculate fuel consumption using Method 12.

11. Calculate capacity-miles:

$$\text{Capacity-Miles} = (\text{Vehicle-Miles})(\text{Vehicle Capacity})$$

12. Estimate pollutant emissions using Method 13.

13. Estimate noise generation using Method 14.

- COMMON ROUTES AND SCHEDULES
- TRANFER FACILITIES
- COMMON STATIONS

1. When applicable, estimate changes in route location and utilize analytical Procedure D.

2. When applicable, estimate changes in service frequency and utilize analytical Method C.

3. When applicable, estimate changes in transfer time and utilize analytical Method G.

• REDUCED COST TRANSFERS

1. Assume or estimate the new transfer cost. Reduce the value of average overall fare using the weighted value of transfer fares, and utilize analytical Procedure B.

• NOISE CONTROL

1. Modifications such as improved mufflers, cooling fans and engine enclosures can reduce noise 10 to 15 dBA. This amounts to around a 12% to 19% reduction when using Method 14.

• POLLUTION CONTROLS

1. Emissions reductions are listed in Method 13 and amount to up to 75% in the basic emission rate for some pollutants.

• ENERGY CONSERVATION

1. Fuel consumption can be reduced up to 5% of the results when using Method 12 through engine modifications and energy conscientious maintenance.

(Continued)

2. Adjust the 100 foot noise level as follows for a barrier 10 feet from the lane edge:

Barrier Height	Adjustment
0	0
5 feet	-5 dBA
10	-10
15	-15
20	-15

3. Use the following adjustment for rows of structures acting as barriers:

Row	Adjustment
1	-4.5dBA
2	-6.0
3	-7.5
4	-9.0
5	-10.0
6+	-10.0

ANALYTICAL PROCEDURE Q

- SAFETY TRAINING
- RAILS AND STANCHIONS
- BOARDING AREA & DOOR IMPROVEMENTS
- VEHICLE LIGHTING
- SEAT BELTS, MODIFICATIONS
- STANDEE RESTRICTIONS
- IN-VEHICLE HAZARD REMOVAL

1. Independently estimate the reduction in accidents by class, for various safety improvements.

   A. 0% to 10% is a probable range for accident reduction.

   B. The Transbus design goal was a reduction of 35% in body damage costs.

   C. Training might reduce passenger accidents associated with stopping 0% to 40%.

   D. Improvement in internal design might reduce passenger accidents 0% to 7%.

2. Calculate the average cost per accident by class using historical data and trends.

3. Calculate new safety cost:

$$\text{Safety cost after} = \frac{(\text{Accidents After})(\text{Cost per Accident})}{(\text{Accidents Before})}$$

4. Revise costs using Method 20.

- SHUTTLE IN HIGH ACTIVITY CENTER

1. Estimate patronage based on type of shuttle service and/or comparable system experience. Passengers per vehicle-mile data can be used, assuming values slightly higher than national experience (3 to 5 pass. per veh-mile). Unusual conditions (other than normal CBD shuttles or free zones) will require special estimates, perhaps using computer network analysis (see Method 101).

2. Assume an appropriate fare level and calculate revenue:

   Fare Revenue = (Passengers)(Fare)

3. Assume an appropriate frequency and calculate occupancy:

   $$\text{Occupancy} = \frac{\text{Passengers in Time Period A}}{\text{Vehicles in Time Period A}}$$

   (Refer to Method 9)

4. Calculate passenger-miles:

   Passenger-miles = (Occupancy)(Vehicle-miles)

   Note: Vehicle-miles are developed as part of shuttle design:

   Vehicle-Miles = (Route Miles)(Daily Frequency)

5. Estimate vehicle-hours, assuming an appropriate speed:

   $$\text{Vehicle-hours} = \frac{\text{Vehicle-Miles}}{\text{Speed}}$$

6. Estimate the number of vehicles required:

   $$\text{Vehicles} = \frac{\text{(Frequency)(Rate Miles)}}{\text{(Speed)}}$$

7. Estimate the number of drivers required:

   Drivers = (Vehicles)(Drivers per Vehicle)

   Note: The driver ratio can equal system-wide averages or can be based on service day, shifts, and peak-base ratio.

8. Estimate fuel consumption using Method 12.

(Continued)

9. Estimate costs using Method 10 if system-wide data is available. If not, select a cost per vehicle-mile value from a similar operation (Refer to Method 11). If special-sized buses are used, see Procedure "L".

10. Estimate capacity-miles:

    Capacity-miles = (Vehicle-miles)(Capacity)

    Note: Capacity probably should equal seats plus standees.

11. Estimate air pollutant emissions using Method B.

12. Estimate noise generation using Method 14.

13. Estimate multi-modal impacts using Procedure X.

- BUS POOL MATCHING

1. Independently estimate market. Utilize Analytical Procedure D as for subscription service.

- PARA-TRANSIT INFORMATION

1. Use Analytical Procedure I for marketing improvements.

- STAGGERED HOURS
- SHORT WORK WEEK
- FLEX-TIME
- EXTEND SHOPPING HOURS

1. Staggered hours will spread peak period volumes. In Manhattan, peak 15-minute volumes were reduced 25%, with the volume displaced to earlier and later periods. A "variable work hours" scheme (or "flex-time") in Ottawa reduced the peak hour/peak period ratio by 20% to 25% at the workplace and 5% to 10% at surrounding cordons and screenlines. A study for downtown Tulsa estimated a 30% to 35% reduction in peak hours. The most appropriate figure can be estimated if the time distribution of start and quit times is known.

   Work week changes (such as the "4-40") will move the peak hour earlier or later, and will change its magnitude as well.

2. Revise bus occupancy:

   $$\text{Occupancy (to specific hours affected)} = \frac{\text{Passengers in Time Period A}}{\text{Buses in Time Period A}}$$

3. If frequencies must be revised based on occupancy, estimate the new value and follow Analytical Procedure C.

4. Estimate multi-modal impacts using Procedure X.

- TRANSIT PASSENGER CHANGES FROM ANALYTICAL PROCEDURES
  A B C D F
  G H R U V

1. Calculate the change in person-trips in autos:

   Person-Trips After =

   (Person-Trips Before)
   ± (Change in Transit Trips)

2. Assume overall vehicle occupancy and calculate vehicle volume:

   $$\text{Vehicle Volume} = \frac{\text{Persons}}{\text{Occupancy}}$$

- STREET AND HIGHWAY CAPACITY CHANGES FROM ANALYTICAL PROCEDURES
  A C D
  F U

1. Determine capacity using Method 22.

2. Determine speeds using Method 23.

   A. If speed changes affect highway route selection, evaluate diversion using Method 26.

3. Calculate vehicle-miles:

   Vehicle-Miles = (Vehicle Volume)(Link Distance)

4. Calculate out-of-pocket and total costs using Method 25.

5. Calculate passenger-miles:

   Passenger-Miles = (Vehicle-Miles)(Occupancy)
   or
   Passenger-Miles = (Occupants)(Trip Length)

   (Refer to Method 9).

(Continued)

6. Estimate fuel consumption using Method 12. Add in transit consumption if appropriate.

7. Estimate accident data using Method 25.

8. Estimate air pollution emissions using Method 13. Add in transit emissions if appropriate.

9. Estimate noise generation using Method 14. Include transit if appropriate.

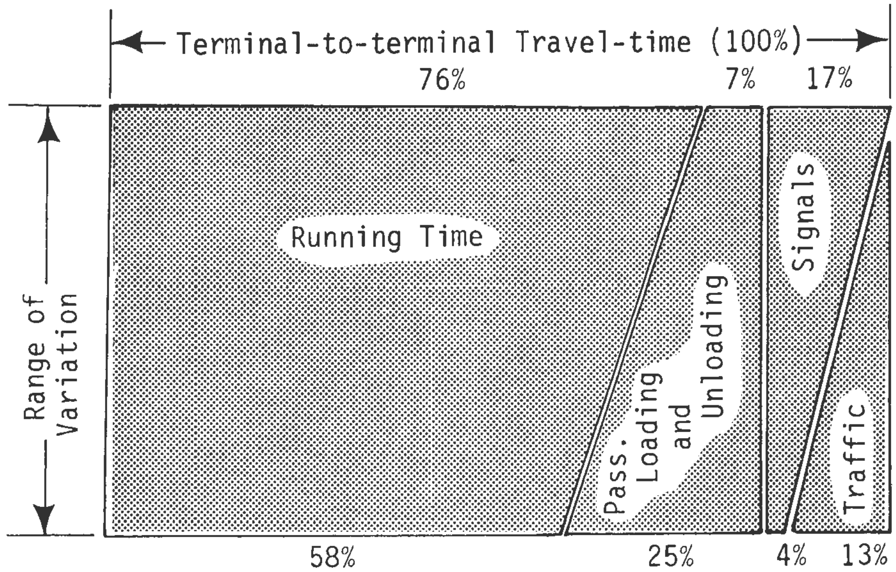
Table of Contents

Analytical Methods

a. If necessary, convert the "before" overall bus speed to travel time:

$$\text{Travel Time in Mins.} = \frac{(\text{60 Mins/Hr.})(\text{Distance in Miles})}{(\text{Speed in MPH})}$$

b. Estimate the percentage of the travel time related to signal delay. The diagram below shows typical ranges. Select a value based on knowledge of the local situation.



c. Using the selected percentage, calculate the minutes of signal delay:

$$\text{Signal Delay in Mins.} = (\text{Travel Time})(\text{\% Signal Delay})$$

d. Estimate the potential time savings based on the proposed design. Deduct the time savings from the minutes of signal delay calculated in Step c. Combine the travel time from the other catagories (Step b) with the new value for signal delay to obtain a new estimate of total travel time. Guidelines for time savings due to bus priority signals are:

(1) The UCTS experiment reduced total delay 20% to 30% in downtown Washington, D. C.

(2) 7 to 11 seconds per signal were saved in Miami.

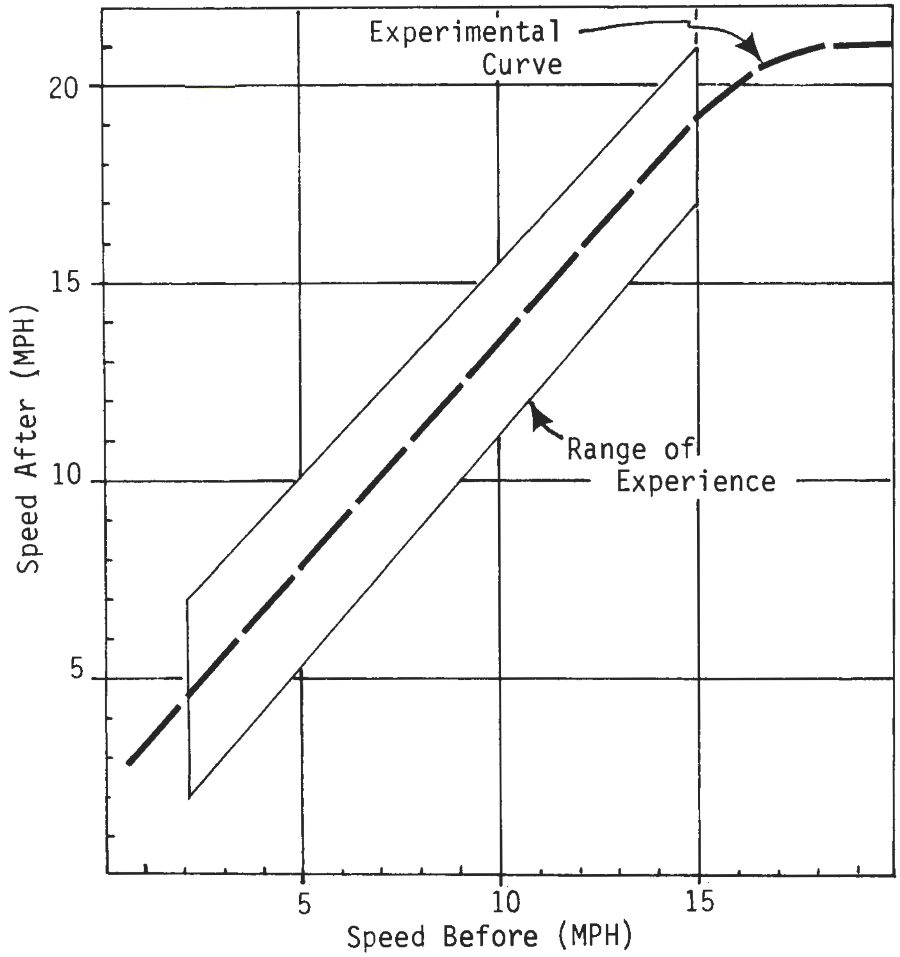
(3) Run time was reduced 10% through 13 intersections in Stockholm.

(4) Travel time savings in other tests were 5%, 7%, and 10%.

e. Convert the new travel time to new speed:

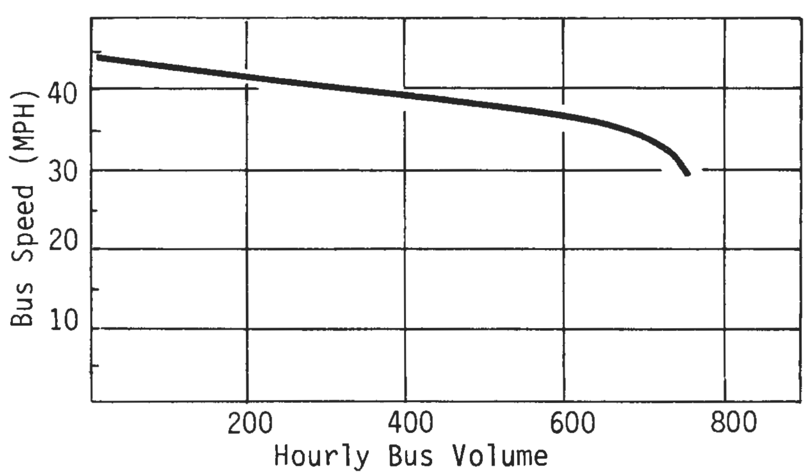
$$\text{Speed} = \frac{(\text{60 mins./Hr.})(\text{Distance in Miles})}{(\text{Travel Time in Mins.})}$$

a. For arterials and CBD streets, use the diagram* below to estimate new speed from the existing speed for curb, median, and contra-flow lanes.



*Experimental

b. For freeways, speed "after" should follow the relationship to bus volume depicted below:



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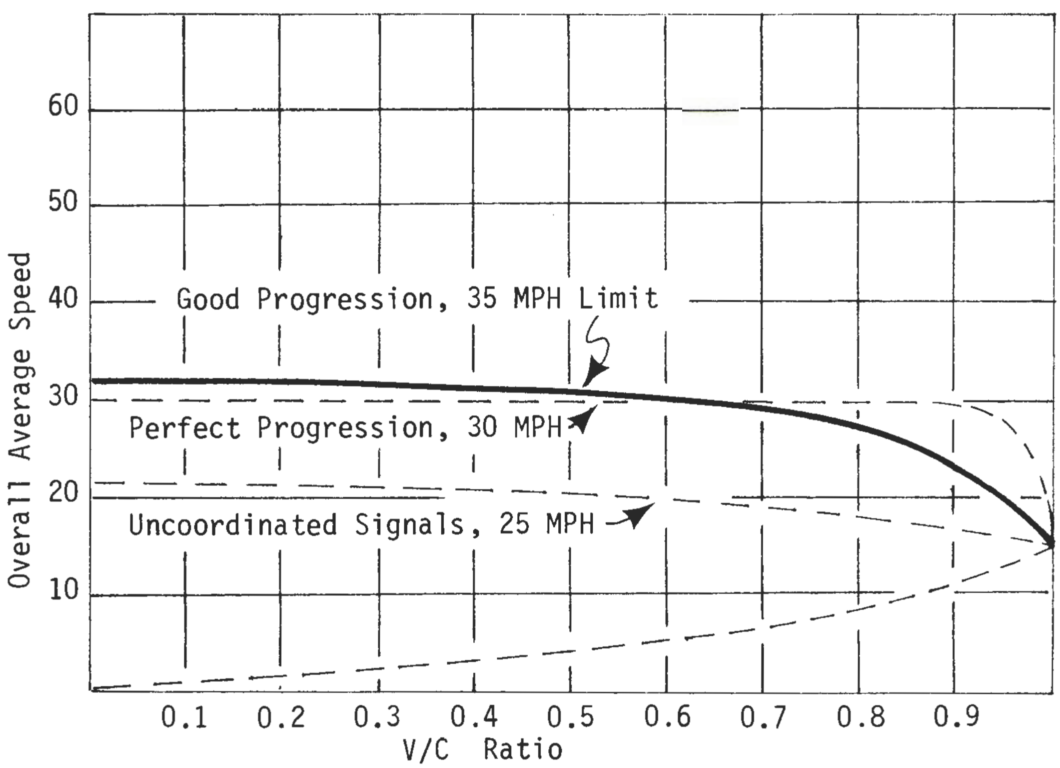
Note: The presence of car and van-pools in the exclusive lane should not affect bus speeds, since volume probably would be managed to preserve service level. Total capacity of an exclusive lane should follow basic capacity experience. See Method 22 for capacity data and Method 23 for speed.

c. If necessary, convert speed to travel time:

$$\text{Time in Mins.} = \frac{(60)(\text{Distance in Miles})}{(\text{Miles Per Hour})}$$

a. Develop independent estimates of capacity using analytical Method 22, the Highway Capacity Manual, or other methods. Calculate the volume/capacity ratio (V/C) before and after the action is implemented. Estimate the change in arterial speed from diagram (1) and freeway speed from (2), either in the absolute terms of the ordinate or as a ratio to be applied to the actual "before" speed. The speed estimated will be for the total vehicle volume. Bus running speed is 80% to 90% of the speed for autos.

(1)



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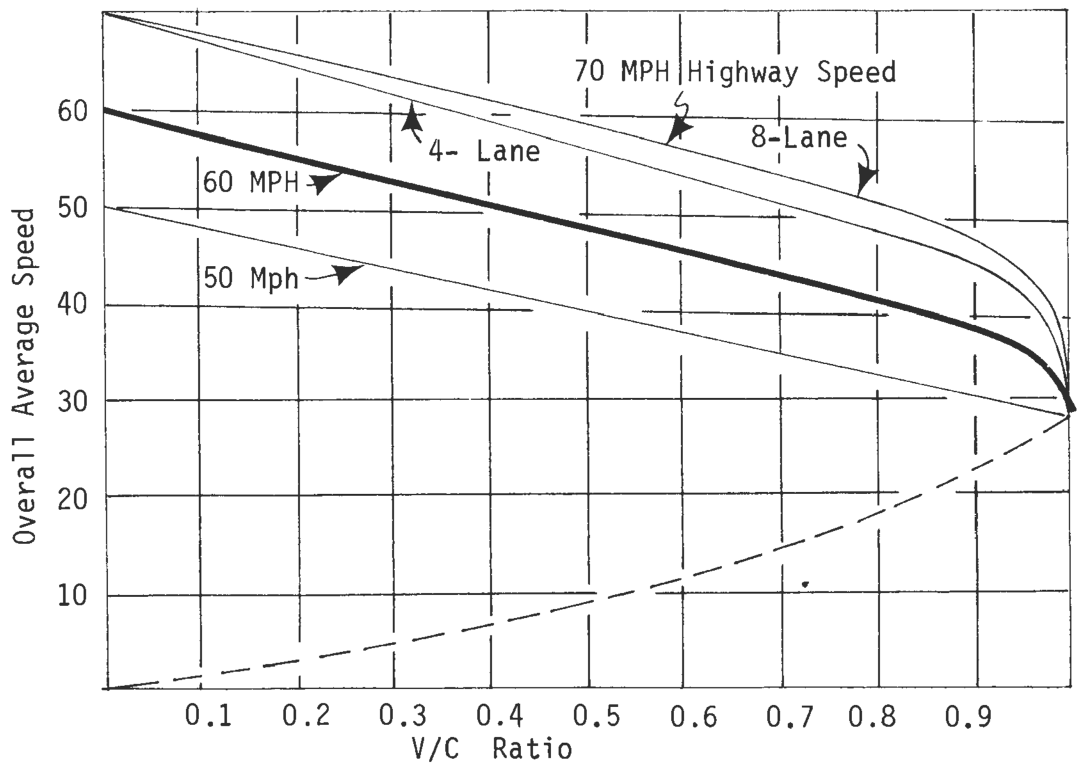
(2)



b. Following are guidelines for the capacity effect of various actions:

(1) Actions that completely eliminate a curb use (bus, bays, off-street stations, parking and stopping restrictions, off-street truck loading, etc.) can increase street capacity up to 40% to 60% depending on the density of the use eliminated. These actions perform like a street widening or parking prohibitions.

(2) Similar effects might be produced by actions to insure that buses can pull completely out of moving traffic lanes (stop lengthening, pavement strengthening, parking and stopping restrictions, etc.) except to a lessor degree. Some reduction in bus delay may result as well. (A survey in New York found up to 0.5 lanes blocked 40% of the time).

(3) Generally, far-side bus stops do not increase or decrease capacity. Shifting a near-side stop to far-side where parking is prohibited can increase capacity from 1% to 10%. Shifting from near-side to far-side with parking might reduce from 1% to 16% if the near-side stop provided a turn refuge.

(Continued)

(4) Actions reducing truck volume may increase capacity 1% for each 1% of reduction in the percentage that trucks make up of the total flow.

(5) General improvements in signals, streets, and highways (such as widening, conversion to one-way, and similar actions) will produce a speed change in proportion to the change in the V/C ratio (see Step "a").

(6) Computer operation of signals may reduce stops up to 5% to 10%, reduce delay up to 30%, and increase speed up to 20%.

c. Convert speeds from Step "a" to overall bus speeds:

(1) Bus running speeds can be taken as 80% to 90% of the speed of the total multi-modal volume.

(2) Convert bus speeds to time:

$$\text{Travel Time} = \frac{(\text{Distance in Miles})(60)}{(\text{Speed})}$$

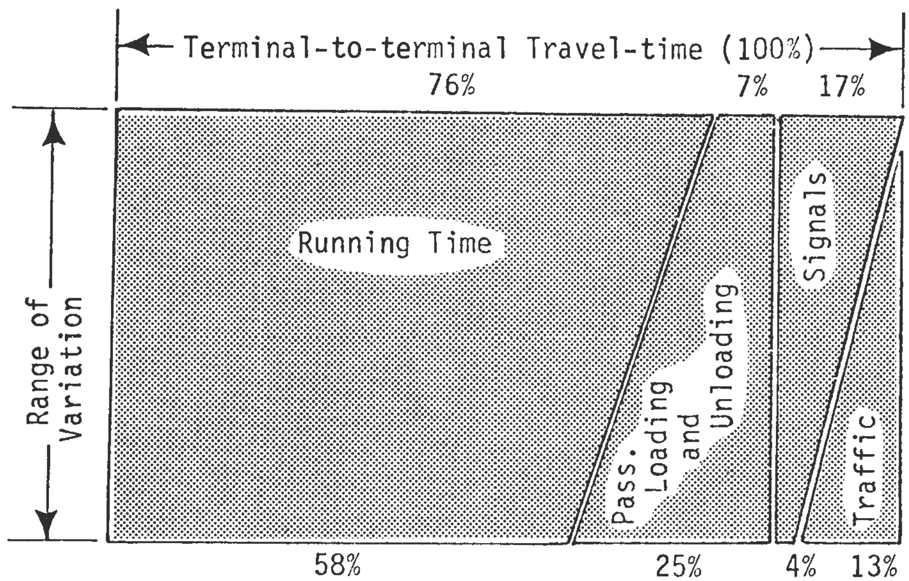
(3) Expand running time to total bus travel time by adding passenger loading time (7% to 25% of total), or by adding loading signal, and traffic delay time, if appropriate, to the situation under study (refer to Methods 1, 2, 3, and 5).

a. Implementation of express bus service on arterials will reduce the time required for the loading and unloading of passengers in proporation to the share of stops eliminated:

(1) Convert "before" speed to travel time:

$$\text{Travel Time in Mins.} = \frac{(\text{60 Mins./Hr.})(\text{Distance in Miles})}{(\text{Speed in Miles/Hr.})}$$

(2) Estimate the percentage of travel time consumed by passenger stops. The diagram shows typical ranges:



(3) Using the selected percentage and the estimated proportion of stops not eliminated, estimate the new minutes for passenger loading and unloading:

$$\text{After Loading Time in Mins.} = \frac{(\text{Before Time})(\text{Stops Remaining})}{(\text{Total Stops Before})}$$

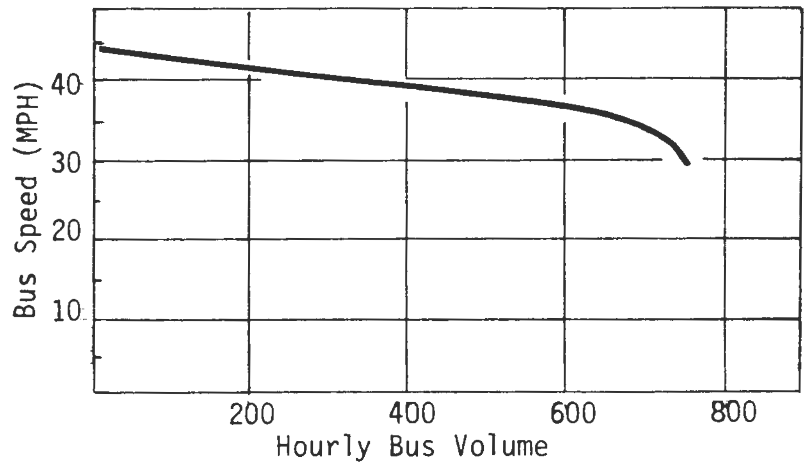
(4) Combine the new loading time with the components not altered to calculate the new total travel time.

(5) Convert travel time to "after" speed:

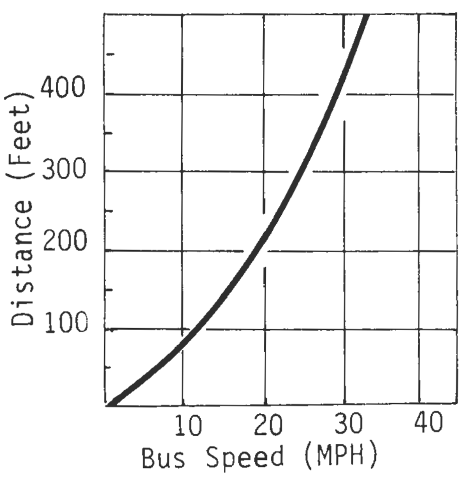
$$\text{Speed} = \frac{(\text{60 Mins./Hr.})(\text{Distance in Miles})}{(\text{Time in Mins.})}$$

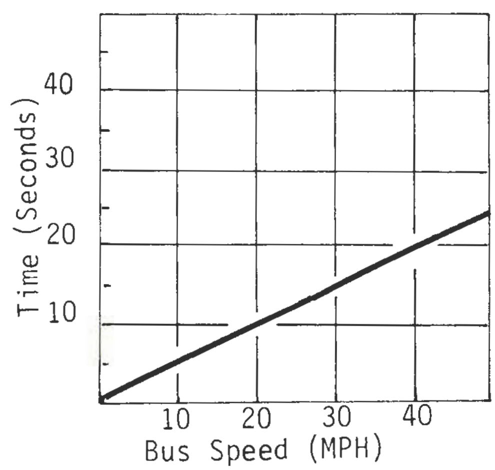
(Continued)

b. Speeds for freeway express service fit generally into the speed/capacity relationship of the curve below:



c. Speeds on exclusive ramps and on metering bypass lanes should be selected with consideration for bus accelleration characteristics as illustrated by the curves below:





Note that ramp metering may increase overall freeway speeds up to double the "before" value, depending on the severity of the starting conditions.

a. The following table lists seconds per boarding passenger for various fare collection systems and door configurations. Select appropriate "before" and "after" values for the action being considered:

Fare Collection Method	Doors			
	One Single	One Double	Two Singles	Two Doubles
Cash, with Zones	3.5	2.1	2.1	1.2
Cash	2.5	1.5	1.5	0.9
Token or Single Coin	2.5	1.5	1.5	0.9
Passes	2.0	1.2	1.2	0.7
On-board (Conductor)	2.0	1.2	1.2	0.7
Pre-payment (in-station, in-barrier)	2.0	1.2	1.2	0.7

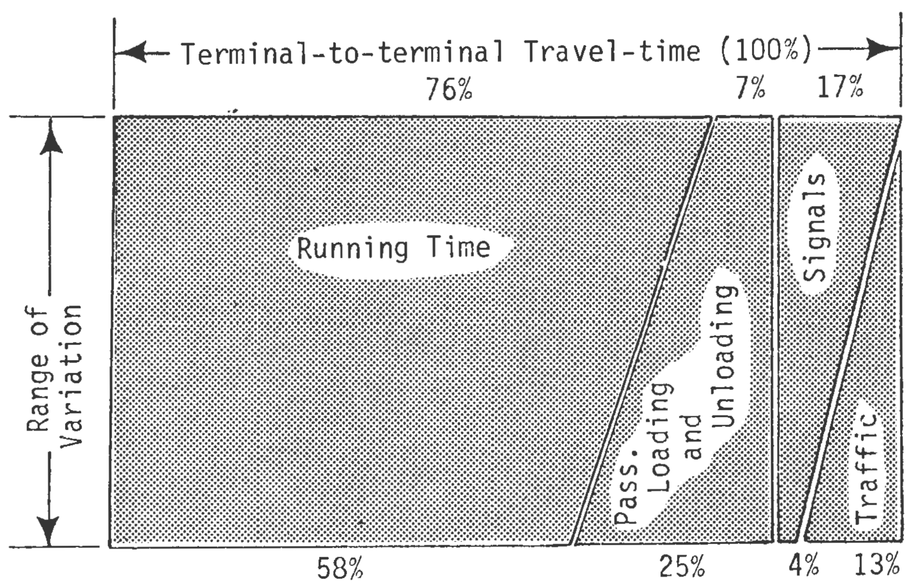
b. Estimate new speed and travel time:

(1) Convert speed to minutes:

$$\text{Travel Time in Mins.} = \frac{(\text{60 Mins./Hr.})(\text{Distance in Miles})}{(\text{Speed in Miles/Hr.})}$$

(2) Estimate the percentage of time consumed by passenger stops. The figure below shows typical ranges:

Terminal-to-Terminal Travel Time (100%)



(Continued)

(3) Calculate "before" loading time:

Loading Time in Mins. = (Travel Time)(% Loading Delay)

(4) Reduce the estimated loading time by the ratio of seconds per passenger from Step a:

Loading Time "After" in Mins. =

$$\frac{\text{(Loading Time "Before)(Secs. Per Pass. "After")}}{\text{(Secs. per Pass. "Before")}}$$

(5) Calculate the new "after" total travel time by combining the new loading time with other components.

(6) Convert time to speed:

$$\text{Speed} = \frac{\text{(60 Mins./Hr.)(Distance in Miles)}}{\text{(Time in Mins.)}}$$

a. Before and after bus patronage estimates can be made using the marginal disutility modal split model. The following variables must be known or estimated for the case under investigation:

Variable	Symbol	Weighting Factor
Walk Time To/From Transit	T_a	2.5
Wait Time for Transit	T_w	2.5
Transit Running Time	T_r	1.0
Transit Fare	F	1.0
Auto Terminal Time	A_t	2.5
Auto Running Time	A_r	1.0
Parking Cost (Daily, at destination)	P	0.5
Highway Distance	D	1.0
Auto Out-of-pocket Cost Per Mile	C_a	1.0
Value of Time	C_t	0.25*
Utility	U	-

*Cost of time is computed as 25% of income. Income, C_t, equals:

$$\frac{\text{(Annual Income)}}{\text{(2080 Hrs/Yr.)(60 Mins/Hr.)}}$$

b. Calculate transit utility:

$$U_t = 2.5\ (T_a + T_w) + T_r + \frac{F}{0.25\ C_t}$$

and auto utility:

$$U_a = 2.5\ (A_t) + A_r + \frac{(0.5)(P) + (C_a)(D)}{0.25\ C_t}$$

(Continued)

(1) The following default values (for use when factual data is not available) can be used to represent an average trip:

Variable	Default Value	Remarks
T_a	6.7 Mins.	800 feet walking at 4 FPS at both ends of the trip.
T_w	10.7 Mins.	Half of average headway.
T_r	36.2 Mins.	8.7 Miles @ 14.5 MPH.
F	$0.36	Average fare.
A_t	0.8 Mins.	280 feet @ 6 FPS.
A_r	18.1 Mins.	8.7 miles @ 29 MPH.
P	$0.26	$1.60 in CBD.
D	8.7 miles	Average trip length.
C_a	$0.054/mile	Out-of-pocket cost, 1977

(2) Values for 0.25 C_t Are:

Annual Family Income	0.25 C_t	Annual Family Income	0.25 C_t	Annual Family Income	0.25 C_t
$ 2,000	0.004	$22,000	0.044	$42,000	0.084
4,000	0.008	24,000	0.048	44,000	0.088
6,000	0.012	26,000	0.052	46,000	0.092
8,000	0.016	28,000	0.056	48,000	0.096
10,000	0.020	30,000	0.060	50,000	0.100
12,000	0.024	32,000	0.064	52,000	0.104
14,000	0.028	34,000	0.068	54,000	0.108
16,000	0.032	36,000	0.072	56,000	0.112
18,000	0.036	38,000	0.076	58,000	0.116
20,000	0.040	40,000	0.080	60,000	0.120

(Continued)

c. Calculate $U_t - U_a$.

d. Pick the mode split percentage from the mode split curve for the most suitable trip purpose.*

c. Apply the mode split percentage to the total person trip volume between the origin areas and the destination area under study.

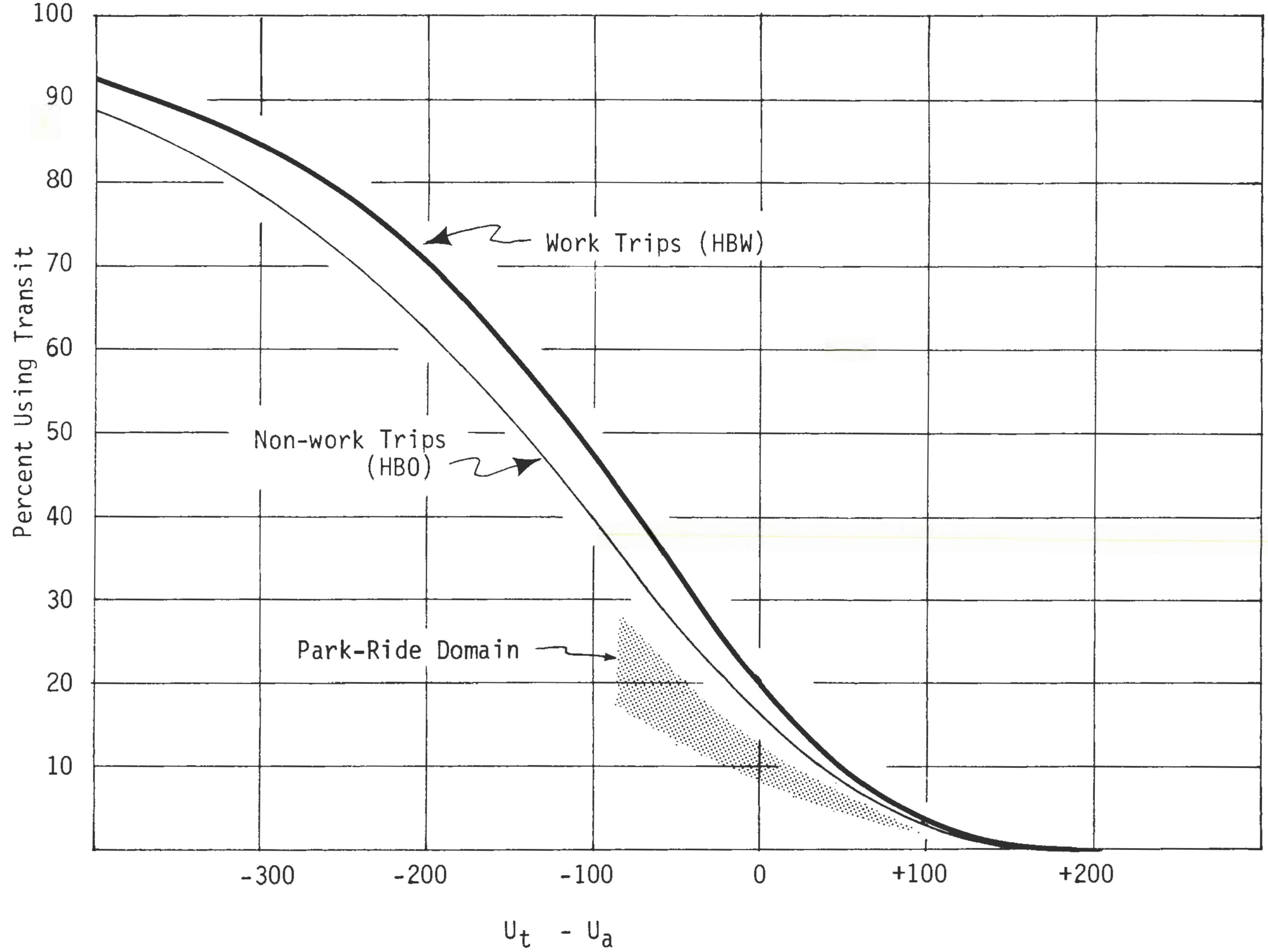
(1) Without question, the best source for person trip data will O-D survey interzonal trip totals or cell values from trip tables developed using calibrated trip distribution models. Anything less can cause large errors in passenger estimates.

(2) If trip table data is not available, the "O-D simulation" approach of Method 19 could be used if the risk of error is acceptable.

(3) If counts of existing vehicle and person volumes are available, a corridor mode split could be calculated and the sensitivity curves of Method 7 used to estimate the changein percent transit, and thereby the change in transit passenger volume. The ratio of before-and-after mode split percentages from the curve can be applied to the calculated corridor mode split to estimate the "after" percentage.

(4) If the person-trip volume to which the mode split percentage is applied is of doubtful accuracy, run through the calculations for several levels of person-trip volume to identify the sensitivity of various results to the volume.

* A special sector has been identified on the plot of disutility and percent transit for park-ride estimation. The discounting of mode shift shown by this sector reflects the reluctance of drivers to leave their autos, as contrasted to shifts that would be expected from bus users. This effect was found in Seattle's Blue Streak experiment and in the field testing of this method. (Experimental)



100
90
80
70
60
50
40
30
20
10
Percent Using Transit
Work Trips (HBW)
Non-work Trips
(HBO)
Park-Ride Domain
-300
-200
-100
0
+100
+200
$U_t - U_a$

a. Calculate the percentage change in the transit variable under study (fare, run time, wait time, access time, or transfers).

b. Enter the sensitivity curves with the calculated percent change in the variable and select a value for percentage change in mode split.

c. Calculate the new transit patronage:

Mode Split After = (Mode Split Before) $\pm$ (Mode Split Change)

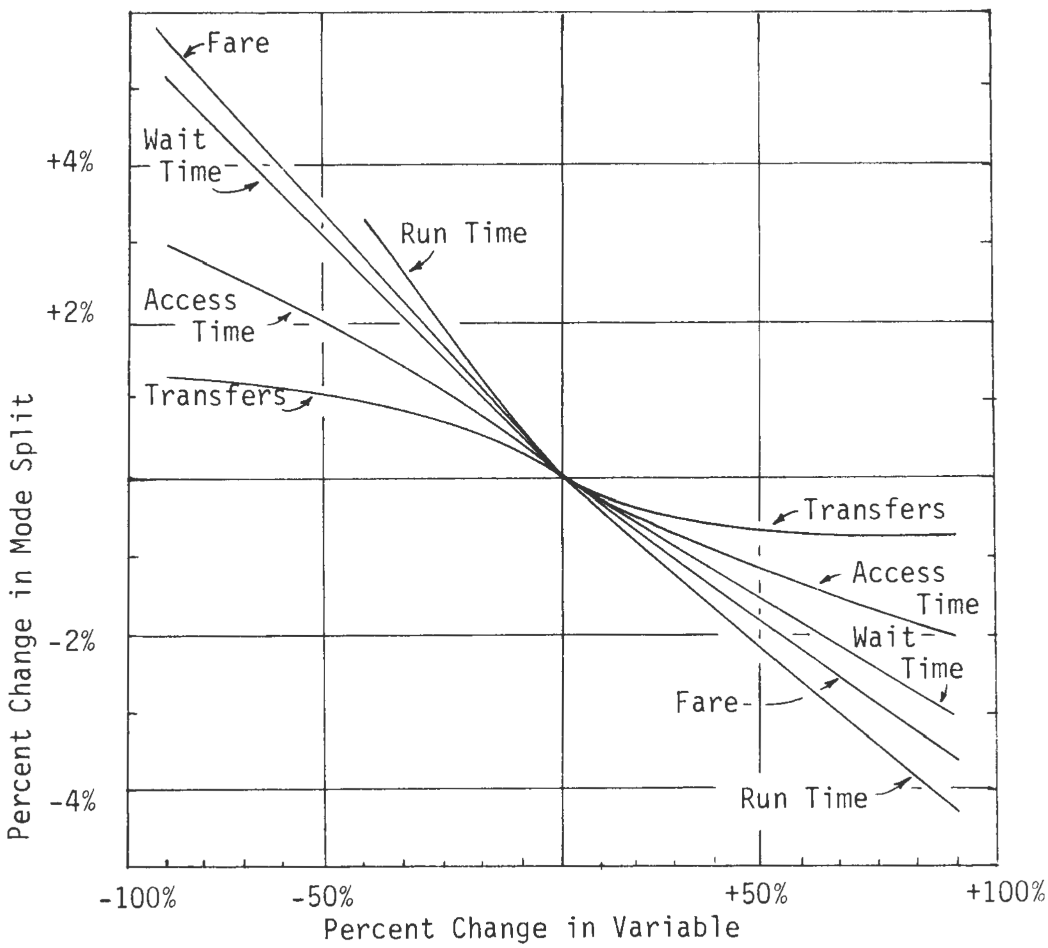
d. Calculate the new transit patronage:

Passenger After = (Total Person Trips)(Mode Split After)

(1) Cross-check effects of fare changes with Method 8.

(2) This method is useful only when an acceptable value of "before" mode split is available from person-trip tables or, accepting less accuracy, from corridor counts.

(Continued)

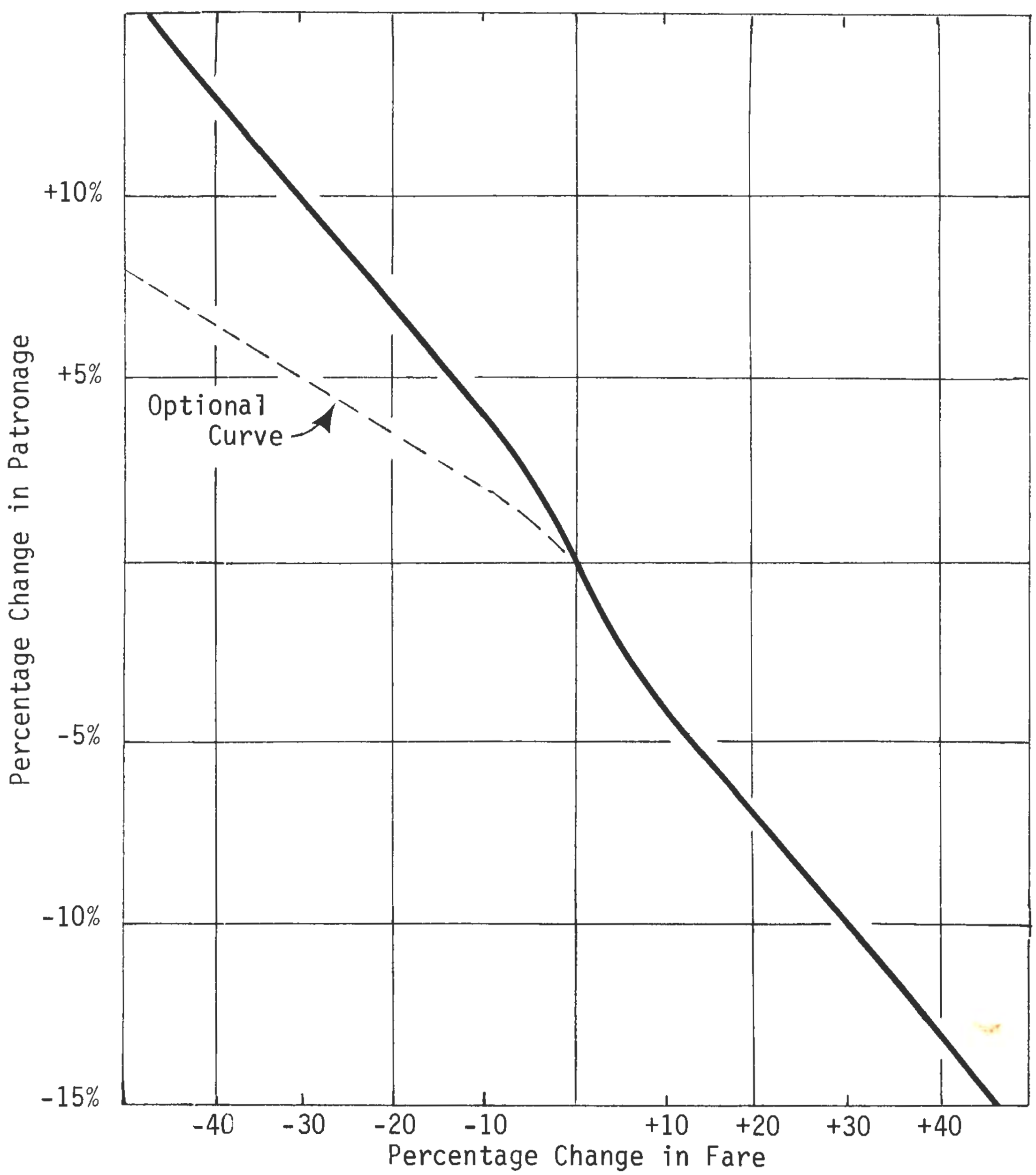


Fare
Wait Time
Run Time
Access Time
Transfers
+4%
+2%
-2%
-4%
Percent Change in Mode Split
-100%
-50%
+50%
+100%
Percent Change in Variable

a. Calculate the percent change in fare.

b. Enter the sensitivity curve and select the appropriate value of percent change in patronage.

(1) Note that an optional curve is shown for fare decreases. The optional curve reflects the situation where a fare decrease will attract back only about half of the passengers lost from earlier fare increases. This conservative assumption may be more realistic and attractive than that of the basic curve.



a. Measure the "span" of the urban area under study (the average diameter of urban development).

b. Enter the trip length curve with the number of miles from Step "a" and select a value for transit passenger average trip length.

c. Calculate passenger-miles of travel:

Daily Passenger-Miles = (Daily Passengers)(Average Trip Length)

(1) "Passengers" can be for various time periods, but the most common usage will be "daily" for a particular route.

d. Calculate average route or system vehicle occupancy:

$$\text{Average Daily Occupancy} = \frac{\text{Passenger-Miles}}{\text{Vehicle-Miles}}$$

e. Adjust the average daily value of occupancy (from Step d) to peak period average occupancy:

Peak Period Average Occupancy =

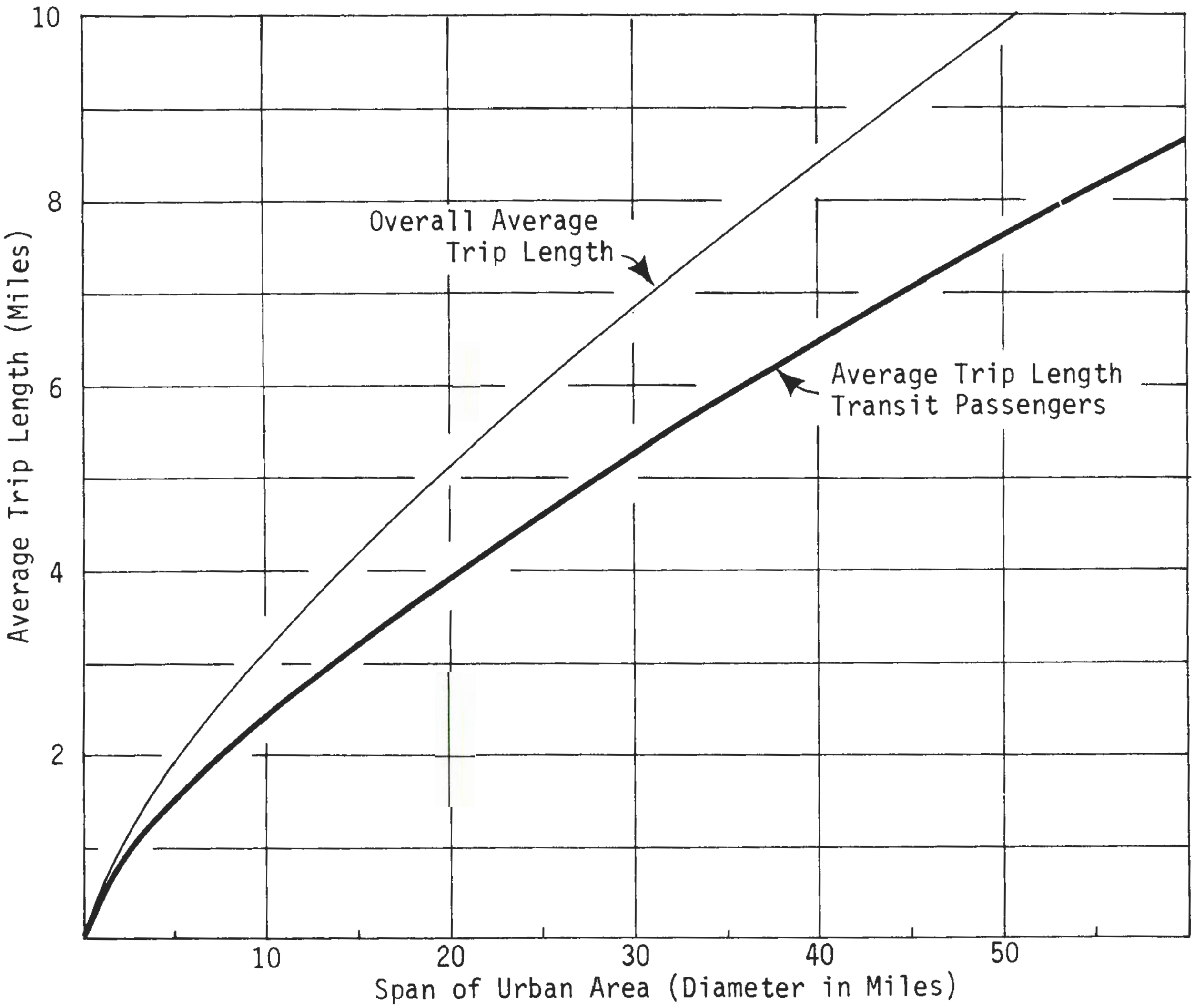
(Average Daily Occupacy)(Peak to Base Factor)

(1) Select "Peak to Base Factor" from the following table if not otherwise available:

Length of Service Day	Peak to Base Factor
20 Hours	3.04
18	2.76
16	2.53
14	2.30
12	2.08

f. Adjust peak period average occupancy (from Step e) to maximum load point (MLP) occupancy using the ratio of route MLP occupancy to average route peak period occupancy (or system MLP occupancy to system average, if working at the system level). A default value of 2.0 can be used, based on the assumption that the route passenger profile is triangular.

*Experimental



Average Trip Length (Miles)
10
8
6
4
2
Overall Average
Trip Length
Average Trip Length
Transit Passengers
10
20
30
40
50
Span of Urban Area (Diameter in Miles)

Note: This method of cost calculation calls for the allocation of operating costs to two or more causative factors. Then, costs can be allocated to routes, time periods, or both based on the assignment of the causative factors. Similarly, changes in cost (by route, time period, both, or the total system) can be calculated using "before" and "after" totals of causative factors. The simplest method of cost estimation uses one factor - usually vehicle-miles. This method uses more than one to enhance the realism of the allocation. The following steps describe the development of the unit costs by factor, and then the application of the cost unit to calculate cost changes.

a. Select the causative factors to be used from among the following:

Vehicle miles
Vehicle-hours } Basic factors
Vehicles
Drivers } Enhancement factors

b. Prepare a worksheet with columns labelled by the factors selected, and the rows labelled by operating expense accounts. Enter the current annual value for each account.

c. Allocate the dollar amount of each account to one or more of the factors. Split accounts among factors if appropriate. Enter the amount allocated in the column for the factor(s) selected. The following tables show typical accounts, with a percentage allocation to factors, for guidance in carrying out this step.

(Continued)

Cost Account (Costs Allocated By Percentage To ⇨)	Four Factors: Vehicle-Miles	Four Factors: Vehicle-Hours	Four Factors: Vehicles	Four Factors: Drivers	Three Factors: Vehicle-Miles	Three Factors: Vehicle-Hours	Three Factors: Vehicles	Two Factors: Vehicle-Miles	Two Factors: Vehicle-Hours
Equipment Maintenance & Garage Expenses:									
Supervision of Shops & Garages	20		80		20		80	100	
Repairs to Shop & Garage Equipment			100				100	100	
Repairs to Buildings & Grounds			100				100	100	
Light, Heat, Power & Water			100				100	100	
Other Shop & Garage Expense			100				100	100	
Repair & Upkeep - Motor Coaches	100				100			100	
Accident Repairs - Motor Coaches	100				100			100	
Servicing of Motor Coaches			100				100	100	
Tire & Tube Expense	100				100			100	
Farebox Maintenance & Servicing		50	50			50	50		50
Transportation Expenses:									
Supervision	20			80	20		80	20	80
Schedules			100				100	100	
Instruction School				100		100			100
Motor Coach Operators Wages		80		20		100			100
Power - Diesel	100				100			100	
Power - Gasoline	100				100			100	
Engine Oil	100				100			100	
Wages of Misc. Trans. Employees	20	40	40	20	20	80		20	80
Other Transportation Expenses	20	40	40	20	20	80		20	80
Traffic Promotion & Advertising:									
Salaries & Expenses - Traffic Prom.	100				100			100	
Transfers, Tokens, & Passes	100				100			100	
Car Card Advertising Expense		50	50			100		100	
Advertising Expense	100				100			100	
Insurance & Safety Expense:									
Salaries & Expense - Insur. & Safety	50	30		20	50	50		50	50
Insurance - Public Liability & P.D.	100				100			100	
Injuries & Damages	100				100			100	
Insurance - Workmen's Compensation	20	40	10	30	20	70	10	30	70
Insurance - Fire & Theft	20		80		20		80	100	
Other Insurance	100				100			100	

(Continued)

Cost Account	Four Factors: Vehicle-Miles	Four Factors: Vehicle-Hours	Four Factors: Vehicles	Four Factors: Drivers	Three Factors: Vehicle-Miles	Three Factors: Vehicle-Hours	Three Factors: Vehicles	Two Factors: Vehicle-Miles	Two Factors: Vehicle-Hours
Administrative & General:									
Salaries of General Officers			100				100	100	
Expenses of General Officers			100				100	100	
Salaries of General Office Employees	30		40	30	30	30	40	70	30
Expenses of General Office Employees	30		40	30	30	30	40	70	30
General Office Supplies & Expenses	50		50		50		50	100	
Pensions	10		10	80	10	80	10	20	80
Health & Accident Insurance	10		10	80	10	80	10	20	80
Death Benefit Expense	10		10	80	10	80	10	20	80
Miscellaneous Employee Welfare Expense	10		10	80	10	80	10	20	80
Medical - Surgical Insurance	10		10	80	10	80	10	20	80
Other General Expenses	80			20	80	20		80	20
Other Management Expense			100				100	100	
Criminal Assault Insurance	100				100			100	
Regulatory Commission Expense	100				100			100	
Outside Survey Expense	100				100			100	
Group Term Life Insurance	10		10	80	10	80	10	20	80
Operating Taxes and Licenses:									
Real Estate			100				100	100	
Social Security Tax	10		10	80	10	80	10	20	80
Business Tax	100				100			100	
Licenses & Permits			50	50		50	50	50	50
Fuel	100				100			100	
Depreciation	20		80		20		80	100	

(Costs Allocated By Percentage To →)

d. Total the columns. Divide the column total by the number of units (Annual vehicle-miles, vehicle-hours, etc.) to yield the cost unit.

For example:

$$\text{Cost per Vehicle-Mile} = \frac{\text{Annual Costs Allocated to Veh-Miles}}{\text{Annual Vehicle-Miles}}$$

$$\text{Cost per Vehicle-Hour} = \frac{\text{Annual Costs Allocated to Veh-Hours}}{\text{Annual Vehicle-Hours}}$$

Cost Per Vehicle =

$$\frac{(\text{Annual Costs Allocated to Vehicles})\frac{1}{(\text{Annualization Factor})}}{\text{Number Vehicles}}$$

(Continued)

d. (Continued)

Note that costs allocated to "Vehicles" must be converted to a daily basis since an annual total for "Vehicles" is meaningless. The same is true for "Drivers", if used.

(1) The annualization factor is an imaginary number of days by which average daily values are multiplied to obtain annual totals. An annualization factor for vehicle-miles would be calculated as follows:

Day	Number	Ratio of Veh-Miles Operated	Weighted Days
Sunday	52	0.0	0.0
Saturday	52	0.5	26.0
Holidays	8	0.0	0.0
Weekdays	253	1.0	253.0
TOTAL	365	-	279.0

The number "279.0" is the annualization factor. It could vary in value for different measurements (such as veh-miles, vehicle-hours, etc.), but it is likely that the only significant difference would be between a service factor (vehicle-miles, cost, etc.) and a patronage factor (passengers or revenue).

e. Once the cost units are calculated, several applications are possible:

(1) Multiply the cost unit by the appropriate factor, with the factors split between peak and base periods. This will produce an estimate of costs per peak and base periods. For example:

Base Period Costs = (Base Vehicle-Miles)(Cost per Vehicle-Mile)

+ (Base Vehicle-Hours)(Cost per Vehicle-Hour).

Note that "Vehicles" and "Operators" (Drivers) are usually assigned only to the peak periods.

(2) Multiply cost unit by the appropriate factor, with the factors assigned to routes. This will produce an estimated cost by route.

(3) Allocate the factors to routes by time period, and apply the cost units to produce an estimate of peak and base costs for each route.

(Continued)

f. When a TSM action results in a change in one or more of the causative factors, apply the cost units to the revised factors to determine the resulting change in operating cost.

Notes:
1. Usually capital costs should not be included, but equipment depreciation will.

2. When splitting between peak and base, assign "vehicles" and "operators" to the peak (none to the base) since fleet size is usually determined by peak needs.

3. "Operators" will probably have to be adjusted for vacations, etc.

4. If actions of the management-improvement type result in cost savings, the dollar value of the account and the cost units must be similarly adjusted if the change is significant.

5. Once the basic allocation of costs is done, it will usually require only adjustments on an annual basis for changing annual totals - not a complete re-allocation.

6. This method obviously applies only in situations where transit is operating and costs are recorded. For new transit operations, utilize cost units from similar sized systems, perhaps with a speed adjustment (if appropriate) from Method 11.

7. Cost inflation has significantly affected operating costs in recent years. The following table illustrates trends:

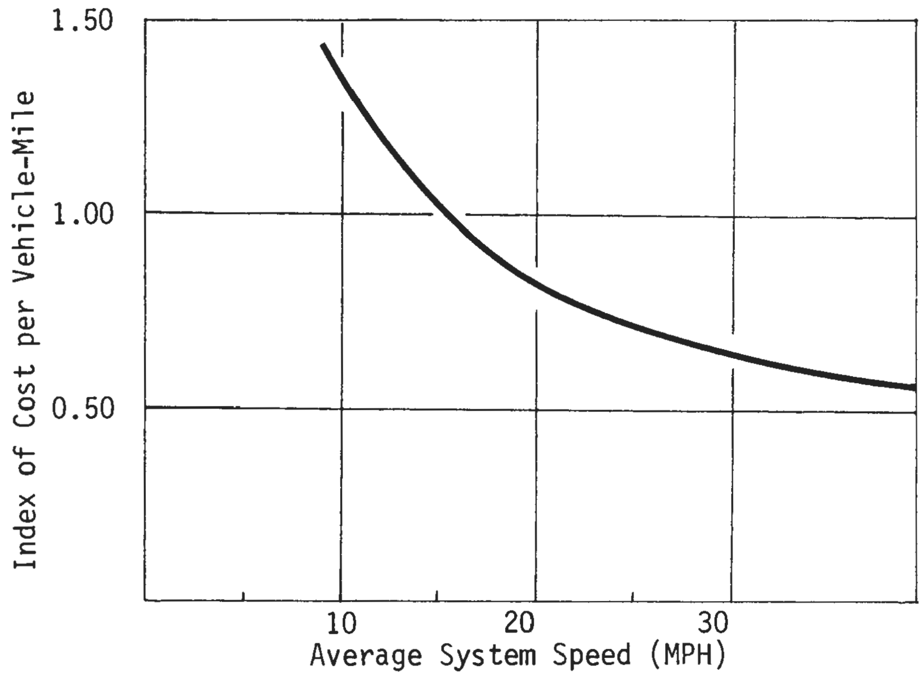
Year	Index for Transit Wages
1967	1.00
1968	1.07
1969	1.16
1970	1.28
1971	1.39
1972	1.46
1973	1.60
1974	1.78
1975	1.94

a. Select an existing bus system similar to the new system being studied. Base the selection on number of buses and comparable wage levels.

b. Determine the cost per vehicle-mile and the average system speed for the selected existing system. Determine the average system speed for the new system.

c. Enter the curve* with both speeds and select index values corresponding to the two speeds.

*Experimental



d. Adjust the cost per vehicle-mile from the existing system to new system conditions:

New System Cost per Veh-Mile =

$$\frac{\text{(Existing System Cost per Veh-Mile)(New System Index)}}{\text{(Existing System Index)}}$$

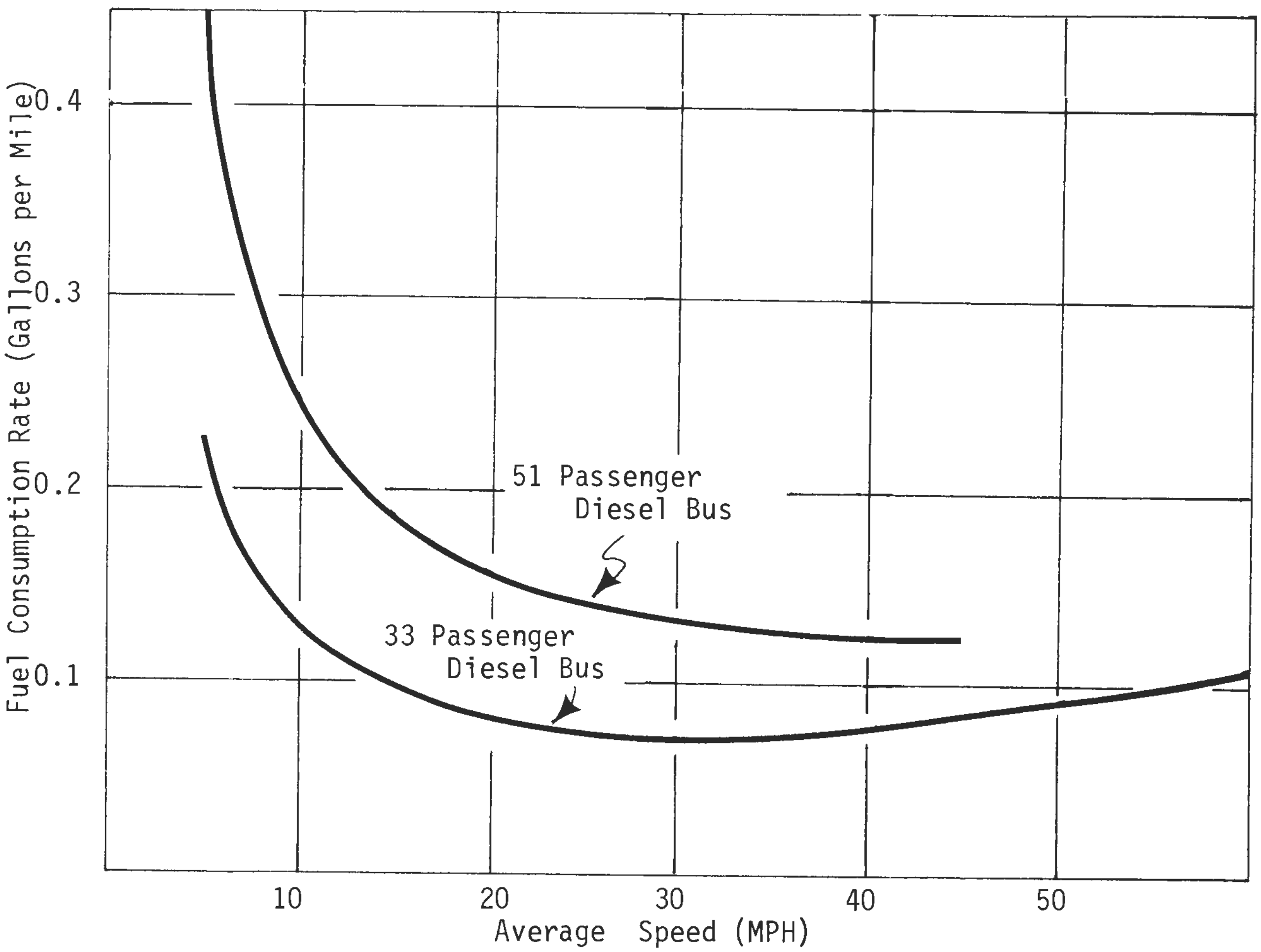
a. Select a "before" and an "after" fuel consumption rate from one of the following sets of curves, entering the curve with mode and the respective average operating speeds.

b. If the absolute value of the curve "before" rate does not equal the actual "before" rate measured in the field, then estimate the new consumption rate by ratio:

$$\text{Fuel Consumption Rate After} = \frac{\text{(Actual Rate Before)(Curve Value After)}}{\text{(Curve Value Before)}}$$

c. Calculate fuel consumed:

$$\text{Fuel Consumed} = \text{(Rate)(Vehicle-Miles)}$$



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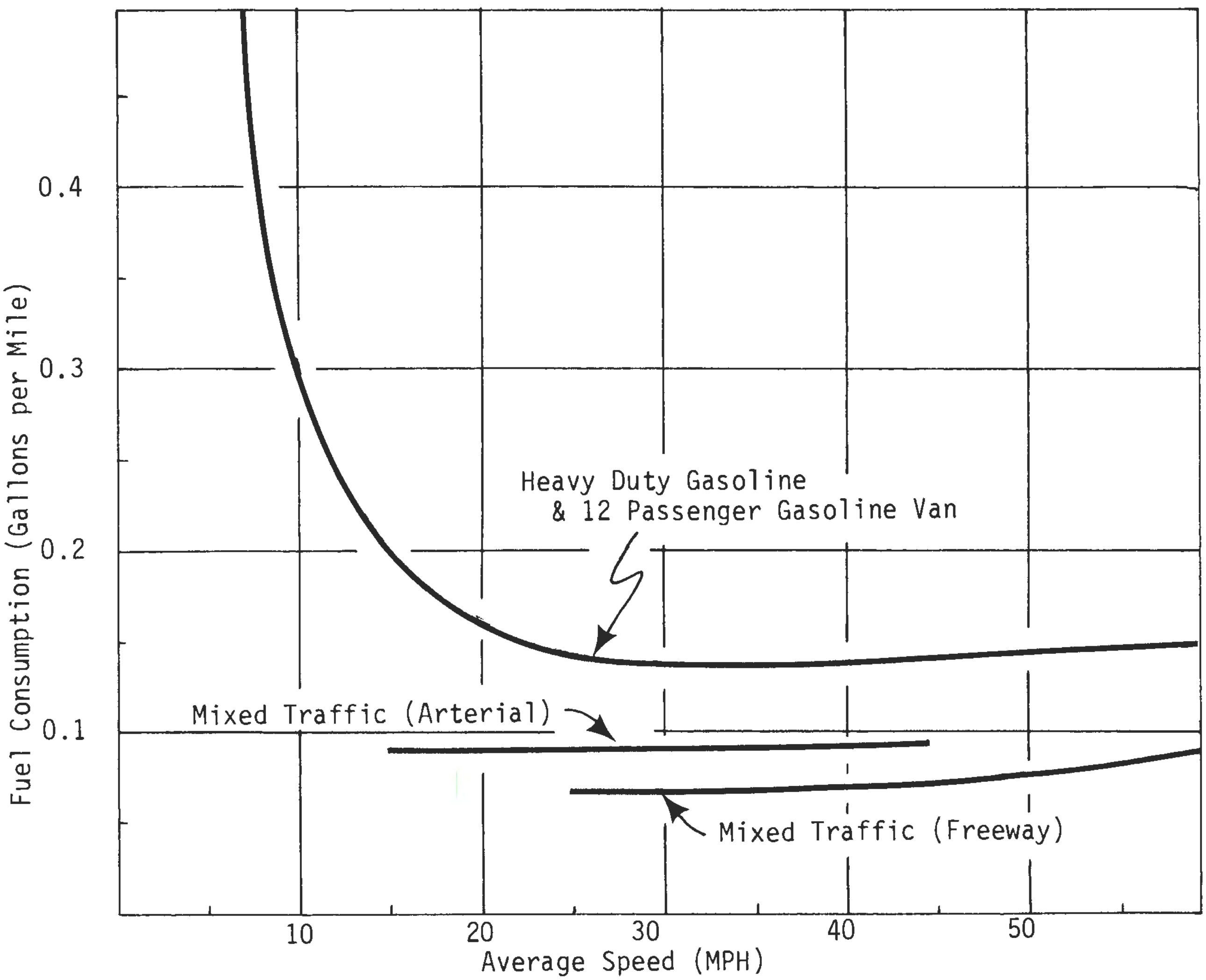


Fuel Consumption (Gallons per Mile)
0.4
0.3
0.2
0.1
Heavy Duty Gasoline
& 12 Passenger Gasoline Van
Mixed Traffic (Arterial)
Mixed Traffic (Freeway)
10
20
30
40
50
Average Speed (MPH)

a. The curves on the following pages show the relationship of emission rate to speed by mode for the three major pollutants: Carbon monoxide, hydrocarbons, and nitrous oxides. Enter the curves with average overall speed to select suitable emission rates Use "before" speeds for "before" rates and "after" speeds for "after" rates.

b. If the absolute "before" value from the curve does not match the actual "before" rate, (when available) then calculate the "after" emission rate by ratio:

$$\text{Emission Rate After} = \frac{(\text{Rate Before})(\text{Curve Value After})}{(\text{Curve Value Before})}$$

Note the rates for small gasoline powered buses ("Autos and 8 to 12 Passenger Buses") and large gasoline powered buses ("Gasoline Trucks and 12 + Passenger Buses") are shown for 1976 and 1980. This reflects the improvements expected from modifications in gasoline engines required by EPA over that period. Interpolate between the curves to obtain an appropriate rate for the year under study.

c. Calculate total emissions (grams or kilograms):

$$\text{Emissions} = (\text{Emission Rate})\ (\text{Vehicle-Miles})$$

d. Estimate potential emission rate improvements as follows:

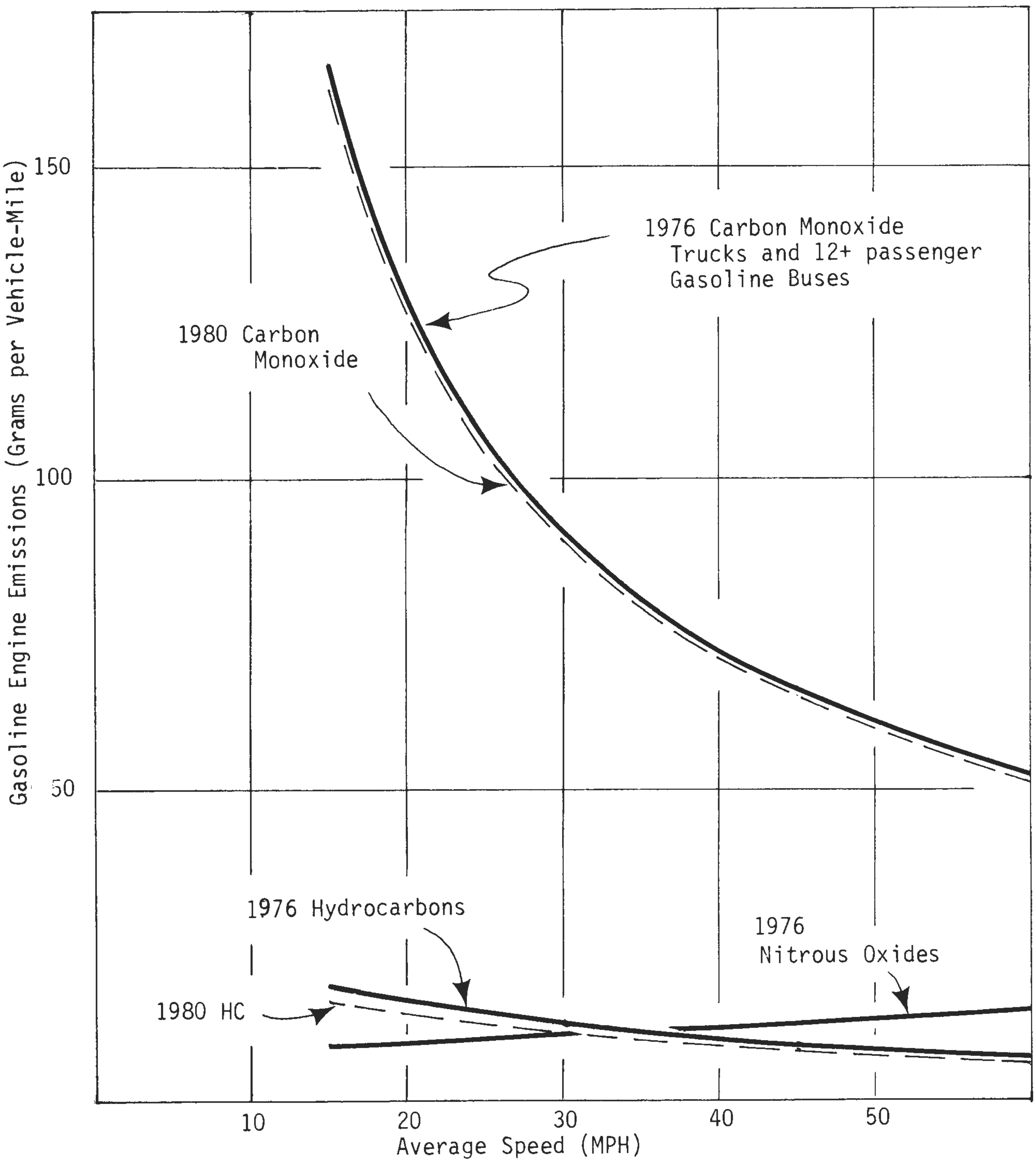
(1) Use of the EIP diesel engine modification kit will reduce the curve rates to the following percentages of those rates:

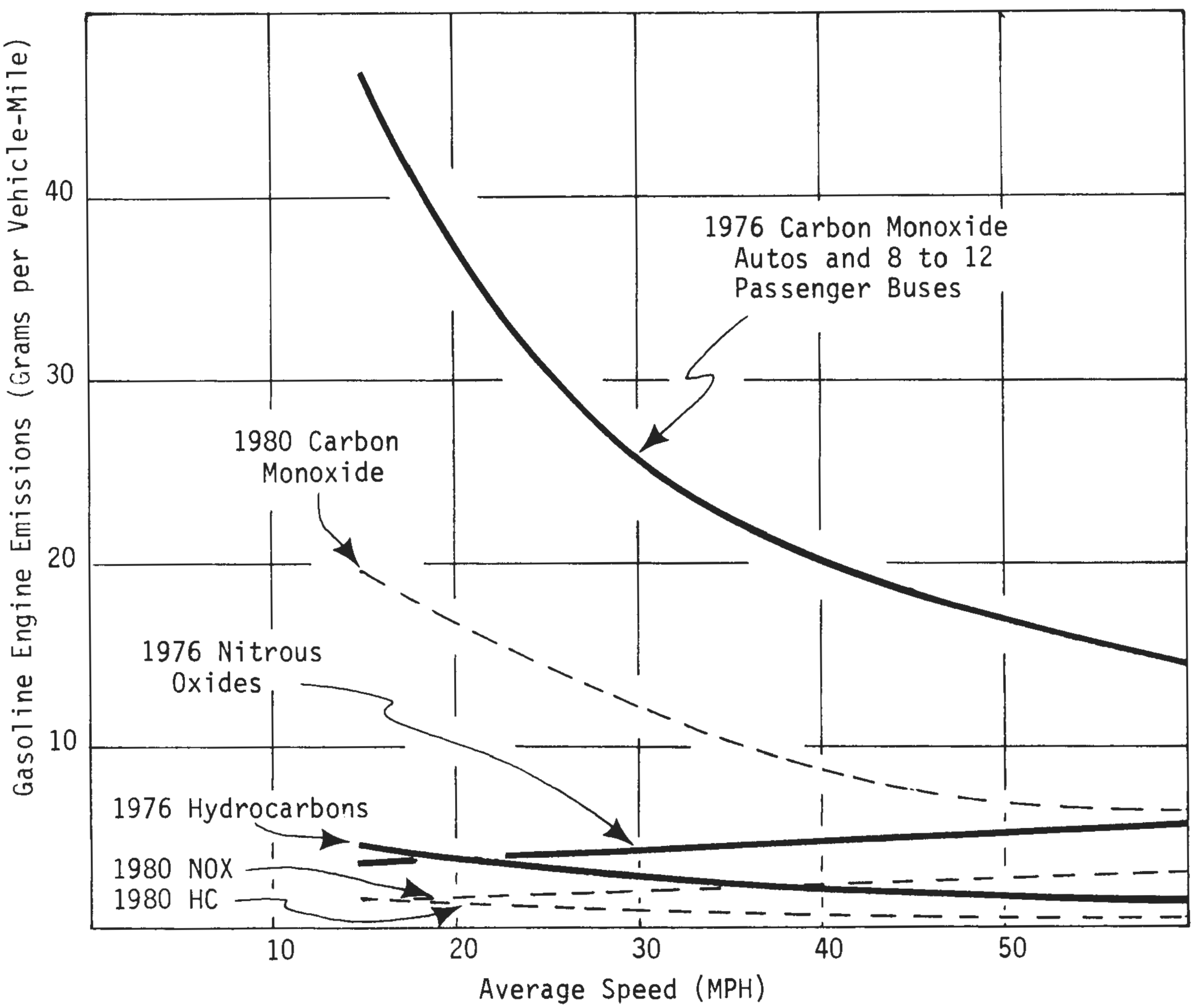
(a)	Carbon Monoxide Emissions	50% to 75% of Curve Rate
(b)	Hydrocarbon Emissions	10% to 20% of Curve Rate
(c)	Nitrous Oxide Emissions	No Change

(2) Similarly, heavy-duty gasoline engine emissions can be improved through engine modification as follows:

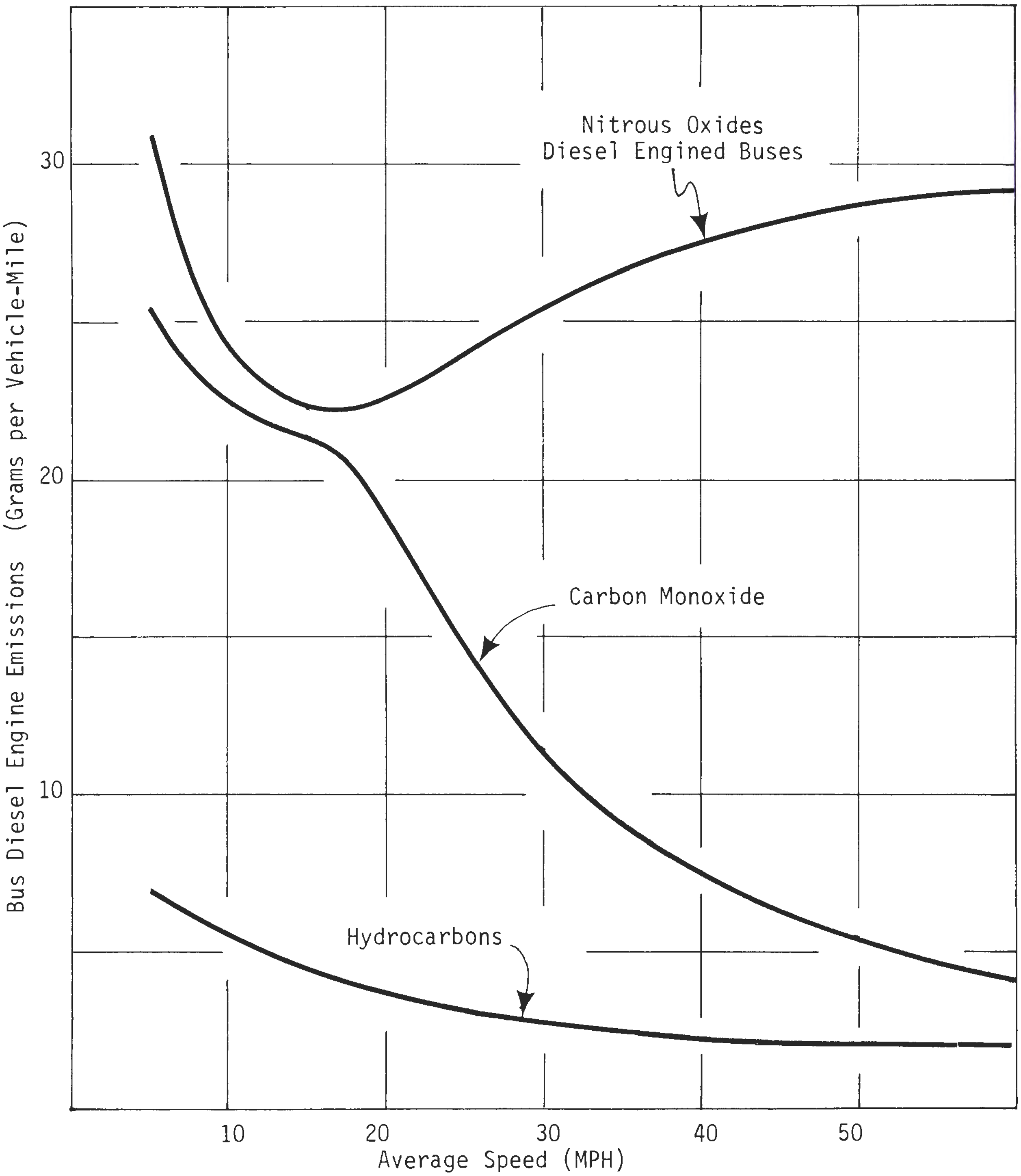
(a)	Carbon Monoxide Emissions	5% to 20% of Curve Rate
(b)	Hydrocarbon Emissions	10% to 30% of Curve Rate
(c)	Nitrous Oxide Emissions	20% to 60% of Curve Rate

(Continued)


Gasoline Engine Emissions (Grams per Vehicle-Mile)
150
100
50
1976 Carbon Monoxide
Trucks and 12+ passenger
Gasoline Buses
1980 Carbon
Monoxide
1976 Hydrocarbons
1980 HC
1976
Nitrous Oxides
10
20
30
40
50
Average Speed (MPH)



1976 Carbon Monoxide
Autos and 8 to 12
Passenger Buses
1980 Carbon
Monoxide
1976 Nitrous
Oxides
1976 Hydrocarbons
1980 NOX
1980 HC
Gasoline Engine Emissions (Grams per Vehicle-Mile)
40
30
20
10
10
20
30
40
50
Average Speed (MPH)

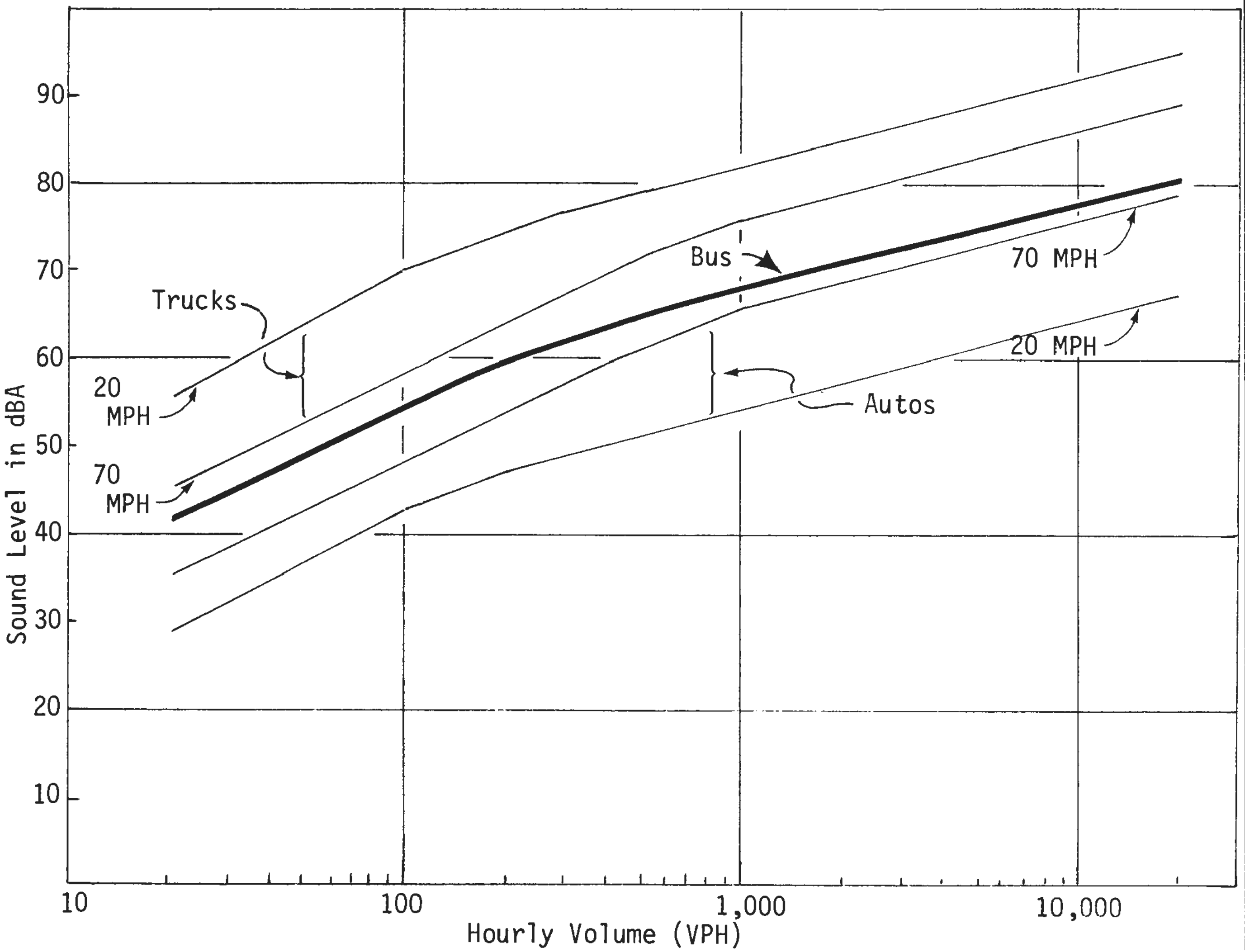


Nitrous Oxides
Diesel Engined Buses
Carbon Monoxide
Hydrocarbons
30
20
10
Bus Diesel Engine Emissions (Grams per Vehicle-Mile)
10
20
30
40
50
Average Speed (MPH)

Note: This method was adapted from NCHRP Report 117 <u>Highway Noise.</u> Reference to this report may be useful for background and more detailed explanations.

a. Using the diagram below and hourly volume count or estimates, select reference sound levels for auto, truck, or bus. For lower volumes, use the curve* on the following page.

*Experimental



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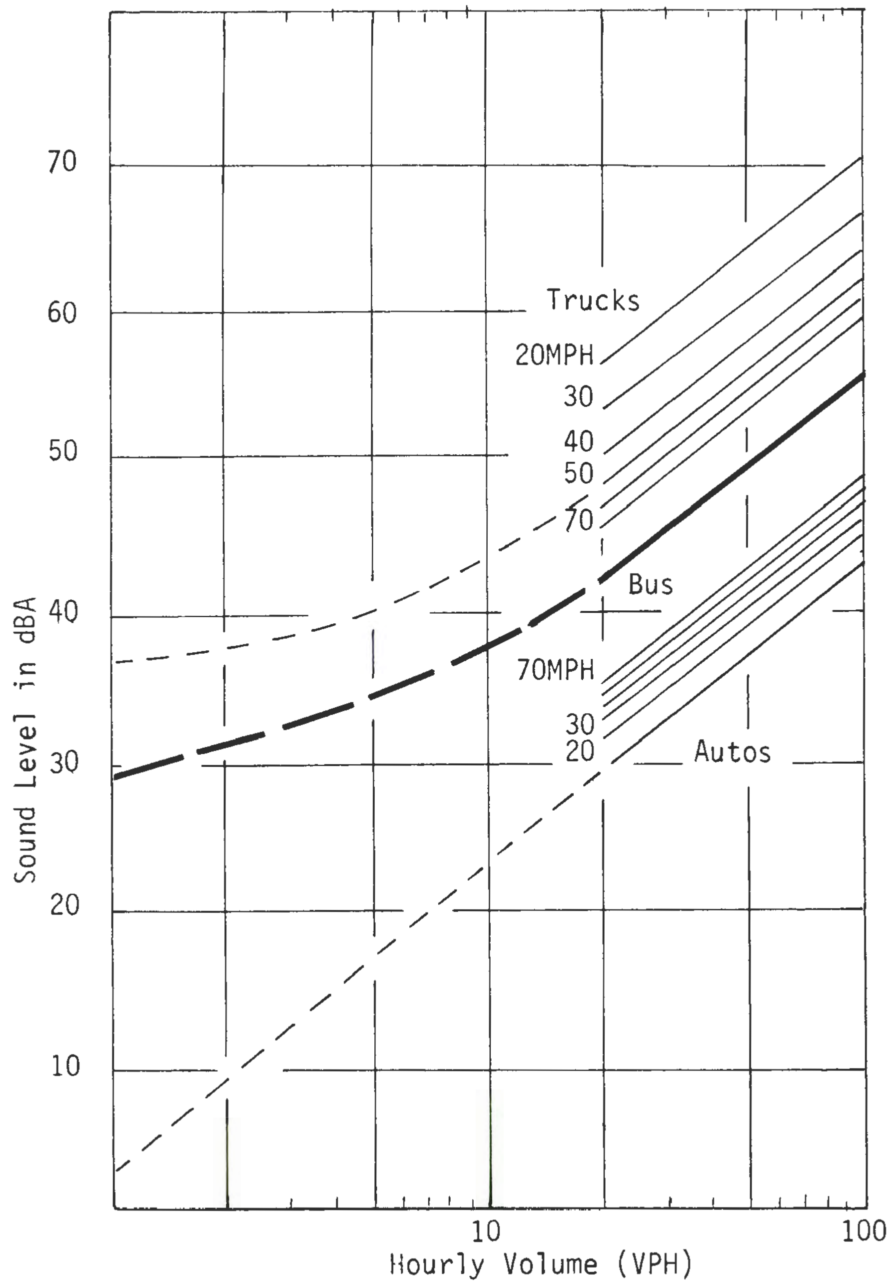
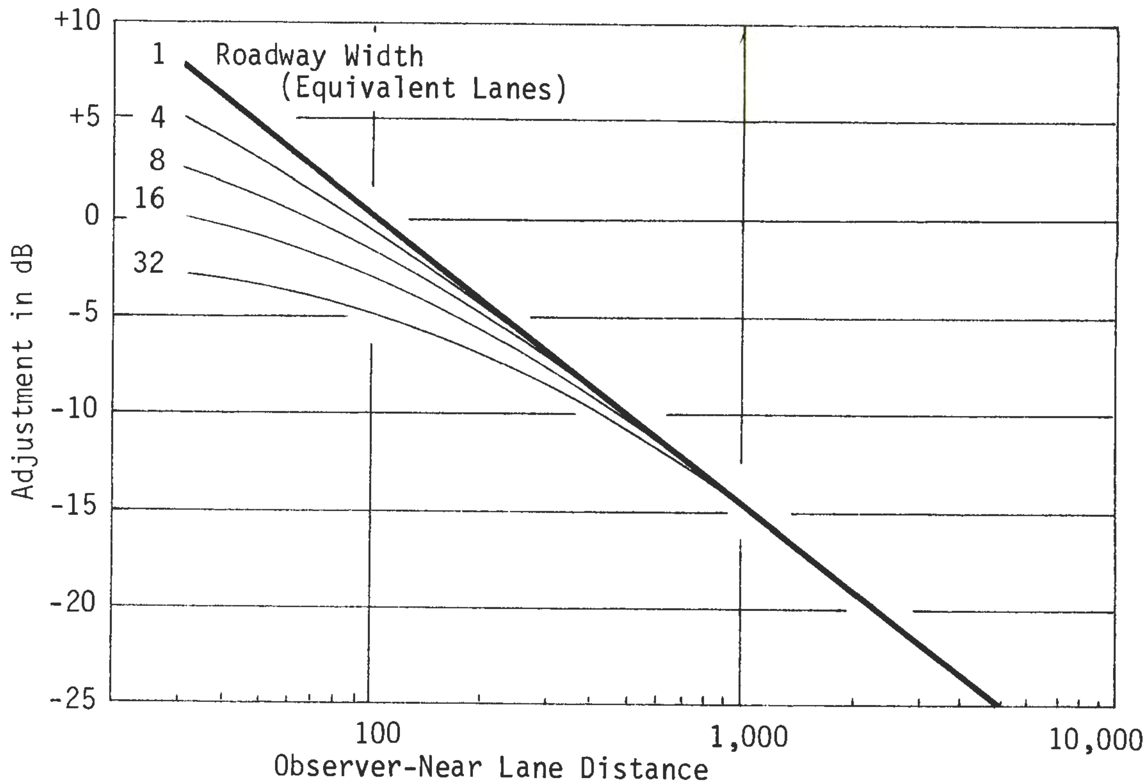


Trucks
20MPH
30
40
50
70
Bus
70MPH
30
20
Autos
70
60
50
40
30
20
10
Sound Level in dBA
10
100
Hourly Volume (VPH)

b. Correct each reference sound level for the desired observation distance and number of roadway lanes using the diagram below:



c. Adjust truck sound for highway gradients as follows:

Gradient (%)	Adjustment (dB)
2	0*
3 to 4	+2
5 to 6	+3
7	+5

*The influence of gradients of 2% or less is considered to be neglible.

(Continued)

d. Adjust for road surface as follows:

Surface Type	Description	Adjustment (dB)
Smooth	Very smooth, seal-coated asphalt pavement	-5
Normal	Moderately rough asphalt and concrete surface	0
Rough	Rough asphalt pavement with larger voids ½ in. or larger in diameter, grooved concrete.	+5

e. Adjust for traffic interruptions as follows:

Vehicle Type	Adjustment (dB)	
	L_{50}	L_{10}
Auto	0	+2
Truck	0	+4

f. Adjust for vertical displacement as follows:

Roadway Type	Adjustment (dB)
Elevated	Zero to -5
Depressed	Zero to -15

(Continued)

g. Add the adjusted value for auto, truck, and bus using the worksheet below:

DECIBEL ADDITION

Source or Element No.	Sound Level - dB	Antilog Columns - Left Digit of Sound Level								Antilog Table	
		9	8	7	6	5	4	3	2	Right Digit of Sound Level	Antilog
										0	1000
										1	1259
										2	1585
										3	1995
										4	2512
										5	3162
										6	3981
										7	5013
										8	6311
Total										9	7944

List sound levels by source or Roadway Elements.

Enter antilog table with right digit of sound level to obtain antilog value.

Enter antilog on work sheet under antilog Columns. Position by entering left digit of antilog under the column numbered the same as the left digit of the sound level.

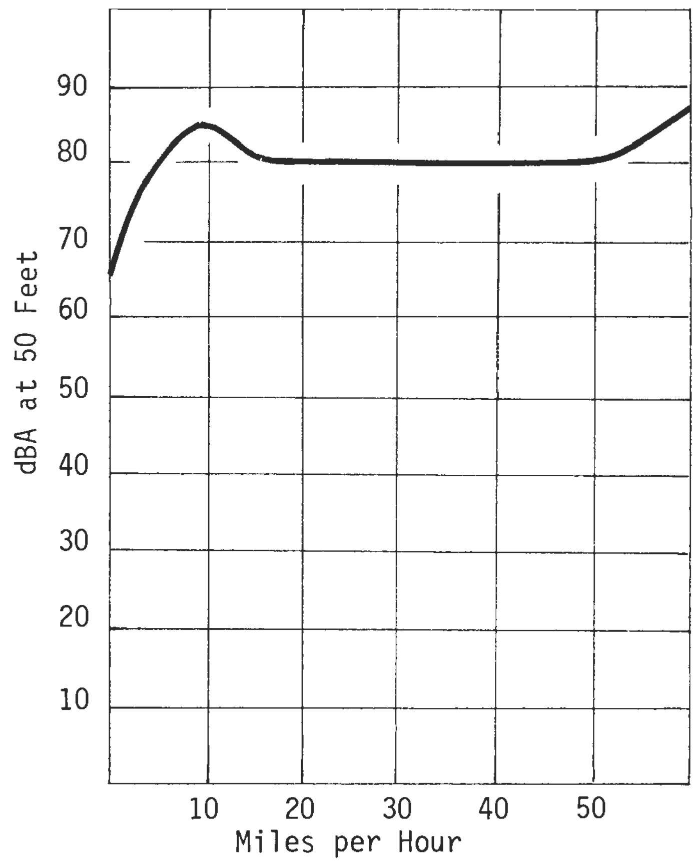
Add the antilog values of the individual sources to obtain the antilog of the total sound level.

Enter antilog table with antilog of total sound level. Obtain right digit of total sound level by selecting digit from table whose antilog is closest numerically to the antilog obtained in Step 4.

Indentify column number containing left most digit of the antilog derived from Step 4. This is the numerical value of the left digit of the total sound level.

(Continued)

h. Most of the foregoing steps apply to bus volumes of 20 per hour or more. Below that volume, each bus passing becomes a descrete event. The sound characteristics of a bus moving out from a stop probably look something like the diagram below. The curve for low volumes in Step "a" was partially based on these characteristics. As an alternative to use of the low volume curve, the impact can be subjectively judged in relation to the number of occurances and the ambient sound levels.



(1) As a comparison, some typical ambient sound levels are:

(a)	Quiet suburban area, night	30 to 40 dBA
(b)	Urban residential, day	40 to 55
(c)	Commercial	45 to 60
(d)	Industrial	50 to 65
(e)	CBD	60 to 75

a. Plot routes on a map at a scale appropriate for matching with maps of census tracts, traffic analysis zones, or land use inventory units.

b. Select one or more route access distance standards. A distance of one-fourth mile from a route is widely accepted as urban route access distance (so that complete coverage would call for routes spaced at one-half mile intervals). In areas of low population densities, one-half mile access distance is sometimes adopted.

c. Using the standard(s) selected, plot the coverage of each route by delineating the one-fourth (or selected standard) mile distance around each route.

d. Add to the display area designated by population density levels. A system of map overlays can facilitate this step.

e. Determine the area measurements of each density level within the route coverage area.

f. Calculate population in the coverage area by:

$$\text{Population} = \sum [(\text{Area A})(\text{Density A}) + \text{---------} (\text{Area J})(\text{Density J})]$$

If area of coverage is desired, sum the area measurements.

g. Calculate overall coverage:

$$\text{Coverage Percent} = \frac{(\text{Population in Coverage Area})(100)}{(\text{Total Population})}$$

The total population can often be taken as that of the jurisdiction providing transit service. Alternatively a lower cut-off point can be set in terms of population density and no attempt made to provide coverage into areas with population densities below the cut-off level. Where that level lies may become obvious through examination of the geographical grouping of population density classes. Also, a frequency diagram of density classes may reveal a "break-point" in the frequency curve that would be a convenient and realistic lower service coverage level. That lower level probably occurs somewhere around 2,000 persons per square mile (a little over 3 persons per acre).

h. Coverage analysis can be embellished by some of the following techniques:

(1) Determine coverage separately for a peak and base periods.

(2) Classify coverage areas by service frequency.

(3) Calculate coverage by route when overlay is not too great.

(Continued)

i. The access time value in the area covered (within one-fourth mile of a route) is used in mode split calculations. It can be estimated at walking speeds of 3.5 to 4.5 feet per second. A good average value for walking distance is 800 feet, yielding an access time of 3.3 minutes on each end of the trip, or 6.7 minutes total.

j. An extension of coverage analysis is described in Method 28, where the socio-economic characteristics of the service area are assessed for transit orientation and dependency.

a. To estimate total, system-wide patronage on a fixed-route, fixed-schedule bus system, calculate expected annual vehicle-miles of service:

$$\text{Annual Veh-Miles} = (\text{Daily Veh-Miles})(\text{Amortization Factor})$$

The annualization factor will depend on the number of days in the year that service is provided. Days when service is less than average weekday (Sundays, holidays, and Saturdays most likely) should be counted at their weighted value (less than one full day). A typical factor is 300.

b. Calculate the ratio of annual vehicle-miles per capita:

$$\text{Annual Veh-Miles Per Capita} = \frac{\text{Annual Vehicle-Miles}}{\text{Population Served}}$$

c. Enter the curve and select a value for annual passengers per capita.

d. Calculate annual passengers:

$$\text{Annual Passengers} = (\text{Passengers Per Capita})(\text{Population})$$

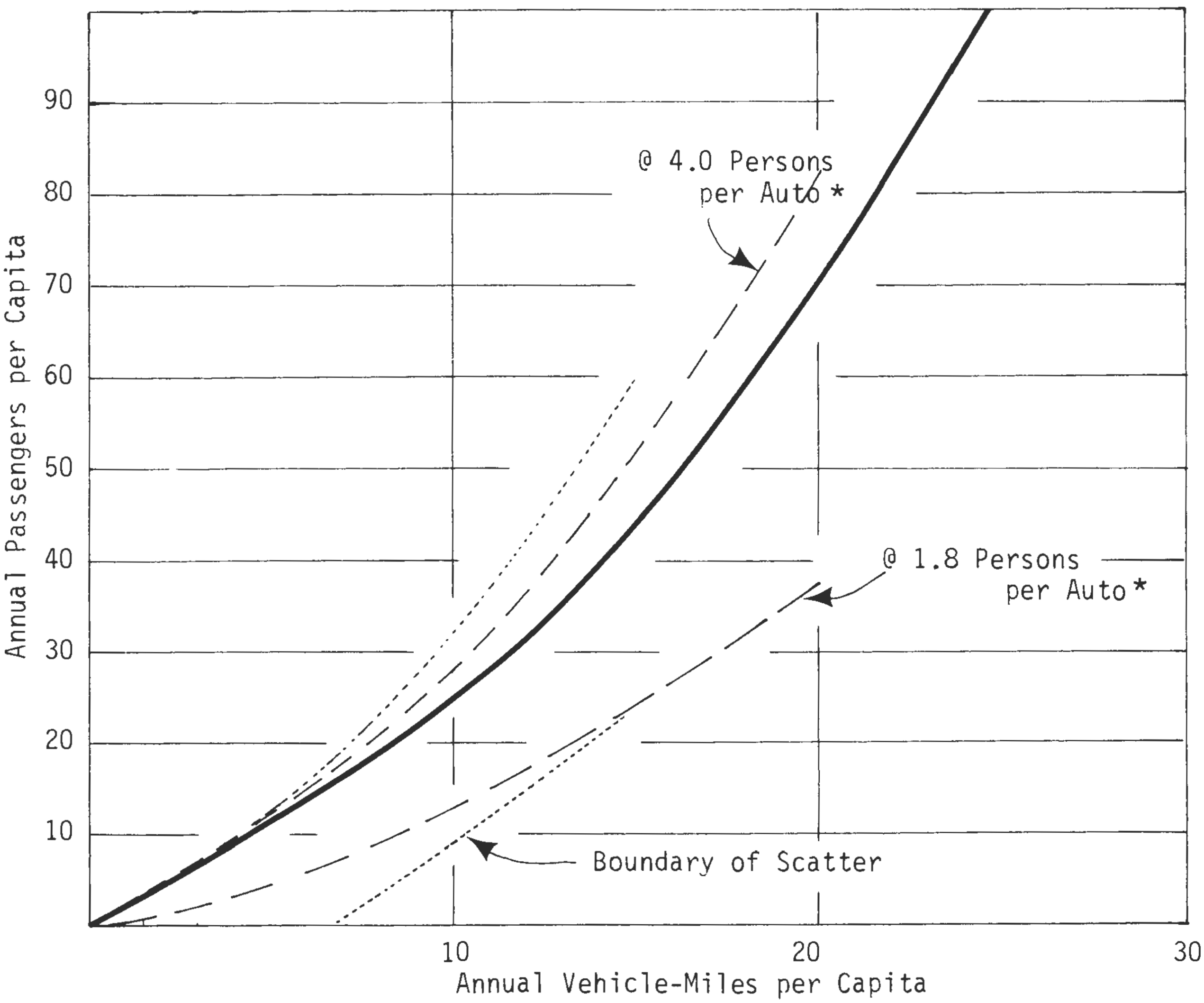
e. Calculate daily passengers:

$$\text{Daily Passengers} = \frac{\text{Annual Passengers}}{\text{Annualization Factor}}$$

Note: The annualization factor for passengers may not be the same as that for service (vehicle-miles). The passenger factor can be developed from revenue data, passenger counts, or screenline counts.

f. Cross-check the answer against other methods, if possible, or for reasonable values of passengers per route mile or per vehicle-mile.

(Continued)

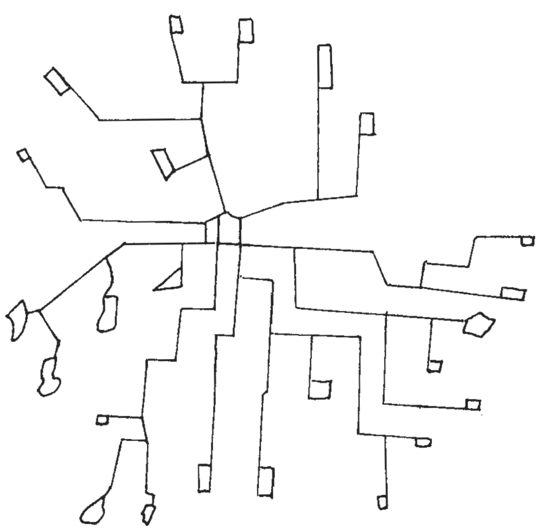


*Experimental

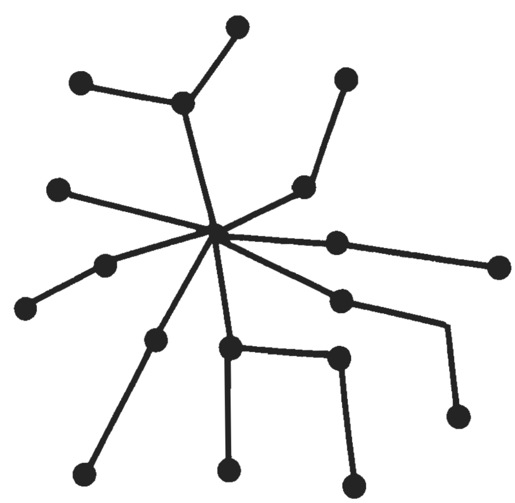
"Demand Compatibility" is a method for the comparison of transit route structure and travel patterns. The purpose of the comparison is to identify the level of compatibility between the two as a means of evaluating the route structure or to identify new market areas. The basic approach is to simplify the description of both the system layout and the trip table containing travel data so that comparisons between the two are simplified as well.

a. Lay out a system of analysis districts that represent the influence area of the system.

    (1) Simplify the route structure into corridors. This step might be facilitated if the route system can be visualized as a system of activity nodes (such as downtown, outlying business centers, and principal transfer points) with inter-connecting links. A simplified system might look like this:



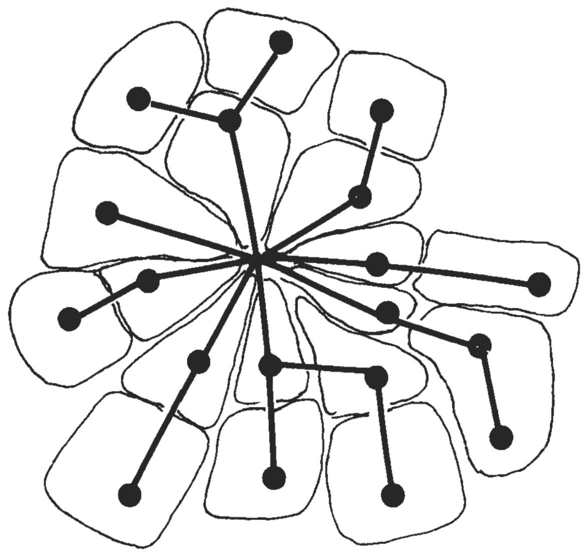
Original Route System



Simplified Links and Nodes

(Continued)

b. Layout a system of analysis districts that represent the influence area of each corridor. For a traditional radial route configuration, the districts would be sectors, probably divided into rings. For example, the district system for the routes in Step "a" would look like this:



In a sense, each district represents a transit service area or a "travel-shed" for the route system. Since the purpose is a visual comparison of data, any more than around 25 districts may be too complicated to handle manually.

c. Prepare an index relating the new analysis districts to analysis zones or whatever geographical grouping is used as the basic unit of reference for travel data.

d. Using computer processing, prepare a table of district-to-district trips. The program most commonly utilized for this is USQUEX in the UTPS system. Input (in addition to the district-zone index) could be either:

(1) Present daily person trips by transit.
(2) Present daily person trips, all modes.

The first would be used to check the route compatibility with present passenger travel patterns. The second would be used to locate new markets such as large cross-town movements.

(Continued)

Note: although this method requires computer use, it is included in the non-automated section of the handbook since it is essentially a non-automated process with computer support.

e. Display the district-to-district travel vehicles in matrix format.

f. By inspection of the present transit system route structure (simplified in Step "a" with the routes combined into corridors), identify the matrix cells that do not have direct, non-transfer service.

g. Prepare a frequency tabulation of district-to-district movements by volume ranges. Select enough class intervals for volume to define the changes in frequency from one class to another, but not so many as to needlessly split the data into fine parts. A dozen or so classes may be sufficient.

 (1) The tabulation can be in this format. In a separate column identify the number of district movements in each class without a direct, non-transfer transit connection:

Daily Person-Trip Volume	Number of District-to-District Movements in Volume Range	Number of Districts-to-District Movements Without Direct Connection
0 to 250		
250 to 500		
500 to 1,000		
1,000 to 2,000		
2,000 to 4,000		
4,000 to 6,000		

h. Identify specific high-volume inter-district travel movements that do not have direct service.

 (1) Generally, all of the higher volume movements (in the matrix) and the inter-district movements higher volume ranges (in the frequency tabulation) should have direct service. The shape of the frequency curve (when plotted) may give a clue to the selection of a volume levels above which all movements should have direct service (and perhaps even the volume levels below which service should not be provided at all unless it is provided as a consequence of servicing larger volume movements. Each inter-district trip volume above the selected level and without direct service is a candidate for a new route.

(Continued)

(2) Although this method is intended to test the relationship between route layout and travel desires, the trip table produced can be useful for many other purposes including patronage estimation under Methods 6 and 17.

(3) This method can be embellished by inserting in the cells of the matrix the number of daily bus trips. Then the ratio of person trips to bus trips in any cell can be used to tailor not only route structure but also level of service to travel volumes.

ANALYTICAL METHOD 18 FOR THE ESTIMATION OF PATRONAGE CHANGES RESULTING FROM CHANGES IN SERVICE HOURS

a. The table below illustrates typical patterns of travel by time of day for O-D survey trips, auto volume counts, and bus passenger counts:

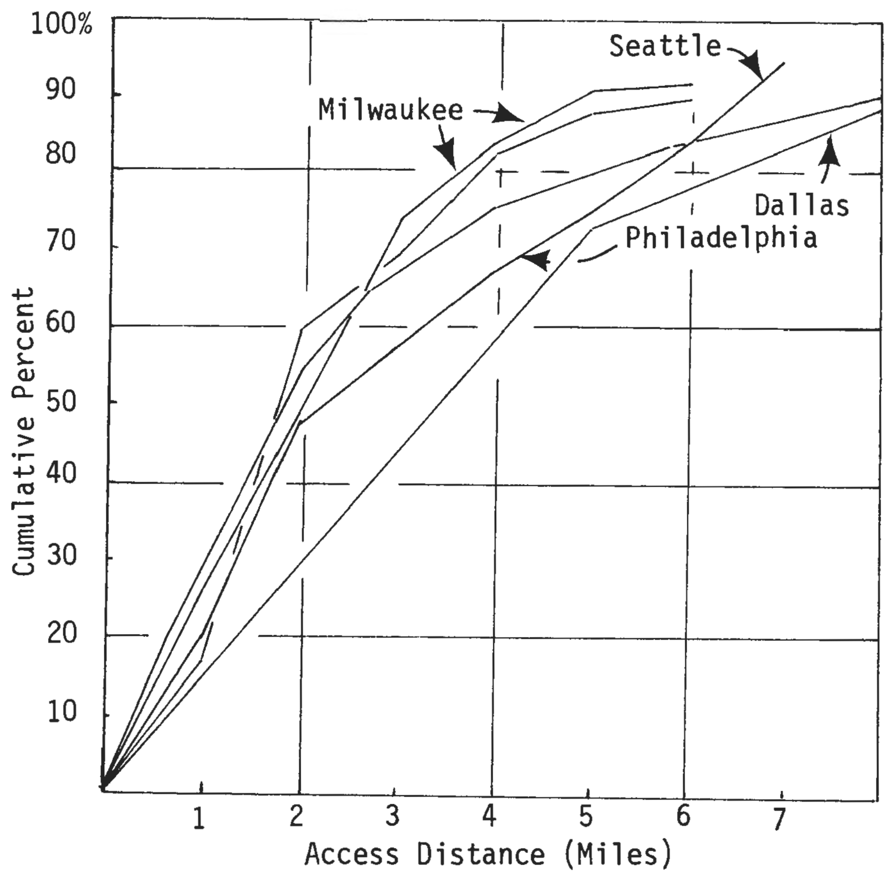
HOUR	HOURLY PERCENT			HOUR	HOURLY PERCENT		
	O-D	AUTO	BUS		O-D	AUTO	BUS
00-01	0.1	1.3		12-13	4.1	4.9	3.5
01-02	0.1	0.7		13-14	4.8	5.4	3.7
02-03	0.2	0.4		14-15	8.2	6.6	5.0
03-04	0.3	0.4		15-16	9.5	8.0	6.4
04-05	0.3	1.0	0.3	16-17	9.9	8.1	14.3
05-06	1.7	3.8	1.7	17-18	7.8	6.2	11.7
06-07	7.3	6.4	6.1	18-19	7.4	4.9	3.6
07-03	9.0	6.7	15.2	19-20	4.9	4.2	2.3
08-09	3.4	5.0	9.8	20-21	3.8	3.8	1.7
09-10	4.0	4.6	4.2	21-22	2.5	3.4	1.5
10-11	4.2	4.7	3.7	22-23	2.1	2.8	1.0
11-12	4.3	4.7	3.4	23-24	0.1	2.0	0.9

b. When changes in service hours are contemplated, the potential ridership in that time period can be estimated from the table and added to or deducted from daily totals.

(1) When extensions of service hours are under consideration, the actual data for ridership in the hour (or half-hour) immediately preceeding or following the proposed extension should be examined for clues about possible transit use in the extended period. When shortening service hours, the volume that will be lost is generally known from counts.

Note: The data in the table above will also be useful when factoring values of various statistics from daily to peak and vice-versa.

a. The curve below illustrates typical park-ride service area radius. If there are no intervening competing facilities, the draw to a park-ride lot is about six or seven miles. The service area is, of course, offset in the opposite direction of the transit service. In Seattle, only 14% of park-ride users backtracked to the lot.



b. When the potential service area is delineated, its characteristics can be used to estimate the park-ride market.

(1) If an O-D or distribution model trip table is available, the number of daily trips from the impact area to the destination (usually the CBD) can be abstracted. This is by far the best type of data for park-ride patronage calculating and is worth extra effort to obtain.

c. If a trip table is not available, the trips to the destination can be estimated, with risk, as follows:

(1) Select a trip generation rate from a nearby, similar zone and calculate total person-trips.

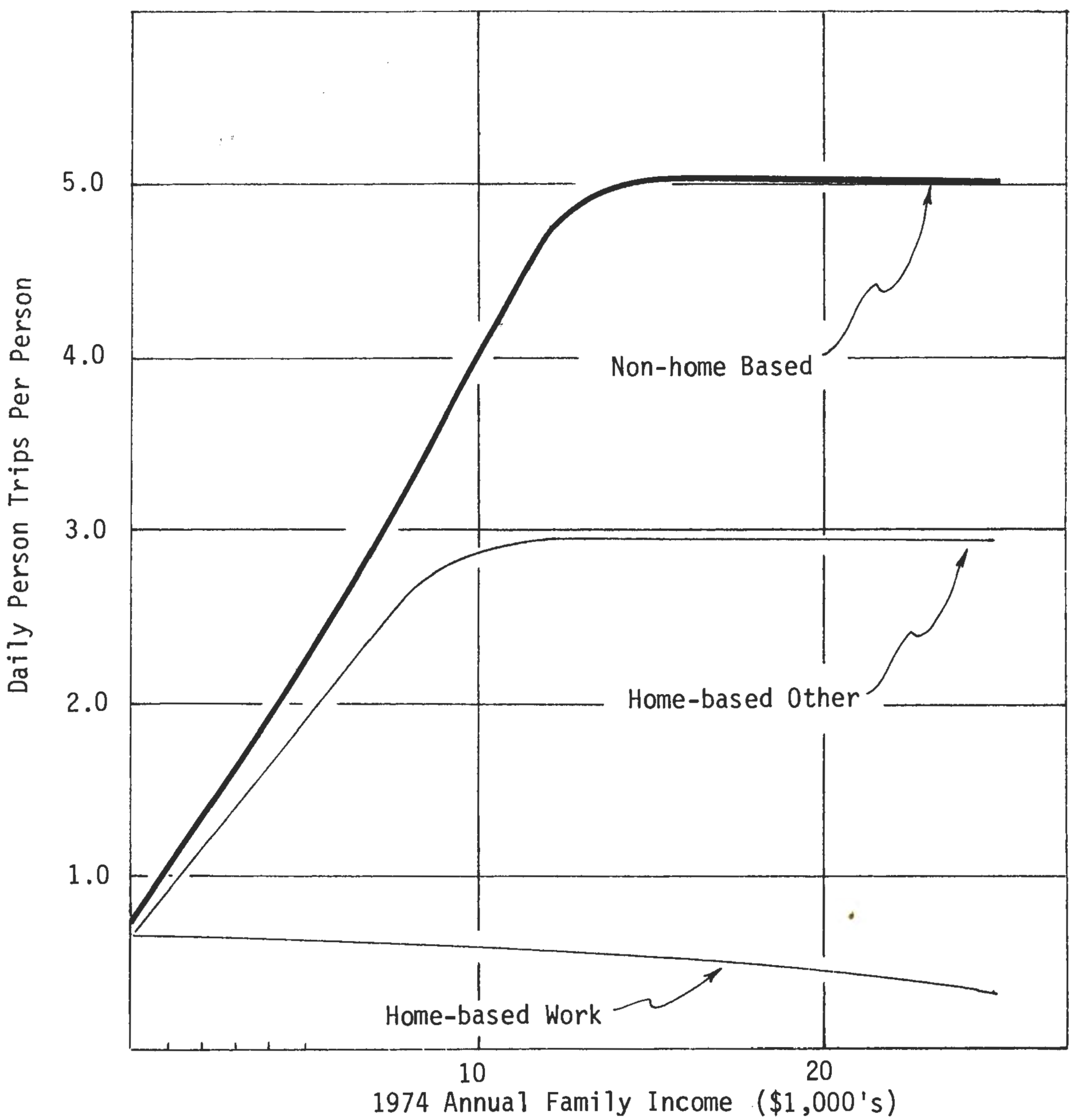
(Continued)

(2) Select a percentage from a nearby zone for the share of trips from that zone to the destination. Use that percentage to calculate daily trips between the service area and the destination.

d. An alternative (and even riskier) process* for downtown trips (which uses Dallas/Fort Worth data) is as follows:

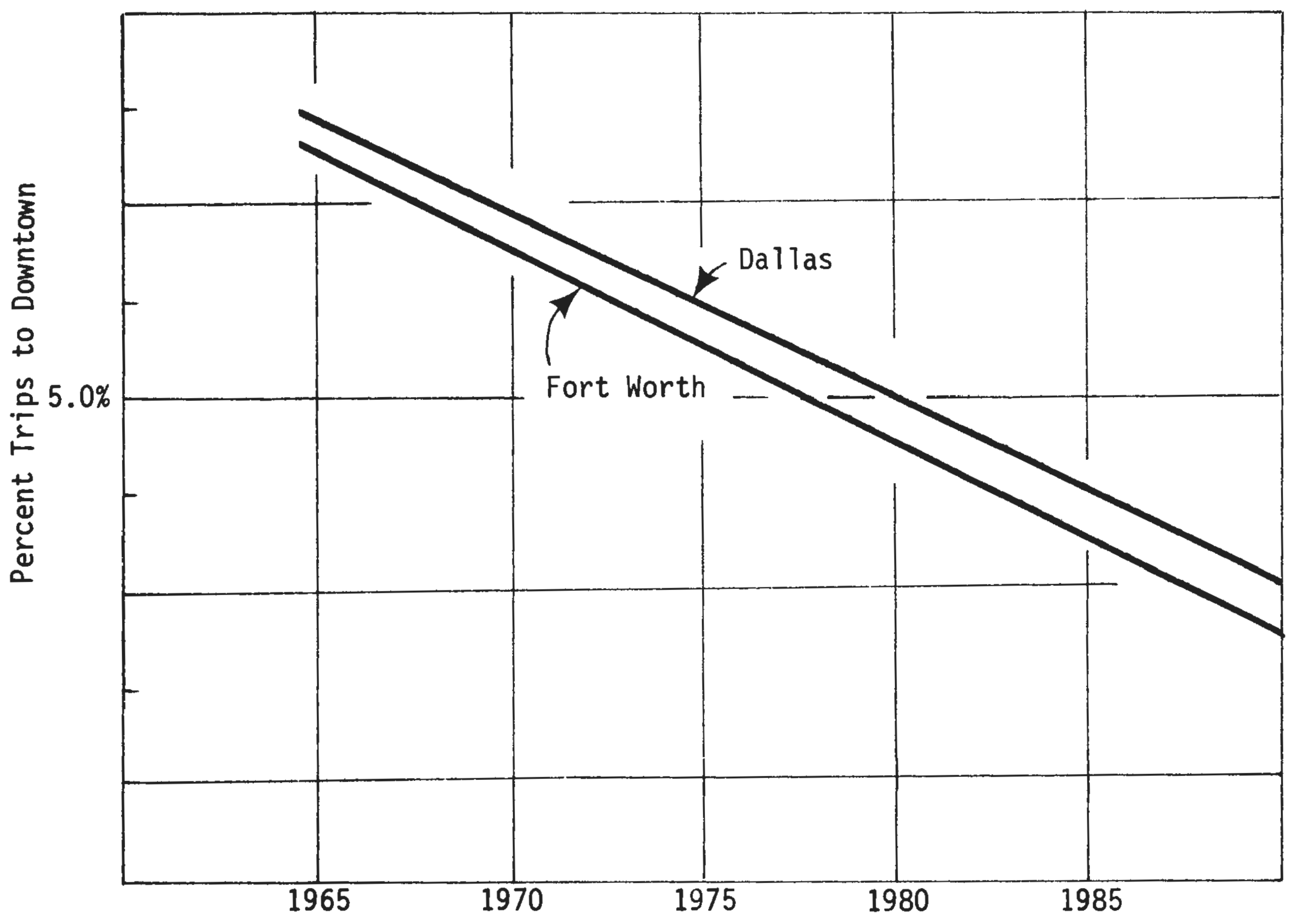
(1) Enter the curve below with annual family income for the service area and select a person-trip generation value. Calculate total daily person-trips (or home-based work person-trips if more suitable):

*Experimental



(Continued)

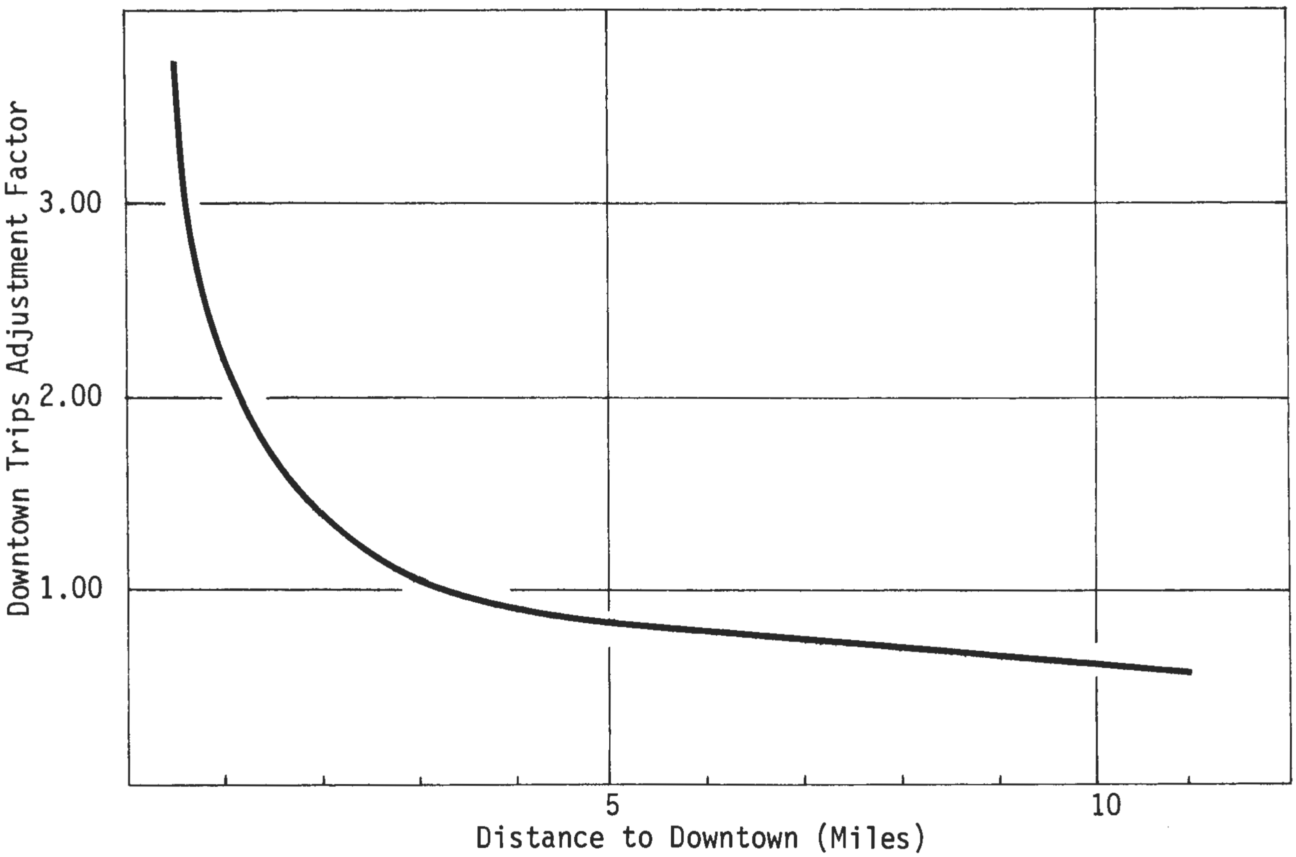
(2) For the study year, select a percentage from the curve below representing travel to downtown:



(3) Calculate person-trips to downtown using the selected percentage.

(Continued)

(4) Multiply the volume of downtown person-trips from Step (3) using an index value from the curve below, entering the curve with distance from downtown for the park-ride service area.



d. Whatever the source of the travel data (hopefully O-D or model trip table data), calculate the park-ride transit patronage using Method 6 for bus vs. auto travel between the park-ride lot and the destination.

Note: In many cases, since park-ride is often oriented to work trips, it will be necessary to further adjust daily transit trips to directional peak period trips using suitable factors from O-D surveys or counts.

ANALYTICAL METHOD **20** FOR THE DEVELOPMENT OF COST UNITS FOR IMPACT ANALYSIS OF MANAGEMENT AND ADMINISTRATIVE ACTIONS

a. Allocate annual costs into the following catagories:

(1) Repairs to revenue equipment.
(2) Light, heat and power for shop and garage.
(3) All other equipment maintenance and garage expense.
(4) Promotion and advertising expense.
(5) Fuel for revenue equipment.
(6) All other transportation expense.
(7) Injuries and damage expense.
(8) Insurance.
(9) All other safety expenses.
(10) Health and crime insurance.
(11) All other administrative and general expense.
(12) Depreciation.
(13) Taxes and licenses.

b. Allocate man-hours to the following catagories:

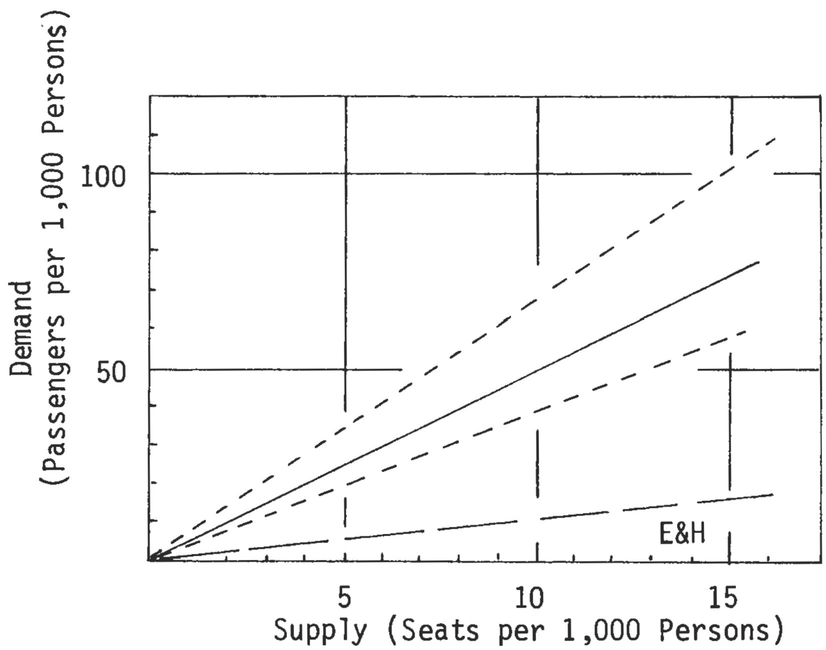
(1) Maintenance.
(2) Promotion and advertising.
(3) Transportation.
(4) Safety.
(5) Administrative and general.

c. Calculate man-hour cost ratios as follows:

(1) Maintenance cost per man-hour = a(3) ÷ b(1)
(2) Promotion cost per man-hour = a(4) ÷ b(2)
(3) Transportation cost per man-hour = a(6) ÷ b(3)
(4) Safety cost per man-hour = a(9) ÷ b(4)
(5) Administrative cost per man-hour = a(11) ÷ b(5)

a. Calculate the ratio of seats supplied (vehicle x capacity) per 1,000 persons in the proposed service area.

b. Using the curve below, determine the probable demand in daily passengers per 1,000 persons in the service area.



(1) The dashed lines cover most existing experience. The fare levels represented are from $0.20 to $0.40, averaging $0.30.

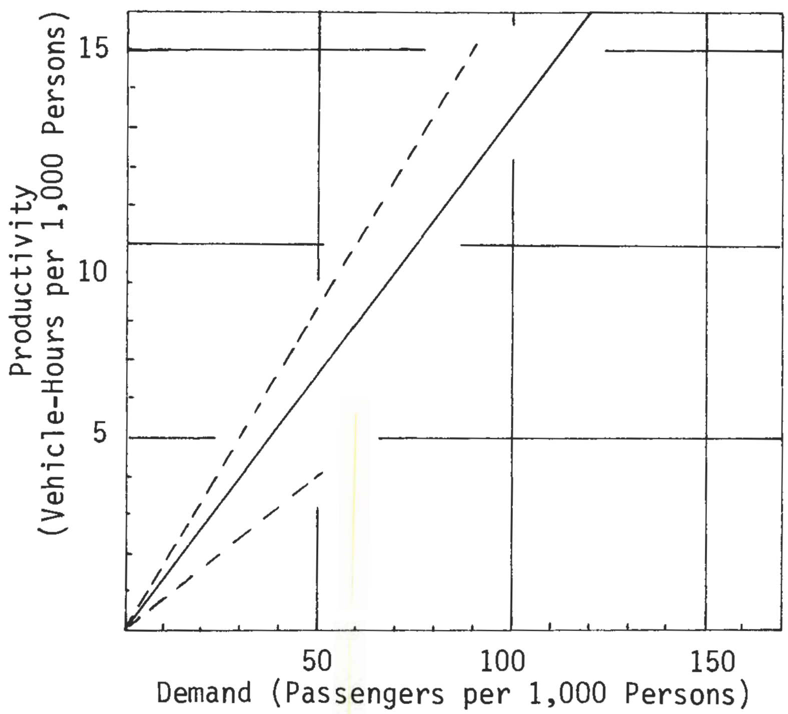
(2) "E and H" represents experience with special services for elderly and handicapped.

(3) "Shared taxi" operations fall within normal limits as indicated by the dashed lines above.

(Continued)

*Experimental

c. Using the curve below, determine the vehicle-hours required per 1,000 persons.



(1) The solid line represents a productivity of 7.5 passengers per vehicle-hour. Actual values can vary from as low as 3 to as high as 20. The dashed lines cover most existing cases.

(2) Services for the elderly should fall within the limits of normal experience as indicated by the dashed lines above (6 to 16 pass. per veh-hour, respectively) but service for the handicapped would follow the lower dashed line at best with rates as low as 1 or 2. Loading time for handicapped can take 2 to 4 minutes per stop.

a. Basic capacity values for street and highway facilities can be determined by any one of several techniques. This method presents simplified data from the Highway Capacity Manual. These capacities are intended for general application where only general design characteristics have been specified or where order-of-magnitude results are acceptable.

b. Some specific capacity changes that might result from transit actions are:

(1) Loss of green time for autos due to bus priority signals (Procedure A).
(2) Loss of a lane due to development of an exclusive bus lane or a high-occupancy vehicle lane (Procedure A).
(3) Removal of a bus stop to an off-street location, bus bay, etc. (Procedure A).
(4) Reduction in lane blockage by buses due to increases in bus stop length (Procedure A).
(5) Change in bus frequency (Procedure C, D).
(6) Change in bus stop location (Procedure A).

c. Some capacity changes that might result from transit-generated multi-modal actions are:

(1) General street and signal improvements (Procedure A).
(2) Changes in curb stopping and parking (Procedure A).
(3) Changes in peak hour demand (Procedure V).

d. Freeway capacities in vehicles per hour in one direction are listed in the following tables. The values are somewhat generalized. Refer to the Highway Capacity Manual for more detailed information. "Maximum" valves have been included in recognition of the fact that freeway volumes sometimes exceed published capacity levels due to special operating conditions or obsolescence of capacity standards. Even the "maximum" value may not represent the ultimate potential:

Number of Lanes (One Direction)	Lane Number	Hourly Vehicle Volume (Passenger Cars) at Level of Service:		
		D	E	Maximum
2	1 (curb)	1,500	1,800	1,900
	2 (median)	1,800	2,200	2,400
	Total	3,300	4,000	4,300
3	1 (curb)	1,400	1,700	1,900
	2	1,700	2,100	2,300
	3 (median)	1,800	2,200	2,400
	Total	4,900	6,000	6,600
4	1 (curb)	1,400	1,700	1,900
	2	1,600	1,900	2,200
	3	1,800	2,200	2,300
	4 (median)	1,800	2,200	2,400
	Total	6,600	8,000	8,800

(Continued)

e. Arterial capacities in vehicles per hour in one direction are listed below for general conditions including: 5% trucks, 60% green time for the arterial, location outside of CBD (factor by 0.8 for CBD), area population of one million, and level of service C. Refer to the <u>Highway Capacity Manual</u> for details.

Type Facility	Parking	Number of Lanes (One Direction)	Hourly Volume (One Direction)
Two-Way	Yes	1	520
		2	1,050
		3	1,650
	No	1	730
		2	1,520
		3	2,340
One-Way	Yes	2	770
		3	1,250
		4	1,810
	One Side	2	1,090
		3	1,930
		4	2,940
	No	1	890
		2	1,730
		3	2,580
		4	3,590

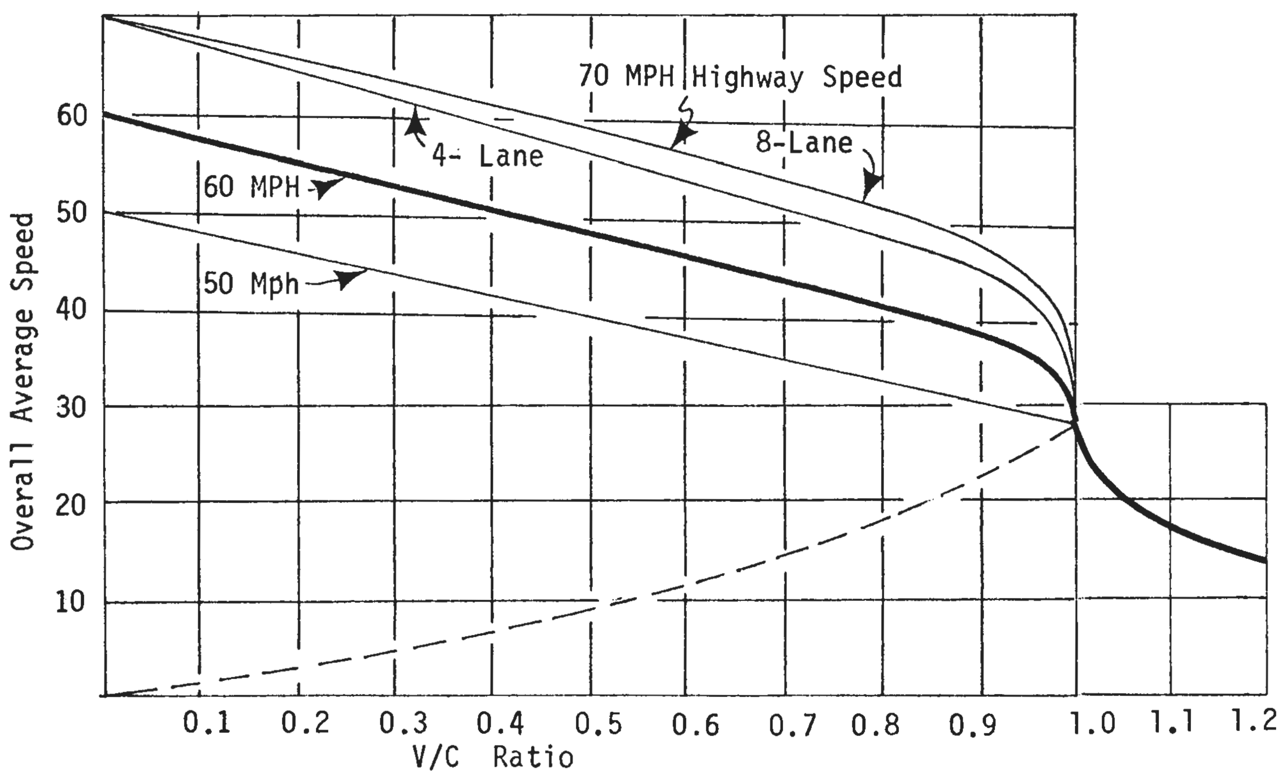
(1) Before-and-after capacities can be taken directly from this table if the field conditions are similar to the assumptions. When a TSM action changes the parking situation or the number of lanes, the capacity change can be read directly from the table. If signal timing is changed, it may be necessary to factor capacities from the table up or down around the assumed 60% green time. Changes such as bus stop relocation or revised bus frequency might require a more detailed analysis in order to gain sufficient precision so that small capacity changes can be reflected.

a. Given the vehicular volume and the facility capacity, calculate v/c ratio:

$$\frac{V}{C} = \frac{\text{Volume}}{\text{Capacity}}$$

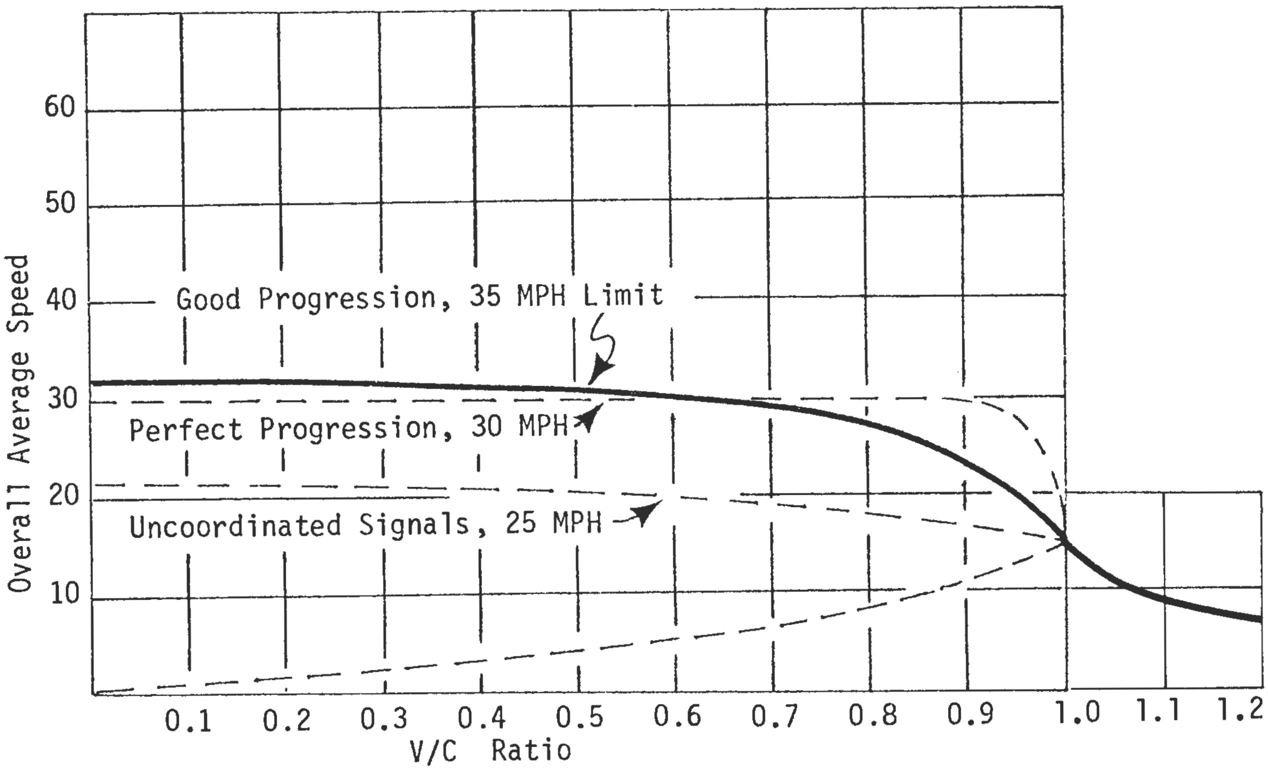
b. Enter one of the two curves below (with "before" and "after" V/C rates) and select corresponding speeds. If the curves do not exactly fit existing conditions for the case under investigation, determine the speed change by moving parallel to the plotted curve from V/C "before" to V/C "after".

(1)



(Continued)

(2)



(3) The extension of the curves beyond a V/C ratio of 1.0, while theoretically impossible, represents the effects that might be created by the "pressure" of predicted volume exceeding capacity. The curve extension would be used only when forecasted volumes are being used, because the situation could not occur in actual operations.*

*Experimental

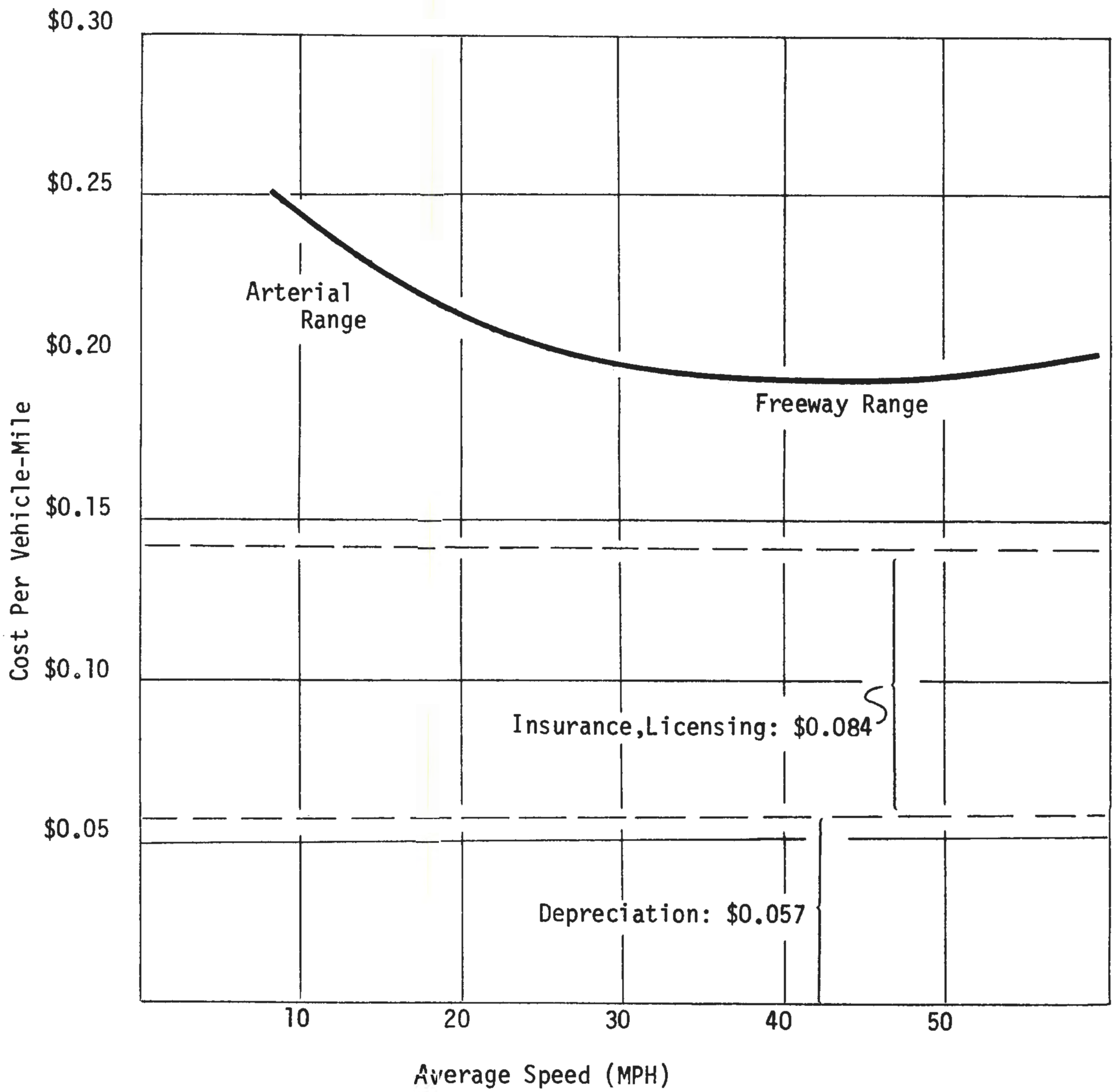
a. Enter the cost vs. speed curve (which is for a 1977 standard-sized auto) with highway type and average vehicle speed. Select a value for cost per vehicle mile. Select either total cost or operating cost, depending on the application undertaken.

b. Correct 1977 costs to other study years using a 12% rate of change.

c. Adjust costs for vehicle type.

Type Vehicle	Ratio of Operating Costs
Large	1.8
Standard	1.0
Compact	0.8
Sub-compact	0.7

(Continued)


$0.30
$0.25
$0.20
$0.15
$0.10
$0.05
Cost Per Vehicle-Mile
Arterial Range
Freeway Range
Insurance,Licensing: $0.084
Depreciation: $0.057
10
20
30
40
50
Average Speed (MPH)

a. Multi-modal accident rate can be selected from the table below:

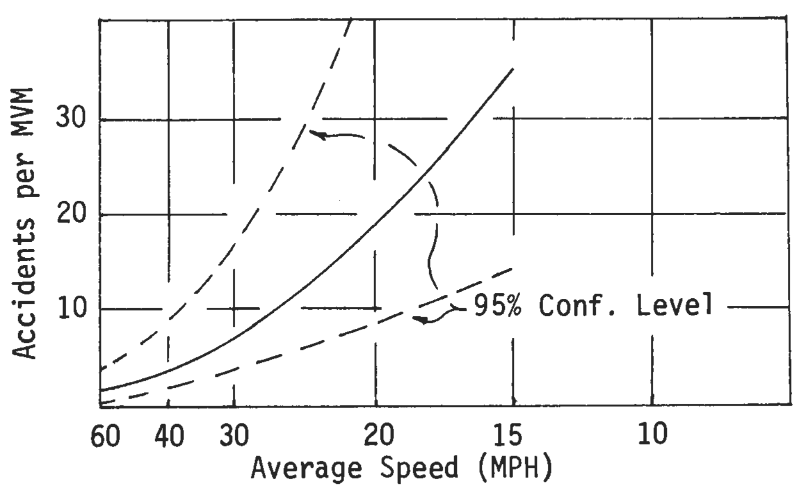
Type Facility	Vehicle Accidents Per Million Vehicle-Miles (MVM)			
	Property Damage	Injury	Fatal	Total
Freeway	4.03	0.64	0.02	4.69
Arterial	16.52	1.64	0.03	18.19
Local	16.52	2.48	0.03	19.03

Note: Substitute local factual data, if available.

b. Passenger accident rates are tabulated below:

Type Facility	Passenger Accidents Per MVM	
	Injury	Fatal
Freeway	1.03	0.02
Arterial	2.65	0.03
Local	3.65	0.03

c. The curve below can be used to adjust arterial values from Step "a" for average speed:



(Continued)

d. Bus accident rates are:

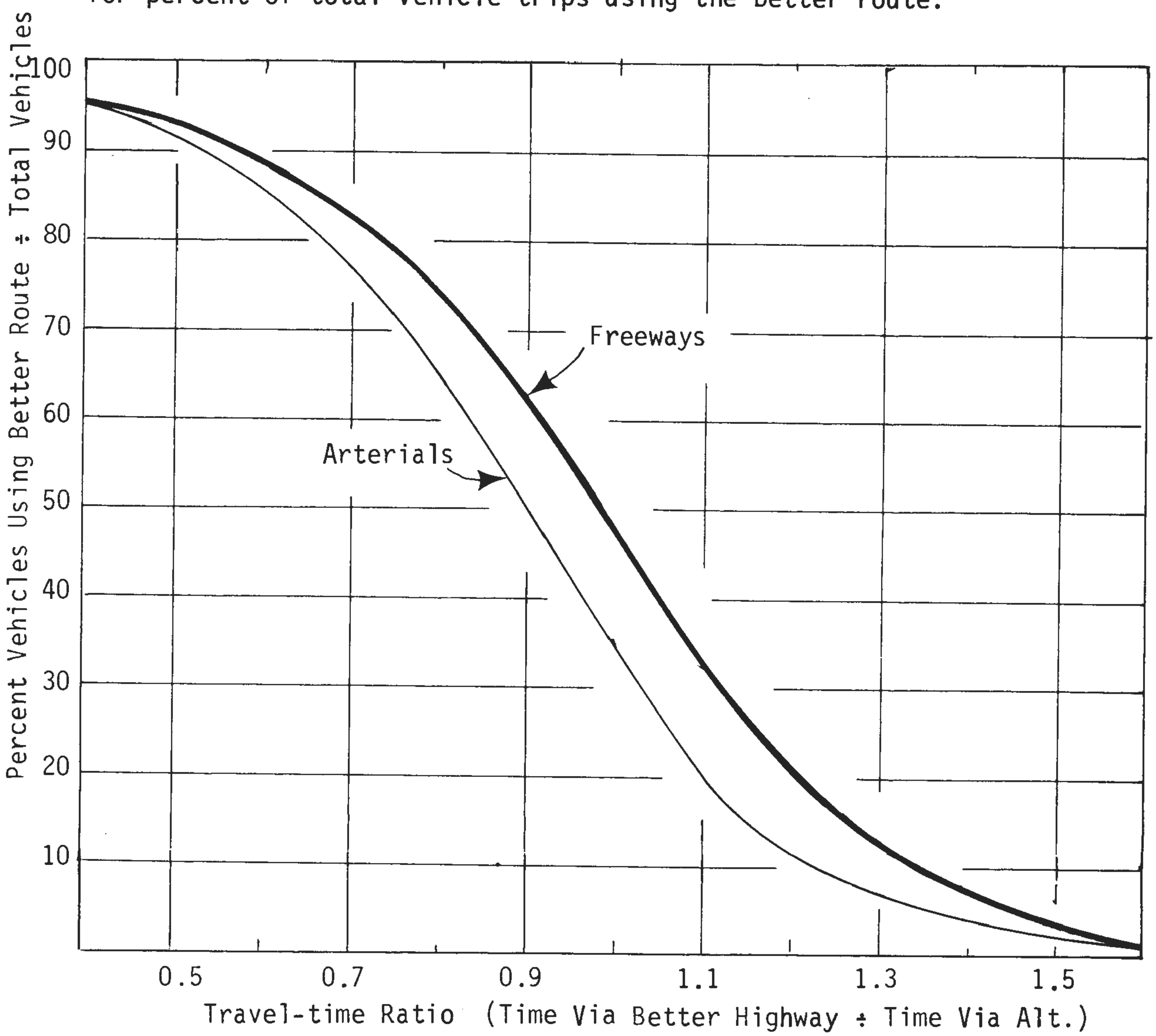
Area Population (1,000's)	Vehicle Accidents Per MVM	Pass Accidents Per MVM
0-100	82.6	12.2
100-250	56.6	16.1
250-500	58.8	17.2
500-1,000	48.2	18.8
1,000 up	67.2	21.5

ANALYTICAL METHOD **26** FOR THE PREDICTION OF TRAFFIC DIVERSION AS A FUNCTION OF TRAVEL-TIME RATIO

a. When two highway routes are competitive, estimate the travel times on each between common points.

b. Calculate a ratio of better route travel time ÷ quickest alternative route travel time.

c. Enter the curve below with the travel time ratio and select a value for percent of total vehicle trips using the better route.



d. Apply the percentage to point-to-point total vehicle volume to calculate route volumes.

(1) Point-to-point total vehicle volume may be difficult to obtain. O-D data is the best source, although in some cases screenline count data can be used.

ANALYTICAL METHOD 27 FOR THE IDENTIFICATION OF TRANSIT DEPENDENCY AS A FUNCTION OF SOCIO-ECONOMIC CHARACTERISTICS

1. Select values for the following socio-economic variables that are associated with transit dependence.

   A. Population Density (Default value: over 5,000 persons per square mile).

   B. Persons per Auto (Default value: under 3.0).

   C. Percent population over 65 years (Default value: over 20%).

   D. Percent population between 6 and 12 years (Default value: over 20%).

   E. Ratio of mobility impaired population (Default value: over 50 per 1,000 persons).

   F. Annual family income (Default value: under $4,000).

2. Using map overlays or any other suitable techniques, identify areas in the transit service area and its immediate vicinity where one or more of the selected values for the socio-economic variables are violated.

3. Repeat Step 2 for earlier periods. Since the census data will be the most probable source for much of the information check at least the last two census, plus any intermediate year special surveys that might contribute data.

4. Inspect the series of map displays (or tabulations, if more appropriate) and divide the study area into:

   A. Areas with high transit orientation or potential, where one or more of the transit dependency variables has been identified as over or under the bench-mark value. (Note: It might be useful to rank areas so-identified by the number of variables in each area contributing to the high transit dependency classification)

   B. Areas with low transit dependency.

   C. Areas that are changing.

5. Assess transit services in relation to the classification of Step 4. Obviously, type 4A areas are candidates for the higher levels of transit service, although they are likely to already have good service as a result of on-going system development. The changing areas, type 4C, should be monitored on a regular basis (more often than 10-year census periods) so that service revisions can be anticipated as these changing areas move from independent status to transit dependency or vica versa. Type 4B areas are where service should be marketed with more emphasis on amenities than on, for example, cost.

CHAPTER THREE: PRIORITY PROGRAMMING

The objective of priority programming is preparation of a ranked list of proposed TSM actions, along with their impact estimates and effectiveness values, for submission to whatever decision process is appropriate for the agencies involved in TSM planning and implementation. This chapter sets forth a non-automated method to prepare such a list.

Like the procedures for action impact calculation, it is very likely that the steps for priority programming will be repeated several times before the final TSM program is ready. For example, if there are alternatives involved, the steps could be operated to produce comparative data for each set of alternatives. After the alternatives are resolved, a second pass through the process could be undertaken to produce a priority ranking list for projects within one mode (transit, for example). Then, the integration of transit and highway projects could require a third exercise of the programming steps based on multi-modal performance measures.

Note that the process in this chapter does not perform evaluation. Rather, the process guides the analyst in developing information to assist the decison-maker in his evaluations.

PERFORMANCE MEASURE CHANGES AND EFFECTIVENESS CALCULATION

Figure 3–1 is a sample of an evaluation worksheet. The worksheet illustrated accomodates two actions and a large number of performance measures. Versions can be drawn that are smaller or larger as desired, depending on the number of actions to be evaluated and the number of performance measures being utilized. Using this type of worksheet requires the following steps:

1. List the name of the performance measure(s) being used.

2. Note the level at which the analysis is being made (route, system, etc.). In priority programming, it is important to keep in mind the level at which impact was calculated in Chapter Two (i.e., system, corridor, route, etc.). Also important is the type of analysis being conducted. Alternatives can be resolved at the route level. Project ranking should be done at the system level. Integration of multi-modal projects will probably require a basis of multi-modal systemwide statistics.

3. Record the "Base Value" of the performance measure representing the unimproved performance of the system (or route) being studied. Performance measures, rather than their factors, are used in this worksheet. It is necessary to convert all performance data (base value or the value revised by action

FIGURE 3-1. TSM ACTION EVALUATION WORKSHEET

			Problem No: Action:					Problem No: Action:				
Performance Measure	Level	Base Value	Revised PM	% Diff.	Sign	Wt.	Eff	Revised PM	% Diff.	Sign	Wt.	Eff
			Total Effectiveness					Total Effectiveness				
Capital Cost Annualized Capital Cost Annual Operating Cost												
Total Annual Cost												

impact) from factors to measures. It will be helpful to show both the factors and the performance measure in the "Base Value" column. For example, show:

$$\frac{\text{(175 Passengers)}}{\text{(80 Vehicle-miles)}} = \text{2.2 Pass. per Veh-Mile}$$

rather than just the resulting ratio "2.2 Pass. per Veh-Mile," which is the performance measure.

4. Next, calculate and enter the changes in each performance measure caused by an action (in the column "Revised PM"). The amount of change predicted in each performance measure factor can be taken directly from Chapter Two's "Action Impact Worksheet" for each action. Then the base value factors (from the "Base Value" column) are simply revised by the magnitude of the change and the revised performance measure calculated. When the value of an action impact on a PM factor is found to be insignificant or zero, the base value is entered in the "Revised" column.

5. Calculate the "% Diff." in the performance measure. Divide the value of that cell in the "Revised" column by the base value, and record the resultant value (times 100) in the "Percent Difference" column. Repeat this for every performance measure listed.

6. Do not record the arithmetic sign of the percent change. Instead, place a negative sign in the "Sign" column for any percentage change which is <u>undesirable</u>. For example, if a base value for a performance measure is too low, and the action decreases the ratio even more, the sign in the "Sign" column will be negative because the impact of that action on that measure is undesirable. Conversely, any improvement in performance will rate a plus sign. The reason for this is that the effectiveness of the action will be the algebraic total of the weighted percentage change in each performance measure, so a move toward objectives must be a "+", and a move away must be "-".

7. An objective assessment of the relative importance of performance measures may become necessary for the calculation of effectiveness, and this requires the development of a set of weights. To compare a 10 percent reduction in travel time to a 10 percent reduction in fuel consumed means nothing unless the relative importance of travel time savings to fuel savings has been defined. (See the discussion of "Performance Measure Weighting" following Step 8.)

8. A dimensionless number representing "effectiveness" is calculated for each action. This is done by multiplying the percentage change in each performance measure by the weight assigned to it and summing (algebraically) down the column. The algebraic total is entered in the space provided in the "Total Effectiveness" row of the evaluation worksheet.

The calculation of total effectiveness for an action is expressed by the formula:

$$TE_1 = \sum (\%_{k1})(RW_{ik})$$

where,

TE_1 = total effectiveness of action 1

$\%_{k1}$ = percentage change in performance measure k caused by action 1

RW_{ik} = relative weight of performance measure k of priority i

Performance Measure Weighting

The complexity of the process of setting weights depends on the number of performance measures being utilized. A handful of measures can be weighted by simply inspecting the list and picking relative values. When only a dozen or fewer performance measures are being used, the weighting process is as follows:

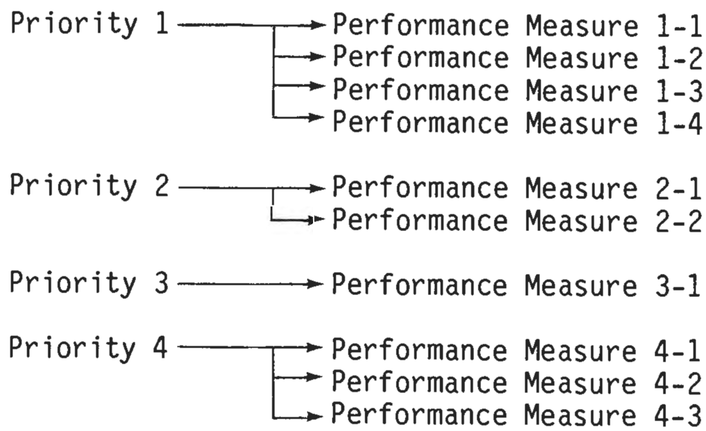
a. Multiply the number of performnace measures utilized by 10 to obtain the total weight.

b. Assign points from this total to each performance measure so that the sum of assigned points equals the total weight from Step a. Points should be assigned on the basis of relative importance. The most important measure will be given the highest number of weighting points, and the least important measure will be given the lowest.

c. Enter these weights in the corresponding line of the evaluation worksheet in the column "Weight".

For example, assume that three PM's are listed. Three measures, multiplied by 10 points per measure, equals 30 total weighting points. If the three measures are all equally important, then assign 10 points to each one. However, if measure A is three times as important as B and C, then A should receive 18 points while B and C get 6 each (a total of 30). If A is slightly more important than B, and B is much more important than C, the weighting might look like this: 14 points for A, 12 points for B, and 4 points for C (the same total of 30).

The situation can be considerably more complicated when a large number of PM's must be ranked. The use of twenty or thirty measures would make the direct assignment of a rational set of weights very difficult. The task of assigning weights in complicated situations can be simplified by developing a classification scheme which relates TSM priorities to individual performance measures. Such an arrangement might be diagramed as shown below. The branches (and an arbitrary numbering system) illustrate the linkage from priority to performance measure:



The members of each group of performance measures can be weighted among themselves because each group is independent of all others. The total weight for each group is determined by multiplying the number of elements in the group by 10. Thus, if the number of performance measures in a group is four, 40 points would be spread among the four PM's to ... portance in that group, just as was described ... for a simpler case. If there are two PM's, ... ed. If only one PM is linked to a priority,

... ures have been weighted within groups, then ... e focus of each PM group are weighted. With ... would be allocated among priorities in pro- ... each priority has in relation to others.

... g weights have been designed to be as simple ... ctual process, when it becomes part of TSM ... en as a participatory activity. The selection ... alone is hazardous. It is seldom easy for ... appreciate the subjective factors that the ... der. Ideally, the weights should be assigned ... s who will approve the TSM program.

... enging step in the whole TSM planning process. ... for assigning weights must be explained. ... nvinced that they should participate and that ... e results.

There are several ways that this process could be approached. Maybe individual interviews would be used to obtain weight distributions, and some sort of averages developed. Probably an informal meeting would be better, so that interaction could occur among the members of the decision-making body. Perhaps unweighted effectiveness could be illustrated first, followed by display of the effects of varying weights among the performance measures. Individuals might be interested in seeing how their selections, and changes in those selections, affect the outcome.

On the other hand, a danger appears in the weighting approach if too many participate. A series of divergent viewpoints will tend to wash-out differences, and the combined weights will fall very close together. A way around this problem would be to prepare alternative weighting patterns representing heavy emphasis on each of the different TSM priorities. Then these can be used to illustrate how alternative weights will affect priorities, and perhaps a consensus can be reached on one pattern or another.

Once the weights are allocated, the process calls for calculation of the relative weights. A relative weight must be calculated for every performance measure. The following formula can be used:

$$RW_{ik} = PW_i \times PMW_k$$

where,

RW_{ik} = Relative weight assigned to performance measure k of priority i

PW_i = Weight of priority i

PMW_k = Weight of performnace measure k

TABULATE AND PLOT PROJECT DATA

After an evaluation worksheet has been completed for each action, the data can be reformatted for the program development process. Just how this process will be carried out and through which channels will vary agency-to-agency. Nevertheless, two simple layouts are suggested for the presentation of the material developed to this point.

First, the base value and revised value of each performance measure can be listed in a format like the "TSM Action Evaluation Summary" in Figure 3–2. The effectiveness number and the cost can be added at the bottom.

In Chapter Two, the first step taken was to prepare a preliminary design for each action and to estimate capital cost and project operating

FIGURE 3-2. TSM ACTION EVALUATION SUMMARY

		Problem Number: Action:	Problem Number: Action:	Problem Number: Action:
		Capital Cost:$	Capital Cost:$	Capital Cost:$
		Life: Years	Life: Years	Life: Years
		Salvage Value:$	Salvage Value:$	Salvage Value:$
		Interest Rate: %	Interest Rate: %	Interest Rate: %
Performance Measure	Base Value	Revised Performance Measure Value	Revised Performance Measure Value	Revised Performance Measure Value
Annualized Capital Cost Annual Project Operating Cost Change in Operating Cost				
Total Annual Cost				
Effectiveness				
Cost Effectiveness				

costs. This information can be used to calculate cost-effectiveness, if desired, or can be used directly as an annual cost in the evaluation process. Total annual costs are calculated by the following formula:

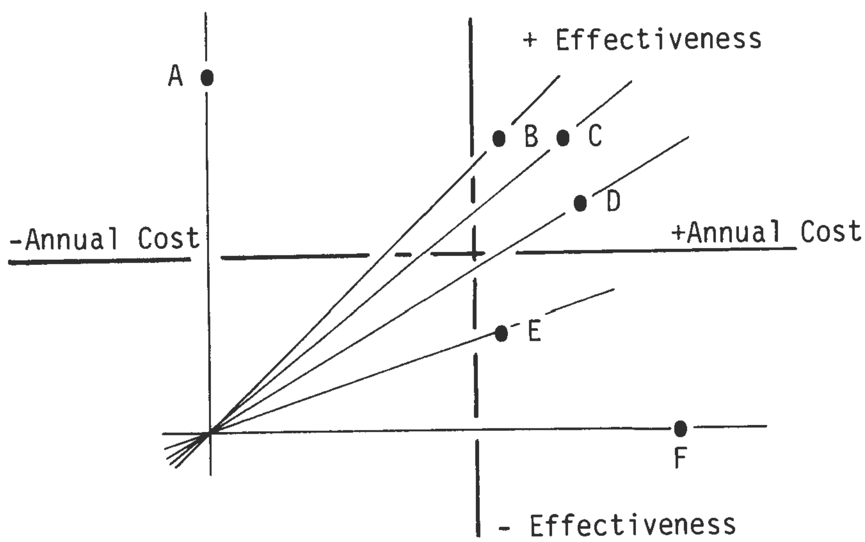
Total Annual Cost = (Annualized Capital Cost) + (Annual Project Operating Cost) + (Plus or Minus Change in Annual Transit Operating Cost)

where,

Annualized Capital Cost = (Capital Cost) (Capital Recovery Factor) - (Salvage Value) (CRF - i)

If a cost-effectiveness ratio is calculated, such as dollars per effectiveness point, space is provided for its entry. However, when evaluating TSM actions, costs may turn out to be negative, i.e., there might be operating cost savings greater than any annualized value of capital cost (if indeed there is any capital cost at all). Further, there may be negative effectiveness as well. Therefore, the cost-effectiveness ratio might take some unusual forms that would confuse the process of evaluation and selection of projects for the TSM program.

A simple cost-effectiveness diagram can be substituted, such as this:



In effect, the axis is relocated to a point defined by the greatest negative cost and the greatest negative effectiveness (points representing actions A and F in the diagram). The slope of the rays passing from the new origin through each point represent the cost-effectiveness, with the most cost-effective project defined by the ray at or approaching the vertical.

Certainly, there may be presentation formats that are more familiar or suit particular conditions better. If so, they should be used. Further, there is nothing in the process described here that is intended to substitute for the more traditional evaluation techniques or the consideration of subjective material. The analyst may wish to add or substitute methodology (i.e., benefit-cost analysis).

In any event, the analytical approach is designed to prepare objective information for use in the process of preparing a TSM program. The steps from this point will likely involve selection from among alternatives, and priority ranking of projects. Each of these subjects is discussed in following paragraphs.

EVALUATION OF ALTERNATIVES

As stated earlier, the process might have to be exercised several times for different purposes. The first set of calculations might be made to evaluate the alternative TSM actions that have been identified for a particular problem. The base value and revised value of the performance measures for each alternative can be entered on the evaluation summary sheet, probably with a separate summary sheet for each set of alternatives.

Evaluation techniques for treating problems such as the selection from among alternatives are found in many forms. Generally, however, they can be divided into two groups: methods which attempt to present as much data as possible, and methods which attempt to organize and refine the data into one or two figures of merit or index numbers.

The first method exposes the decision-maker to the entire array of information. It avoids any possibility of masking any weaknesses in the characteristics of the project. The decision-maker can choose with relative security because of the richness of the data available to him. However, the drawback to the method is the confusion that might result from presentation of more data than the decision-maker can effectively grasp and utilize.

The second method attempts to distill the profuse data generated during analysis to a single number that represents the worth of a project. Alternatives can presumably be ranked on the basis of how their index numbers compare with the index numbers of the other potential solutions. There is little chance of confusion because all characteristics are presumably represented by one factor. The drawback is, of course, that reducing the data generated by the analysis down to a single array of numbers will conceal items of special interest and weaknesses that might otherwise have been disclosed.

These two types of evaluation are not exclusive in any way. Rather, they are complementary. The Action Evaluation Summary worksheet contains data in a format so that both methods of evalution can be applied. The first method is supported in a simple and straightforward manner with the tabulation of changes in system performance measures. The second method is supported by listing the weighted effectiveness of each action.

Project cost information can be used to constrain the selection process. Obviously, an alternative which exceeds the possible budget or takes too large a slice may have to be dropped from further consideration, thus simplifying the evaluation of other alternatives. Consideration of manpower and time constraints is also appropriate.

PROJECT RANKING

As alternatives are resolved, the number of actions is narrowed down to one action (or action package) intended to solve each problem identified at the start of the TSM planning process. With minor modifications, the same technique used to assist in the selection of the best alternative can be used to rank the surviving alternatives with the other TSM projects, in order from the most effective to the least effective.

First, another version of the Evaluation Worksheet is prepared. The actions are ranked by effectiveness or cost-effectiveness.

Second, project cost constraint is checked for any projects which clearly do not fit the budget.

Third, each action is compared to those directly above or below it on the effectiveness ranking. This is where the revised and base values of performance measures prove useful. If this evaluation exposes a strong feeling that the action being checked is out-of-place, the ranking can be modified to correct its priority. However, the final TSM program will not likely be sensitive to slight displacements of the rankings, so priority modification due to small differences should be avoided.

The final result of this exercise will be a listing of the actions and their costs, with the actions ranked according to their cost-effectiveness, modified by subjective evaluation of the individual changes to system performance.

HIGHWAY AND TRANSIT PROJECT INTEGRATION

The same concept can be carried to a multi-modal ranking of projects. In such a case, a set of systemwide, multi-modal performance measures must be chosen that are relevant for both highway and transit[1].

Then, the change in performance measure factors caused by an action, transit or highway, can be calculated using a multi-modal version of the Action Impact Worksheet, and the resulting changes in performance

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[1]See Appendix D for further discussion.

used to calculate revised performance measures at the multi-modal system level. Input will be from both transit and auto actions, or actions affecting both jointly.

The Evaluation Worksheet and Evaluation Summary are used in the same fashion as described earlier, as media for listing transit and highway TSM actions, ranked by effectiveness or cost-effectiveness, and displaying the actual change in performance predicted for each action.

One variation that might be useful when it is desired to mix transit and highway projects, but still utilize some performance measures that are purely transit in nature, would be to assume perfect performance on the part of the street system. For example, the actual transit coverage of the population could be measured, and coverage by autos could be assumed as 100 percent. This device could be put into play when a larger number of performance measure comparisons are desired.

TSM PROGRAM PREPARATION

All of the steps outlined, and all of the analytical procedures and methods, are designed so that the decision-making authority in each agency is provided with an array of objective information to assist in reaching logical decisions, selecting and implementing the most effective TSM projects, and providing program continuity year-to-year. The administrative steps involved in finalizing the program will vary, but there are several end-point tasks that remain for the analyst.

First, maintenance of an inventory of TSM actions implemented during the course of the year is an important administrative task. The TSM program being prepared for the coming year will become, at the end of that year, the starting point for a progress report of TSM activities to be included in the MPO's annual report. That progress report would be enhanced if the routine actions, such as bus schedule changes or parking restrictions, are documented when they are implemented and listed with the more complex TSM actions in the report.

Second, the overall impact of the proposed program on system performance should be assessed. This involves the same calculations utilized in figuring the revised value of any performance measure, but now the sum of all actions is applied to the base value factors. For example, the cumulative impact on system average speed can be estimated by tabulating the plus and minus changes in vehicle-hours and vehicle-miles for each action in the program and so on[1].

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[1] It was suggested in Volume 1 that automated methods might be appropriate for this step. The TSM actions that are selected for implementation can be pooled with actions from other agencies (both transit and highway) and evaluated by the MPO for impact and priority.

Third, as the TSM program appears to be solidifying, the analyst should step back and ask himself "Have I proposed actions and a program that will enhance the utilization of existing transportation resources to the greatest extent possible at the present?" If not, the process has not fully accomplished its purpose; and the steps taken, assumptions made, and calculations completed should be reviewed with an eye for possibilities that have been overlooked.

APPENDIX "A": DESIGN NOTES AND GUIDELINES

During the field testing of the handbook's analytical procedures and methods, a need arose for aids that could be used in the development of the preliminary designs and cost estimates called for by Step 1 of the impact module (Chapter III). The need seemed to be greatest in relationship to transit actions since street and highway design data is readily available in references such as the Transportation and Traffic Engineering Handbook, the Highway Capacity Manual, and various highway design texts.

Some material that would be useful at the design stage has been included in various analytical procedures and methods. The material ranges from simple guidelines for estimating impact where the consequences of actions have never been quantified, to specific factors and curves. In addition, there are three particularly rich sources that contain design data about transit TSM actions. These are:

- Transportation and Traffic Engineering Handbook, Institute of Traffic Engineers, 1976.
- Bus Use of Highways, NCHRP Report 155, Wilbur Smith and Associates, 1975.
- Transportation System Management: State of the Art, INTERPLAN Corporation, September 1976.

Figure A-1 provides an index that identifies which of these reference provides information that would be useful for the design of transit TSM actions, related to "Action Type". The analytical methods and procedures with design data are also indexed.

GENERAL COMMENTS

It was found, during the testing, that preliminary design and impact estimation often overlapped. This was particularly true when dealing with actions affecting transit speed. It was necessary to check system design (which was usually an existing service) with the new speeds to determine if revisions were necessary in the number of buses or the frequency of service. Similarly, after estimating patronage on a new system (park-ride, for example) it was necessary to check vehicle occupancy and occasionally revise the schedule developed in the preliminary design to eliminate vehicle overloading.

Fixed-route System Design

Preliminary design will often involve the layout of all or a part of a traditional fixed-route, fixed-schedule bus system. These steps can be followed:

1. Prepare a map of routes that provide coverage of the desired service area. Spacing can vary from quarter-mile where densities are very high (20,000 persons per square mile) and auto ownership low (less than 0.5 cars per household), to a mile (densities under 6,000 combined with more than 1.5

cars per household). Half-mile spacing is the norm. Routes should be direct and simple, follow the same street inbound and outbound, and avoid loops.

2. Determine reasonable operating speeds. Travel time data can be adjusted for bus performance (80% to 90% of auto speed), and required passenger loading time (7% to 25% of total bus scheduled travel time). Typical bus scheduled speeds (MPH) are:

Functional Street Classification	Type of Area		
	CBD	Central	Outlying
Freeway	17-32	20-38	22-45
Primary Arterial	8	12	15
Secondary Arterial	6	10	14
Collector	3	8	12

   Speeds are likely to be different for peak and base periods, with the faster speeds in the off-peak base period.

3. Calculate the round trip time for each route. Add in a 5 or 10-minute recovery time.

4. Assume headways. Peak period values range from 5 to 30 minutes, with base (off-peak) periods up to an hour. It is convenient to design routes with one hour (or sometimes two) round trip times.

5. Calculate the vehicles required for peak and base periods (= Round Trip Time in Hours x Frequency in Buses per Hour). Round-off the calculated value and adjust the headway and/or recovery time.

6. A simple schedule can be developed by plotting individual bus round-trips along a time-of-day scale. The peak and base runs and the driver requirements can be easily seen.

At this point statistics like vehicle-miles and cost can be calculated, and patronage estimated in accordance with the appropriate method. Occupancy must be checked to ensure that vehicle load factors do not exceed 1.0 to 1.5. An acceptable value for load factor, passengers ÷ seats, must be assumed.

Bus Priority Signals

Priority signals, unless combined with exclusive lanes or other measures, will probably not contribute large time improvements unless implemented on a large scale (say, more than two dozen signals).

Exclusive or Preferential Lanes

Good results can be obtained with these measures, but applications to date have generally tended to be in situations where surplus street or highway capacity was available in one direction of travel or the other. At least 40 buses per hour should be scheduled to use the lane, and 60 is better. "Before" speeds should be less than 15 MPH or there won't be much improvement, and the spare capacity should be available through devices such as parking prohibitions on arterials or contra-flow usage on freeways.

Park-ride

The higher probabilities of success with a park-ride operation will occur when a quick ride between the lot and the destination is provided and when the cost of destination parking and the cost of the park-ride trip are at least comparable. Also, depending upon land use and capital costs, a distance of eight miles between the park-ride lot and the destination seems about right.

Shuttle Service

Although shuttle service in high activity centers (HAC's) has sometimes been proposed in terms of people-movers and special guideway systems, shuttles actually in operation tend to be CBD systems linking downtown with fringe parking at stadiums or government buildings, "10¢ specials", or regular service with a down-town free fare zone. CBD shuttles usually feature small buses, short (under 10 minutes) headways, and limited hours (such as 8 A.M. to 6 P.M.). Downtown free zones seem to be very effective in generating intra-CBD travel and winning friends for transit, if the fare collection system can accomodate the free zone.

Express Service

Express service requires a route where speed increases can really be attained, and enough origin-to-destination patrons to keep the buses reasonably full. The express portion of the route should comprise at least 25% of its length, with 50% to 75% better.

Demand-responsive Service

A lot of information is available about demand-responsive operations, such as TRB Special Reports 147, 164, and 164. Much of that data has been distilled into analytical method 21.

Elderly and Handicapped Service

In meeting the nees of the mobility disadvantaged, transit system have provided reduced fares, special services and special design features. Experiments in special services have included reverse-commute systems and structural modifications to equipment to provide easier access for the handicapped. Special systems often include demand-responsive service. NCHRP Report 39 is a good source of information.

FIGURE A-1. INDEX OF DESIGN REFERENCES

ACTION TYPE	Transportation & Traffic Engineering Handbook	Bus Use of Highways NCHRP Report 155	Transportation Systems Management State of the Art	Analytical Procedure	Analytical Method
Bus Priority Signals		●	●		1
Exclusive Facilities for HOV		●	●		
Exclusive Bus Facilities		●	●		
Improved Bus Stop Operations	●	●	●		3
Bus Stop Amenities		●	●	I	
Change in Fare Structure	●		●		
Increase Loading Efficiency	●	●	●		5
Route Modifications	●	●	●		
Schedule Modifications	●		●		
Service Modifications	●		●		
Fleet Modifications	●	●		L,M	
Intermodal Integration		●	●		
Marketing Improvements			●	I	
Programming Improvements			●	J	
Management Improvements			●	J	
Supervision of Operations			●		
Maintenance Improvements			●	J	
Engine Modifications	●			P	
Security Improvements			●		
Safety Improvements				Q	
Special Transit Services		●	●	M	
Common Carrier Para-transit			●	H	21

APPENDIX "B": DATA REQUIREMENTS

This appendix summarizes the data requirements for the analytical procedures and methods so that the analyst can become familar with the type of data he must collect, and so that he can plan ahead for any special surveys or special data manipulation that might fall outside of the normal practice of the agencies involed.

In addition to illustrating data requirements, the tabulations in this appendix also identifies data that is produced by the procedure or method.

Figure B-1 displays the requirements and products for analytical procedure A. The upper part of the table is in three parts, since procedure A has several different entry points.

Data requirements are indicated by the dot symbol • , and data produced by a star ✱. The lower portion of the table is in a slightly different format, showing which of the more-frequently used analytical methods are called for in the procedure. The type of data that the method supplies to the procedure is in the left-hand column. Figure B-2 shows the data requirements (and only the requirements) for these seven analytical methods used by procedure A. By inspecting the two tables (Figures B-1 and B-2), the analyst can see the overall input-output for procedure A.

Figure B-3 continues with the inventory of data for those procedures with a single entry point. Figure B-4 covers procedure X, another multiple-entry example. A number appearing in parenthesis by a symbol indicates that an analytical method (other than the seven listed in B-2) is associated with that particular piece of information.

Not all of the procedures are listed. Analytical Procedures N, O and S either refer in turn to other procedures, or require independent estimates of non-quantifiable impacts, or both. They do not have specific data requirements. Procedures J, K and L are in the same general category, but both refer to analytical method 20 which calls for annual transit operating cost totals by account and man-hours broken-down into several broad classes.

In a similar manner, procedure Q utilizes method 20 and subjective impact estimates, but requires in addition data on transit safety program costs per accident and the numbers of accidents occurring in a prior time period (usually one year).

Procedure P addresses environmental and energy improvements; utilizing methods 12, 13, and 14; and accepts as input data the height of noise barriers and the number of rows of structures between a highway and the location under study for noise impact.

Some of the analytical procedures will have slight variations or options associated with their data needs. Although the tabulations in this appendix illustrate the overall requirements, the individual procedure should be checked to see if any particular specifications apply.

FIGURE B-1. DATA REQUIREMENTS: PROCEDURE A

Data Description	Procedure A		
	Signals, Ramps, and Loading	Exclusive Lanes	Stop, Capacity Improvements
Speed, time before	• (1,4,5)	• (2)	• (3)
Project length	• (1,4,5)	• (2)	
Delay classification	• (1,4,5)		
Speed, time after	* (1,4,5)	* (2)	* (3)
Highway volume before			• (3)
Highway capacity before			• (3)
Highway capacity after			• (3)
Type fare collection, doors (before & after)	• (5) • (5)		
Frequency before		•	
Frequency after		*	
Vehicles before		•	
Vehicles after		*	
Drivers before		•	
Drivers after		*	
Fare before		•	
Fare after		•	
Revenue after		*	
Vehicle-miles before		•	
Vehicle-miles after		*	
Vehicle-hours before		•	
Vehicle-hours after		*	
Max. Occupancy before		•	
Max. Occupancy after		*	
Vehicle capacity		•	
Capacity-miles		*	
Passengers before		•	
Route miles		•	

Legend:
Associated Method
Data Required
Data Produced

ANALYTICAL METHODS UTILIZED

Passengers after	Methods 6 or 7
Passenger-miles	Method 9
Average Occupancy	Method 9
Maximum occupancy	Method 9
Costs	Method 10
Fuel consumed	Method 12
Emissions	Method 13
Noise	Method 14

FIGURE B-2. DATA REQUIREMENTS: HIGH-USE METHODS

Data Description	Analytical Method 6	7	9	10	12	13	14
Transit access time	•	•					
Wait time	•	•					
Run time		•					
Transfer time		•					
Fare	•	•					
Auto terminal time	•						
Auto run time	•						
Parking cost	•						
Auto operating cost	•						
Distance	•						
Income	•						
Mode split		•					
O-D volume	•						
Area size			•				
Passengers			•				
Vehicle-miles			•	•			
Service hours			•				
Route profile			•				
Cost by account				•			
Vehicle-hours				•			
Vehicles				•			
Drivers				•			
Mode					•	•	•
Type vehicle					•	•	•
Speed					•	•	•
Vehicle-miles					•	•	
Vehicle volume							•
Roadway design							•

FIGURE B-3. DATA REQUIREMENTS (GENERAL)

Data Description	Analytical Procedure											
	B	C	D	E	F	G	H	I	M	R		T
Speed, time before		•										
Speed, time after			• *	•	•		•		•	•		
Frequency before		•										
Frequency after		• *	• *	•	•					•		
Vehicles before		•	•	•								
Vehicles after		*	• *	*	*		•21		*	*		•
Fare before	•	•	•	•		•		•				
Fare after	•	•	•	•	•	•	•	•	•	•		
Revenue after	*	*	*	*			*		*	*		
Vehicle-miles before			•									
Vehicle-miles after		*	*	*	*		*		*			
Vehicle-hours before												
Vehicle-hours after		*	*	*	*		*		*	*		
Drivers before		•	•	•								
Drivers after		*	*	*	*		*		*	*		
Max. occ. before	•	•				•		•				
Max. occ. after	*	*	*			*		*				
Vehicle capacity		•	•	•	•		•21		•	•		
Capacity-miles		*	*	*	*		*		*	*		
Passengers before		•	•			•		•	•			
Headway		*										
Route miles		•	•	•	•					•		
Occupancy after		•		*						*		*
Passengers after	*8		*16	*18			*	•	*	*		•
Trip table			•17		• 17	• 17						
Drivers per vehicle					•		•		•	•		
Pass. per veh-mile			•							•		
Mode split before												
Veh-miles per capita			• 16									
Population density			• 15		•15							
Service hours				•18								
O-D volume					•							
Transfers						•						
Population							•21	• 21				
Highway speed												
Cost												

ANALYTICAL METHODS UTILIZED

	B	C	D	E	F	G	H	I	M	R		T
Passengers after	6,7	6,7	6,7		6	6						
Passenger-miles	9		9			9	9		9			9
Average occupancy	9		9			9	9		9			9
Max. occupancy	9		9			9	9		9			9
Costs		10	10	10	10		10		10	10		
Fuel consumed			12	12	12		12		12	12		
Emissions		13	13	13	13		13		13	13		
Noise		14	14	14	14		14		14	14		

FIGURE B-4. DATA REQUIREMENTS: PROCEDURE X

Data Description	Procedure X	
	Change in Person-trips	Change in Capacity
Person-trips before	•	
Vehicle occupancy ratio	•	
Person-trips after	*	
Vehicle volume before		• (22)
Vehicle volume after	*	• (22)
Capacity before		• (22)
Capacity after		* (22)
Speed before		• (23)
Speed after		* (23)
Link distance	•	
Vehicle-miles	*	
Operating Costs	* (24)	
Accidents	* (25)	

ANALYTICAL METHODS UTILIZED

Passenger-miles	Method 9
Fuel consumed	Method 12
Emissions	Method 13
Noise	Method 14

APPENDIX C: SYSTEM PERFORMANCE MEASURES

Performance measures are classified into two groups—transit and multi-modal. The reason for this is that a relatively large number of transit performance measures are needed for diagnosis of transit system operations and as the format for predicting future performance if candidate TSM actions are implemented. However, not all of these PM's would be applicable to the non-transit or multi-modal transportation system. Therefore, the set of multi-modal measures is needed that covers both systems. This is the key to the process of integrating transit and highway priorities.

TRANSIT PERFORMANCE MEASURES

Figure C-1 lists transit performance measures with a classification by area and time period of applicability. This list is furnished as a catalogue of performance measures from which a choice can be made. It is unlikely that all of the measures would be used at a single time, particularly since many of the PM's are ratios that describe the same aspect of performance.

Some PM's can be calculated for parts of the system as small as a link, and for time periods as short as an hour.[1] Others are systemwide and practical only for longer time periods. Generally, the PM's will be the most effective if they are as fine-grained as possible, particularly in terms of area. The transit route is probably the most useful geographical unit. The basic time period might be a year for some cases (like accident rate), but the best description of system performance will result when a typical day is split into peak and base periods.

Performance measures can be calculated using the methods outlined in Figure C-2. To use this table, performance measures which are in ratio form must be broken down into their component parts, called performance measure <u>factors</u>. The calculation methods opposite the factors in Figure C-2 are suggested for use in determining the current value of any factor. By recombining two factors into the proper ratio, the current value of any selected performance measure can be determined.

The suggested geographical limits and time periods for the calculations are based upon a maximum disaggregation in order to allow performance

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[1] A link here has the same meaning as in network coding use, i.e., a portion of a system between significant landmarks of that system. The link in the transit system would be a specific part of a route (or routes following the same path) between two easily-identifiable points along that route such as a freeway or arterial intersection, an intersection with other routes(s), or any other important feature.

FIGURE C-1. TRANSIT PERFORMANCE MEASURES

TRANSIT PERFORMANCE MEASURE	AREA OF APPLICABILITY					TIME PERIOD COVERAGE				
	SPOT	LINK	SUB-AREA	ROUTE	SYSTEM	HOUR	DAY	WEEK	MONTH	YEAR
Vehicle-Miles Per Gallon of Fuel				•	•		•	•	•	•
Passenger-Miles Per Gallon of Fuel				•	•		•	•	•	•
Operating Ratio				•	•	•	•	•	•	•
Matinenance Cost Per Vehicle				•	•		•	•	•	•
Per Vehicle-Mile				•	•		•	•	•	•
Per Passenger-Mile				•	•		•	•	•	•
Per Maintenance Man-Hour					•		•	•	•	•
Per Passenger				•	•		•	•	•	•
Percent Transfers				•	•		•	•	•	•
Fare				•	•	•	•			•
Frequency (Scheduled Service)	•	•	•	•	•	•	•	•	•	•
Average Wait (Unscheduled Service)	•	•	•	•	•	•	•	•	•	•
Response Time (Demand-response Service)	•	•	•		•	•	•	•	•	•
Vehicle Occupancy	•	•	•	•	•	•	•	•	•	•
Vehicle Accidents Per Vehicle-Mile		•	•	•	•				•	•
Passenger Fatalities Per Million Vehicle-Miles		•	•	•	•				•	•
Per Million Passenger-Miles		•	•	•	•				•	•
Per Million Passengers		•	•	•	•				•	•
Passenger Injuries Per Million Vehicle-miles		•	•	•	•				•	•
Per Million Passenger-Miles		•	•	•	•				•	•
Per Million Passengers		•	•	•	•				•	•
Staff Fatalities Per Million Vehicle-Miles					•				•	•
Staff Injuries Per Million Vehicle-Miles					•				•	•
Road Calls Per Maintenance Man-Hour					•		•	•	•	•
Crime Incidents Per Million Vehicle-Miles			•	•	•				•	•
Crime Incidents Per Million Passengers			•	•	•				•	•
Schedule Adherence	•	•	•	•	•	•	•	•	•	•
Coverage in Acres		•	•	•	•	•	•			
Coverage in Percent of Population					•	•	•			

FIGURE C-1. (Continued)

TRANSIT PERFORMANCE MEASURE	AREA OF APPLICABILITY					TIME PERIOD COVERAGE				
	SPOT	LINK	SUB-AREA	ROUTE	SYSTEM	HOUR	DAY	WEEK	MONTH	YEAR
Demand Compatibility					•	•	•			
Deadhead Mileage Percent					•		•	•	•	•
Vehicle-Miles Per Vehicle				•	•		•	•	•	•
Per Route-Mile		•	•	•	•	•	•	•	•	•
Per Employee					•		•	•	•	•
Per Operator				•	•		•	•	•	•
Per Operator Man-Hour				•	•		•	•	•	•
Per Maintenance Man-Hour					•		•	•	•	•
Per Road Call				•	•				•	•
Vehicle-Hours Per Vehicle				•	•		•	•	•	•
Per Route-Mile		•	•	•	•	•	•	•	•	•
Per Employee					•		•	•	•	•
Per Operator				•	•		•	•	•	•
Per Operator Man-Hour				•	•		•	•	•	•
Overall Vehicle Speed	•	•	•	•	•	•	•	•	•	•
Passengers Per Vehicle-Mile		•	•	•	•	•	•	•	•	•
Per Vehicle				•	•		•	•	•	•
Per Route-Mile		•	•	•	•	•	•	•	•	•
Per Employee					•		•	•	•	•
Per Vehicle-Hour		•	•	•	•	•	•	•	•	•
Passenger-Miles Per Vehicle-Mile		•	•	•	•	•	•	•	•	•
Per Vehicle				•	•		•	•	•	•
Per Route-Mile		•	•	•	•	•	•	•	•	•
Per Employee					•		•	•	•	•
Per Capacity-Mile		•	•	•	•	•	•	•	•	•
Employees Per Vehicle					•		•	•	•	•
Per Vehicle-Mile					•		•	•	•	•
Passenger Revenue Per Vehicle-Mile				•	•	•	•	•	•	•
Per Vehicle-Hour				•	•	•	•	•	•	•
Per Passenger				•	•	•	•	•	•	•
Per Passenger-Mile				•	•	•	•	•	•	•
Per Capacity-Mile				•	•	•	•	•	•	•
Per Vehicle				•	•	•	•	•	•	•
Per Route-Mile				•	•	•	•	•	•	•
Per Employee Man-Hour					•		•	•	•	•
Per Operator Man-Hour				•	•		•	•	•	•

FIGURE C-1. (Continued)

TRANSIT PERFORMANCE MEASURE	AREA OF APPLICABILITY					TIME PERIOD COVERAGE				
	SPOT	LINK	SUB-AREA	ROUTE	SYSTEM	HOUR	DAY	WEEK	MONTH	YEAR
Total Cost Per Vehicle-Mile				●	●	●	●	●	●	●
Per Vehicle-Hour				●	●	●	●	●	●	●
Per Passenger				●	●	●	●	●	●	●
Per Passenger-Mile				●	●	●	●	●	●	●
Per Capacity-Mile				●	●	●	●	●	●	●
Per Vehicle				●	●	●	●	●	●	●
Per Route-Mile				●	●	●	●	●	●	●
Per Employee Man-Hour					●		●	●	●	●
Per Operator Man-Hour					●		●	●	●	●
CBD Work Accessibility			●				●			
CBD Shop Accessibility			●				●			
Employement Center Accessibility			●				●			
Shopping Center Accessibility			●				●			
Job Mobility			●				●			
Shopping Mobility			●				●			
Educational Mobility			●				●			
Health Care Mobility			●				●			
Recreational Mobility			●				●			
CO in grams per person-mile		●	●	●	●	●	●			
HC in grams per person-mile					●		●			
NO_x in grams per person-mile					●		●			
Total CO in kilograms		●	●	●	●	●	●			
Total HC in kilograms					●		●			
Total NO_x in kilograms					●		●			
Noise Levels	●	●	●			●				
Population Within Critical Noise Contours		●	●	●	●	●				

FIGURE C-2. CALCULATION OF PERFORMANCE MEASURE FACTORS

TRANSIT PERFORMANCE MEASURE FACTOR	SOURCE AND SUGGESTED METHOD OF CALCULATION
Vehicle-Miles Vehicle-Hours Speed Frequency	Abstract from run or schedule records; preferably at the link or route level and separately by peak and base periods.
Operators Operator Man-Hours Vehicles Deadhead Miles	Abstract from run or schedule records; preferably at the route level and separately by peak and base periods.
Miles of Route	Measure from route map or abstract from records, preferably at the link level
Passengers	Estimate at the link or route level for peak and base periods using counts, revenue data, and/or computer network output.
Revenue	Abstract from fiscal records at the route level, usually for an average day or week-day.
Fare	Calculate at the route level as revenue per passenger.
Cost	Allocate annual cost by account to 2, 3, or 4 factors (see Analytical Method 10) and then to routes, either for an average day/weekday or by peak and base periods.
Transfers	Abstract from operating records at the originating route level for an average day/weekday.
Number of Employees Maintenance Man-Hours Employee Man-Hours	Abstract from personnel records for the total system for an average day.
Vehicle Accidents Passenger Fatalities Passenger Injuries Crime Incidents	Abstract from operating records at the route level as an annual total.
Road Calls	Abstract from maintenance records at the route level as an annual total.
Fuel Consumed	Abstract from maintenance records at the route level for an average day/weekday. (Convert to BTU's for multi-modal comparisons)

FIGURE C-2. (Continued)

TRANSIT PERFORMANCE MEASURE FACTOR	SOURCE AND SUGGESTED METHOD OF CALCULATION
Passenger-Miles	Calculate using occupancy and vehicle-miles or number of passengers and link distance. Check against survey trip length. Calculate at the link or route level for an average day/weekday.
Capacity-Miles	Calculate at the link or route level for an average day/weekday using vehicle-miles and bus capacity (including standees).
Maintenance Cost	Abstract from fiscal records, system-wide for an average day/weekday.
Occupancy	Abstract from count records or estimate at the link level, by peak and base periods, using counts and/or passenger and vehicle frequency data.
Staff Fatalities Staff Injuries	Abstract from personnel records as an annual total.
Schedule Adherence	Abstract from count records or estimate at the link level, for peak and base periods, from surveys.
Coverage	Calculate population or acreage coverage using maps of routes (with standard walking distances) and population or population density by zone or census tract. Separate by peak and base if differences are significant.
Demand Compatibility	Layout analysis districts oriented around routes and route corridors. Prepare and review transit-trip and person-trip tables. Identify direct and non-direct transit service district-to-district. Prepare frequency diagrams (see Analytical Method 17).
Accessiblity	Requires computer network analysis. Output number of trip origins by selected purposes (i.e., work and/or shipping) within a specified travel time (i.e., 30 minutes) from target zone or area (see Analytical Method 105). Calculate for peak and base if significantly different.

FIGURE C-2. (Continued)

TRANSIT PERFORMANCE MEASURE FACTOR	SOURCE AND SUGGESTED METHOD OF CALCULATION
Mobility	Requires computer network analysis. Output number of opportunities (i.e., jobs, shopping floor area and health/recreation/education facilities) within a specified travel time (i.e., 30 minutes) from target zone or area (see Analytical Method 106).
Emissions	Calculate at the link level, by peak and base periods if desired, using typical emission rates (see Analytical Method 13).
Noise	Calculate at the link level, by time period, using typical noise generation rates (see Analytical Method 14).

evaluation in small areas (such as links) and critical time periods (such as the peak period). The selection of time and area for these calculations should be made, as was the selection of performance measures themselves, in a fashion that will produce a useful picture of transit performance and will allow estimation of the change in a PM when an action is implemented.

When "daily" totals are to be used, a decision must be made whether to use an average day; an average weekday; or an average weekday plus average Saturday, Sunday, and holidays. The decision depends upon the amount of variation that exists and what is being sought in terms of performance evaluation. When performance measures are calculated at the route level, or for a peak period, it is a simple matter to aggregate data so that systemwide and/or daily values can be developed as well.

Note that several factors (fuel consumption, pollutant emissions, and noise) are somewhat meaningless for transit alone, and will probably have to be considered on a multi-modal basis along with autos and trucks for realistic and useful results. Noise evaluation is probably useful only for specific conditions or locations.

When completed, the results of performance measure calculation must be displayed effectively. Useful display techniques are described in Figure C-3 for each performance measure. The techniques referred to in the column headings are as follows:

- Systemwide Value -- This is a single number reflecting the overall performance of the entire transit system. For example, "Vehicle-miles per Vehicle" would be a typical systemwide statistic, and could be compared to experience at other similar systems.

- Route Listing -- This is a list containing a value for each route in the system. Within the list, routes can be ranked in any desired order for comparative purposes. For example, "Passengers per Vehicle-mile" could be calculated for each route and routes compared one to the other.

- Frequency Tabulation -- This is a more general form of the "Route Listing" above; and can also be applied to links, zones, subareas, and so on. In the frequency listing, the values for any particular performance measure are arranged in a column, or may be grouped into intervals covering a range of values. The number of occurrences of that value (or values falling in that interval) would be listed next to the value. A frequency diagram (histogram) can be substituted.

FIGURE C-3. TRANSIT PERFORMANCE MEASURE DISPLAY TECHNIQUES

TRANSIT PERFORMANCE MEASURE	SYSTEM-WIDE VALUE	ROUTE LISTING OR FREQUENCY TAB	ROUTE OR LINK MAP	ZONE OR SUBAREA MAP
Vehicle-Miles Per Vehicle	•	•	•	
Per Route-Mile	•	•	•	
Per Employee	•			
Per Operator	•	•	•	
Per Operator Man-Hour	•			
Per Maintenance Man-Hour	•			
Per Road Call	•	•	•	
Vehicle-Hours Per Vehicle	•	•	•	
Per Route-Mile	•	•	•	
Per Employee	•			
Per Operator	•	•	•	
Per Operator Man-Hour	•			
Overall Vehicle Speed	•	•	•	
Passengers Per Vehicle-Mile	•	•	•	
Per Vehicle	•	•	•	
Per Route-Mile	•	•	•	
Per Employee	•			
Per Vehicle-Hour	•	•	•	
Passenger-Miles Per Vehicle-Mile	•	•	•	
Per Vehicle	•	•	•	
Per Route-Mile	•	•	•	
Per Employee	•			
Per Capacity-Mile	•	•	•	
Employees Per Vehicle	•			
Per Vehicle-Mile	•			
Passenger Revenue Per Vehicle-Mile	•	•	•	
Per Vehicle-Hour	•	•	•	
Per Passenger	•	•	•	
Per Passenger-Mile	•	•	•	
Per Capacity-Mile	•	•	•	
Per Vehicle	•	•	•	
Per Route-Mile	•	•	•	
Per Employee Man-Hour	•	•	•	
Per Operator Man-Hour	•			
Total Cost Per Vehicle-Mile	•	•	•	
Per Vehicle-Hour	•	•	•	
Per Passenger	•	•	•	
Per Passenger-Mile	•	•	•	
Per Capacity-Mile	•	•	•	
Per Vehicle	•	•	•	
Per Route-Mile	•	•	•	
Per Employee Man-Hour	•	•	•	
Per Operator Man-Hour	•			

FIGURE C-3. (Continued)

TRANSIT PERFORMANCE MEASURE	SYSTEM-WIDE VALUE	ROUTE LISTING OR FREQUENCY TAB	ROUTE OR LINK MAP	ZONE OR SUBAREA MAP
Vehicle-Miles Per Gallon of Fuel	•	•	•	
Passenger-Miles Per Gallon of Fuel	•	•	•	
Operating Ratio	•	•	•	
Maintenance Cost Per Vehicle	•			
Per Vehicle-Mile	•			
Per Passenger-Mile	•			
Per Maintenance Man-Hour	•			
Per Passenger	•			
Percent Transfers	•	•	•	
Fare	•		•	
Frequency (Schedulated Service)	•	•	•	
Average Wait (Unscheduled Service)	•	•	•	
Response Time (Service)				•
Vehicle Occupancy	•	•	•	
Vehicle Accidents Per Vehicle-Mile	•	•	•	
Passenger Fatalities Per Million Vehicle-Miles	•	•	•	
Per Million Passenger-Miles	•	•	•	
Per Million Passengers	•	•	•	
Passenger Injuries Per Million Vehicle-Miles	•	•	•	
Per Million Passenger-Miles	•	•	•	
Per Million Passengers	•	•	•	
Staff Fatalities Per Million Vehicle-Miles	•			
Staff Injuries Per Million Vehicle-Miles	•			
Road Calls Per Maintenance Man-Hour	•			
Crime Incidents Per Million Vehicle-Miles	•	•	•	
Crime Incidents Per Million Passengers	•	•	•	
Schedule Adherence	•	•	•	
Coverage in Acres	•		•	•
Coverage in Percent of Population	•		•	•
Demand Compatibility	•	•		•
Deadhead Mileage Percent	•	•	•	

FIGURE C-3. (Continued)

TRANSIT PERFORMANCE MEASURE	SYSTEM-WIDE VALUE	ROUTE LISTING OR FREQUENCY TAB	ROUTE OR LINK MAP	ZONE OR SUBAREA MAP
CBD Work Accessibility				•
CBD Shop Accessibility				•
Employment Center Accessiblity				•
Shopping Center Accessibility				•
Job Mobility				•
Shopping Mobility				•
Educational Mobility				•
Health Care Mobility				•
Recreational Mobility				•
CO in grams per person-mile	•	•	•	
HC in grams per person-mile	•			•
NO_x in grams per person-mile	•			•
Total CO in kilograms	•	•	•	
Total HC in kilograms	•			•
Total NO_x in kilograms	•			•
Noise Levels			•	•
Population Within Critical Noise Contours	•	•	•	•

- Route or Link Map -- This involves plotting on a map the specific values calculated for each route or link being examined for quick and easy visual inspection.

- Zone or Subarea Map -- This involves plotting on a map the specific values calculated for each zone or subarea being examined.

Other methods are available, and should be used whenever they might be more suitable for a specific case.

NON-TRANSIT PERFORMANCE MEASURES

Figure C-4 lists performance measures covering non-transit (or multimodal) system performance.

The "non-transit" performance measures are fewer in number than are those in the transit set, but it seems likely that a larger share of the non-transit measures will be used than is the case for transit measures.

Performance measures can be calculated using the methods outlined in Figure C-5. As was the case for the transit PM's, those performance measures which are in ratio form have been broken down into their component performance measure factors. After calculating the current value of any factor, two factors can be recombined into the proper ratio, thereby determining the current value of any selected performance measure.

The calculation of non-transit factors is simpler and follows more familiar methods than does the calculation of transit PM factors. Most of the calculations are suggested for the link level, and split between peak and off-peak as appropriate.

When transit exists, its characteristics should be integrated into the traffic flow so that the "non-transit" factors are really multi-modal.

Once quantified, the results of performance measure calculation must be displayed effectively. Useful display techniques are described in Figure C-6. The techniques appearing as column headings are as follows:

- Areawide Value -- This is a single number reflecting the overall performance of the transportation system in a particular area. A regional accident rate or average user cost are examples.

- Listing or Frequency Tabulation -- This display technique produces an array of numbers describing the performance of particular parts of the system, such as links, zones, areas,

FIGURE C-4. NON-TRANSIT PERFORMANCE MEASURES

NON-TRANSIT PERFORMANCE MEASURE	AREA OF APPLICABILITY					TIME PERIOD COVERAGE				
	SPOT	LINK	SUB-AREA	FACILITY	AREA	HOUR	DAY	WEEK	MONTH	YEAR
Overall Vehicle Speed	•	•	•	•	•	•	•	•	•	•
Out-of-Pocket Costs Per Passenger		•	•	•	•	•	•	•	•	•
Total Cost Per Vehicle-Mile		•	•	•	•	•	•	•	•	•
Per Passenger		•	•	•	•	•	•	•	•	•
Per Passenger-Mile		•	•	•	•	•	•	•	•	•
Vehicle-Miles Per Gallon of Fuel		•	•	•	•	•	•	•	•	•
Passenger-Miles Per Gallon of Fuel		•	•	•	•	•	•	•	•	•
Vehicle Occupancy	•	•	•	•	•	•	•	•	•	•
Vehicle Accidents Per Million Vehicle-Miles		•	•	•	•				•	•
Passenger Fatalities Per Million Vehicle-Miles		•	•	•	•				•	•
Per Million Passenger-Miles		•	•	•	•				•	•
Per Million Passengers		•	•	•	•				•	•
Passenger Injuries Per Million Vehicle-Miles		•	•	•	•				•	•
Per Million Passenger-Miles		•	•	•	•				•	•
Per Million Passengers		•	•	•	•				•	•
CBD Work Accessibility					•	•	•			
CBD Shopping Accessibility					•	•	•			
Employment Center Accessibility					•	•	•			
Shopping Center Accessibility					•	•	•			
Job Mobility					•	•	•			
Shopping Mobility					•	•	•			
Educational Mobility					•	•	•			
Health Care Mobility					•	•	•			
Recreational Mobility					•	•	•			
CO in grams Per Passenger-Mile		•	•	•	•	•	•			
HC in grams Per Passenger-Mile			•	•	•		•			
NO_x in grams Per Passenger-Mile			•	•	•		•			
Total CO in kilograms		•	•	•	•	•	•			
Total HC in kilograms			•	•	•		•			
Total NO_x in kilograms			•	•	•		•			
Noise Levels	•	•	•			•				
Population Within Critical Noise Contours		•	•	•	•	•				

FIGURE C-5. CALCULATION OF NON-TRANSIT PERFORMANCE MEASURE FACTORS

NON-TRANSIT PERFORMANCE MEASURE FACTOR	SOURCE AND SUGGESTED METHOD OF CALCULATION
Vehicle Speed	Abstract from survey data or estimate for links by peak/off-peak periods using surveys, speed limit data or Speed - V/C curves.
Vehicle - Miles	Calculate using volume and distance for link and for peak/off-peak.
Passengers (Occupants)	Estimate for link and for peak/off-peak the number of occupants using vehicle volume data and occupancy survey data.
Passenger-Miles	Estimate for link and for peak/off-peak using occupants (from above) and distance. Check against O-D survey trip length data.
Vehicle Occupancy	Abstract from survey data or estimate from surveys and area knowledge for link and for peak/off-peak.
Vehicle Accidents Passenger Fatalities Passenger Injuries	Abstract from traffic engineering records using annual totals.
Emissions Noise	Estimate using volume, speed, and vehicle type data with pollutant emission/noise generation rates.
Fuel Consumed	Estimate using volume, speed, and consumption rate factors.
Out-of-pocket Cost Total Cost	Estimate using volume, speed, and current cost units.
Accessibility Mobility	Requires computer network analysis. Calculate numbers of trip originas (by purpose) or opportunities (jobs, etc.) within a specified distance (i.e., 30 minutes from target zone or area).

FIGURE C-6. NON-TRANSIT PERFORMANCE MEASURE DISPLAY TECHNIQUES

NON-TRANSIT PERFORMANCE MEASURE	ARE-WIDE VALUE	LISTING OR FREQUENCY TABULATION	LINK MAP	ZONE OR SUBAREA MPA
Overall Vehicle Speed	•	•	•	
Out-of-Pocket Costs Per Passenger	•	•	•	
Total Cost Per Vehicle-Mile	•	•	•	
Per Passenger	•	•	•	
Per Passenger-Mile	•	•	•	
Vehicle-Miles Per Gallon of Fuel	•	•	•	
Passenger-Miles Per Gallon of Fuel	•	•		
Vehcile Occupancy	•	•	•	
Vehicle Accidents Per Million Vehicle-Miles	•	•	•	
Passenger Fatalities Per Million Vehicle-Miles	•	•	•	
Per Million Passenger-Miles	•	•	•	
Per Million Passengers	•	•	•	
Passenger Injuries Per Million Vehicle-Miles	•	•	•	
Per Million Passenger-Miles	•	•	•	
Per Million Passengers	•	•	•	
CBD Work Accessiblity				•
CBD Shopping Accessibility				•
Employment Center Accessibility				•
Shopping Center Accessibility				•
Job Mobility				•
Shopping Mobility				•
Educational Mobility				•
Health Care Mobility				•
Recreational Mobility				•
CO in grams Per Passenger-Mile	•	•	•	
HC in grams Per Passenger-Mile	•	•	•	
NO_x in grams Per Passenger-Mile	•	•	•	
Total CO in kilograms	•	•	•	
Total HC in kilograms	•	•	•	
Total NO_x in kilograms	•	•	•	
Noise Levels			•	•
Population Within Critical Noise Contours	•	•	•	•

and so on. These numbers can be listed in a specified, appropriate order; or can be combined into frequency by class interval. Accident rate by link would be an example, and individual links could be compared to system averages or grouped by percentile.

- Link Map -- This involves plotting on a map the specific values for each link of the system being examined.

Other methods are available and should be used whenever they might be more suitable.

APPENDIX D: AN EXAMPLE OF IMPACT AND PRIORITY CALCULATIONS

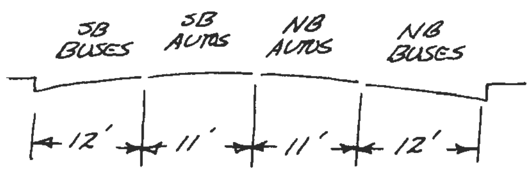
This appendix has been prepared to assist the handbook user in understanding the procedures and methods. A sample calculation for the impact of one transit TSM project is included, and then this project is used as the subject of the cost-effectiveness determination along with two other projects whose impacts were calculated separately.

PRELIMINARY DESIGN AND COST ESTIMATE

PROJECT #1A: EXCLUSIVE BUS LANE

PROJECT LENGTH = 1.5 MILES

PROPOSED CROSS-SECTION:



TWO-WAY TRAFFIC
PARKING PROHIBITED

ESTIMATED COST:

6' WIDENING	$ 150,000
SIGNS, MARKINGS	4,000
	$ 154,000

EXISTING BUS OPERATIONS:
ROUTE 2

ROUND TRIP TIME = 80 MINS
ROUND TRIP DISTANCE = 12.2 MILES
HEADWAY = 20 MINUTES } PEAK & BASE
4 VEHICLES ASSIGNED }
SYSTEM-WIDE AVERAGE FARE = $0.44
6 DRIVERS ASSIGNED
DAILY PASSENGERS = 623
AVERAGE OCCUPANCY = 15.0

AVERAGE BUS SPEED THRU PROJECT AREA = 3.6 MPH

AVERAGE R.T. SPEED = $\frac{(12.2 \text{ MILES})(60)}{(80 \text{ MINUTES})}$ = 9.2 MPH

SERVICE DAY = 16 HOURS

EXISTING TRAFFIC DATA:

DAILY VOLUME = 7,800
P = 10%
D = 0.67
AVERAGE OCCUPANCY = 1.3

EXISTING CROSS-SECTION:
2-LANES, 2-WAY, WITH PKG.

AVERAGE HIGHWAY SPEED = 17.0 MPH
SPEED LIMIT: 30 MPH

CALCULATE IMPACTS

FOR AN EXCLUSIVE BUS LANE, USE ANALYTICAL PROCEDURE "A" (FIGURE 2-2)

STEP 1: GIVEN EXISTING BUS SPEED IN THE PROJECT AREA OF 3.6 MPH, METHOD 2 (PART "a") YIELDS AN "AFTER" SPEED OF 6.4 MPH.

STEP 2: A. "BEFORE" TIME = $\frac{(1.5 \text{ MILES})(60)}{(3.6 \text{ MPH})}$ = 25.0 MINUTES

"AFTER" TIME = $\frac{(1.5)(60)}{6.4}$ = 14.1 MINUTES

TIME SAVINGS = (25.0 - 14.1) = 10.9 MINUTES EACH DIRECTION

NEW ROUND TRIP TIME = 80.0 - (10.9)(2) = 58.2 MINUTES (USE 60)

B. ROUND TRIP AVERAGE SPEED "AFTER" = $\frac{(12.2 \text{ MILES})(60)}{(60 \text{ MINUTES})}$ = 12.2 MPH

VEHICLES REQUIRED "AFTER" = $\frac{(3 \text{ PER HR})(12.2 \text{ MILES R.T.})}{(12.2 \text{ MPH})}$ = 3 (SAVES 1 VEHICLE)

C. SINCE VEHICLE NEEDS ARE REDUCED, MAINTAIN ORIGINAL FREQUENCY.

D. REDUCE VEHICLES ASSIGNED FROM 4 TO 3 AFTER IMPLEMENTATION.

STEP 3: USE BOTH METHODS, 6 AND 7, AND COMPARE RESULTS:

METHOD 6:

VARIABLE	BEFORE	SOURCE	AFTER
T_a	6.7 MINS	DEFAULT VALUE	
T_w	10.0 MINS	HALF OF HEADWAY	
T_r	16.3 MINS	2.5 MILES @ 9.2 MPH (1)	12.3 MINS (2)
F	$0.44	GIVEN	
A_t	0.8 MINS	DEFAULT VALUE	
A_r	8.8 MINS	2.5 MILES @ 17.0 MPH (1)	
P	$0.26	DEFAULT VALUE	
D	2.5 MIS.	ASSUMED VALUE	
C_a	$0.054/MIS	DEFAULT VALUE	
C_t	0.028	AREA INCOME $14K	

(1.) ASSUMED TRIP LENGTH = 2.5 MILES

(2.) 2.5 MILES @ 12.2 MPH

$$U_t = 2.5(6.7+10.0) + 16.3 + \frac{0.44}{0.028} = 73.8 \text{ "BEFORE"}$$

$$U_t = 2.5(6.7+10.0) + 12.3 + \frac{0.44}{0.028} = 69.8 \text{ "AFTER"}$$

$$U_a = 2.5(0.8) + 8.8 + \frac{(2.5)(0.054) + 0.26/2}{0.028} = 20.3$$

$U_t - U_a$ = 53.5 "BEFORE"

$U_t - U_a$ = 49.5 "AFTER"

MODE SPLIT: 9% "BEFORE", 10% "AFTER" (WORK TRIP CURVE)

(MEASURED OFF OF THE CURVE WITH AN ENGINEERING SCALE)

METHOD 7:

PERCENT CHANGE IN RUN TIME = $\frac{(10.9 \text{ MINUTES})(2)}{(80 \text{ MINUTES})} = -27.3\%$

THE CURVE SHOWS A +1.5% CHANGE IN MODE SPLIT.

ESTIMATES OF NEW PATRONAGE:

$(523)\left(\frac{10\%}{9\%}\right) = 581$ BY RATIO OF MODE SPLIT (METHOD 6).

$(523)\left(\frac{9.0\%+1.5\%}{9.0\%}\right) = 610$ BY RATIO OF MODE SPLIT (METHOD 7).

$\frac{523}{(7800)(1.3)} = 5.2\%$ ESTIMATED MODE SPLIT ON ARTERIAL

$(523)\left(\frac{5.2\%+1.5\%}{5.2\%}\right) = 674$ USING ESTIMATED MODE SPLIT & CHANGE FROM METHOD 7.

USE THE AVERAGE OF THE THREE ESTIMATES, 622.

STEP 4: REVENUE = (523)($0.44) = $230 "BEFORE" } DAILY
= (622)($0.44) = $274 "AFTER" } DAILY

STEP 5: OCCUPANCY "AFTER" = $\frac{(15.0)(622)}{(523)} = 17.8 \leftarrow 5$ (O.K.)

STEP 6: PASS-MILES = (523)(2.5) = 1,308 "BEFORE"
= (622)(2.5) = 1,555 "AFTER"

NOTE: USING ASSUMED TRIP LENGTH OF 2.5 MILES.

STEP 7: SINCE STEP 2B INDICATED THAT VEHICLES ASSIGNED COULD BE REDUCED FROM 4 TO 3, AND FREQUENCY HAS BEEN HELD AT 3 PER HOUR:

VEHICLE-MILES "BEFORE" = (3 PER HR)(16 HRS/DAY)(12.2 MILES)
= 585.6 DAILY VEH-MIS

VEHICLE-HOURS = $\frac{585.6}{9.2 \text{ MPH}}$ = 63.7 "BEFORE"

= $\frac{585.6}{12.2 \text{ MPH}}$ = 48.0 "AFTER"

STEP 8: (SKIP, SEE 2B & 7)

STEP 9: DRIVERS "AFTER" = $\frac{(\text{6 DRIVERS "BEFORE"})(\text{3 VEHS})}{(\text{4 VEHS})}$ = 4.5

(USE PART-TIME, IF POSSIBLE)

STEP 10: USING COST ACCOUNT DATA FROM PAST YEAR; ANNUAL TOTALS OF VEH-MILES, VEH-HOURS, AND FLEET SIZE; AND AN ANNUALIZATION OF 250, PREPARE A SPREAD OF COSTS USING METHOD 10:

ACCOUNT	TOTAL (1)	PERCENT TO: VEH-MIS	PERCENT TO: VEH-HRS	PERCENT TO: VEHS	AMOUNT TO: (4) VEH-MIS	AMOUNT TO: VEH-HRS	AMOUNT TO: VEHS
					$	$	
ADMINISTRATION	$23,500			100 (2)			$23,500
BENEFITS	34,160	10	80	10	3,420	27,330	3,420
SS TAXES	10,920	10	80	10	1,090	8,740	1,090
OTHER TAXES	4,320	50 (2)		50 (2)	2,160		2,160
GARAGE COSTS	14,280			100 (2)			14,280
EQUIPMENT MAINTENANCE	42,840	100			42,840		
TRAFFIC SUPERVISION	19,800	20		80	3,960		15,840
DRIVERS WAGES	93,240		100			93,240	
FUEL	23,280	100 (2)			23,280		
PROMOTION	14,000	100 (2)			14,000		
INSURANCE	2,400	100 (2)			2,400		
CLAIMS	2,880	100 (2)			2,880		
EMPLOYEE CLAIMS	840	100 (3)			840		
SAFETY	12,500	50 (3)	50 (3)		6,250	6,250	
DEPRECIATION	43,846	20		80	8,770		35,080
	$342,806				$111,890	$135,560	$95,370

(1) FURNISHED BY TRANSIT SYSTEM.
(2) JUDGEMENT ALLOCATION BASED ON METHOD 10.
(3) ASSUMED TO BE SALARIES.
(4) ROUNDED-OFF TO $10.

	VEH-MIS	VEH-HRS	VEHS
ALLOCATED COSTS	$111,890	$135,560	$95,370
ANNUAL UNITS	206,250	18,750	2,500 (5)
UNIT COST	$0.54	$7.23	$38.15

(5) (10 VEHS IN FLEET)(250 ANNUALIZATION) = 2,500

THEREFORE:

COSTS "BEFORE" = (585.6)($0.54) + (63.7)($7.23) + (4)($38.15) = $930
COSTS "AFTER" = (585.6)($0.54) + (48.0)($7.23) + (3)($38.15) = $778
} DAILY

STEP 11: METHOD 12:

FUEL CONSUMPTION = (0.26 GALS/MIS @ 9.2 MPH)(585.6 VEH-MIS) = 152 GALS "BEFORE"
= (0.21 GALS/MIS @ 12.2 MPH)(585.6 VEH-MIS) = 123 GALS "AFTER"
} DAILY

STEP 12: (SKIP, NOT USING "CAPACITY-MILES" FOR ANY PURPOSE)

STEP 13: METHOD 13:

"BEFORE"

HC = (6 GRAMS/VEH-MILE @ 9.2 MPH)(585.6 VEH-MIS)

= 3,514 GRAMS DAILY EMISSIONS

NOX = (25)(585.6) = 14,640 GRAMS DAILY

"AFTER"

HC = (5)(585.6) = 2,928 GRAMS DAILY

NOX = (23)(585.6) = 13,467 GRAMS DAILY

STEP 14: REFERRING TO METHOD 14, THE CURVE FOR SOUND LEVEL AT A BUS VOLUME OF 3 PER HOUR PROVIDES AN ESTIMATE 30 TO 35 dBA. HOWEVER, VOLUME PER HOUR DOES NOT CHANGE "BEFORE" AND "AFTER", AND THE CURVE IS NOT SENSITIVE TO SPEED, SO SOUND LEVELS CANNOT BE EXPECTED TO CHANGE AS FAR A BUSES ARE CONCERNED.

FOR AUTOS (ASSUMING TRUCKS ARE NOT SIGNIFICANT IN THE FLOW), PRESENT SOUND LEVELS AT (7800)(0.10)(0.67) = 523 VEHICLES PER HOUR AT 17 MPH WOULD BE 45 TO 50 dBA.

STEP 15: USING PROCEDURE "X":

SINCE CAPACITY WILL BE CHANGED BY IMPLEMENTATION OF EXCLUSIVE BUS LANES, AND MODE SPLIT VERY LITTLE, USE THE STEPS ON THE RIGHT OF THE PAGE.

STEP 1. METHOD 22:

EXISTING CAPACITY FOR 2-LANES, WITH PARKING IS GIVEN AS 520 IN ONE DIRECTION.

WITH 2-LANES AND NO PARKING, CAPACITY WOULD BE 730, ONE DIRECTION.

HALF OF A 4-LANE STREET, NO PARKING, WOULD BE:

$$\frac{1520}{2} = 760 \text{ ONE DIRECTION.}$$

USE 730.

STEP 2: METHOD 23

$$V/C = \frac{(7800)(0.10)(0.67)}{520} = \frac{523}{520} = 1.01 \text{ "BEFORE"}$$

SPEED FROM CURVE = 14 MPH (ACTUAL = 17 MPH)

$$V/C = \frac{523}{730} = 0.72 \text{ "AFTER"}$$

SPEED FROM CURVE = 29 MPH

$$\text{SPEED "AFTER"} = \frac{29}{14}(17) = 35 \text{ MPH}$$

WITH A SPEED LIMIT OF 30 MPH, USE $\left(\frac{30}{35}\right)(35) = 30$ MPH

STEP 3. (SKIP, CHANGE IN VEH-MILES INSIGNIFICANT)

STEP 4. METHOD 25:

THE CURVE SHOWS THAT OUT-OF-POCKET COSTS WOULD BE:

($0.22 - 0.14) = $0.08 "BEFORE" AT 17 MPH } PER VEHICLE MILE

($0.20 - 0.14) = $0.06 "AFTER" AT 30 MPH

DAILY SAVINGS = (7,800)(1.5 MILES)($0.08 - 0.06) = $ 234

STEP 5. (SKIP, CHANGE IN PASS-MILES INSIGNIFICANT)

STEP 6. METHOD 12:

FUEL CONSUMPTION = (7800)(1.5)(0.09 GALS/MILE) = 1,053 GALS "BEFORE" } DAILY

= (7800)(1.5)(0.09) = 1,053 "AFTER"

NO IMPACT

STEP 7. INSPECTION OF THE CURVE IN PART "C" OF METHOD 25 INDICATES THAT A REDUCTION IN ACCIDENT RATE CAN BE EXPECTED.

STEP 8. METHOD 13:

"BEFORE"

HC = (7800)(1.5)(4 GRAMS/VEH-MIS @ 17MPH) = 46,800 GRAMS } DAILY

NOX = (7800)(1.5)(4) = 46,800 GRAMS

"AFTER"

HC = (7800)(1.5)(3) = 35,100 GRAMS } DAILY

NOX = (7800)(1.5)(4) = 46,800 GRAMS

COMBINING BUS AND AUTO (ASSUMING TRUCKS NOT SIGNIFICANT):

	"BEFORE"	"AFTER"
HC	46,800	35,100
	3,500	2,900
	50,300 GRAMS	38,000 GRAMS
NOX	46,800	46,800
	14,600	13,500
	61,400 GRAMS	60,300 GRAMS

} DAILY

(LITTLE CHANGE)

STEP 9. METHOD 1A:

AT AN HOURLY VOLUME (BOTH WAYS) OF 780 AUTOS (AGAIN ASSUME TRUCKS INSIGNIFICANT), CURVE SHOWS:

"BEFORE" SOUND LEVEL = 50 TO 55 dBA.

"AFTER" = ABOUT 55 dBA

A SMALL INCREASE IS INDICATED, PROBABLY NOT SIGNIFICANT.

All of the above estimates indicate that the project, if implemented, would have a favorable impact:

- One bus would be made availible for reassignment (or the frequency on Route 2 could be increased without more equipment).
- A small increase in passengers and revenue might result.
- A cost savings could result.
- Reduced fuel consumption and pollutant emission are possible.
- An improvement in auto flow is possible.

The results of the calculations are entered on an "Action Impact Worksheet". Not all of the results are listed, however, since previously selected Performance Measures require only a few of the calculations. The PM's are:

- Bus Speed
- Cost per Vehicle-Mile
- Passengers per Vehicle-Mile
- HC Emissions per Passenger-Mile
- NOX Emissions per Passenger-Mile

Therefore, only the factors of these measures are needed.

FIGURE 2-1. ACTION IMPACT WORKSHEET

Problem Number: 1A	Analytical Procedure: "A"
Action: EXCLUSIVE BUS LANES ON 1.5 MILES OF ROUTE 2.	

Performance Measure Factor	Level of Impact	Initial Value	Estimated Change	Revised Value
BUS SPEED	ROUTE, DAILY	9.2 MPH	+3.0	12.2 MPH
VEHICLE-MILES	↓	585.6	~	585.6
PASSENGERS	↓	523	+99	622
PASSENGER-MILES	↓	1,308	+247	1,555
OPERATING COST	↓	$930	-152	$778
HC EMISSIONS	↓	3,514 GRAMS	-586	2,928 GRAMS
NOX EMISSIONS	↓	14,640 "	-1,173	13,467 "

EVALUATION OF ALTERNATIVES

These values are then transferred to an "Action Evaluation Worksheet" for the calculations necessary to resolve a set of alternatives.

Included on the same worksheet are calculations for another Route 2 action, a one-way pair of streets, which is an alternative to Project 1A, the exclusive lanes.

Data from the Impact Worksheet have been used to calculate the value of the revised PM. All signs have been set to "+" since all of the changes were predicted to be favorable.

Weights were developed as follows:

(5 PM'S)(10 POINTS EACH) = 50 WEIGHTING POINTS

PERFORMANCE MEASURE	ALLOCATED WEIGHTING POINTS
BUS SPEED	10
COST PER VEH-MILE	15
PASS PER VEH-MILE	15
HC PER PASS-MILE	5
NOX PER PASS-MILE	5
	50

Once the points were assigned, the total effectiveness could be calculated:

$$+(33)(10) + (16)(15) + (19)(15) + (30)(5) + (23)(5) = +1120$$
$$+(35)(10) + (17)(15) + (6)(15) + (35)(5) + (17)(5) = +955$$

At this point, cost data was also calculated and entered:

ASSUME 10 YEAR LIFE
INTEREST RATE = 8%, C.R.F. = 0.14903
$ (154,000)(0.14903) = $22,950 ANNUAL COST FOR PROJECT 1A.

TABULATION AND PLOTTING OF DATA

This array of information was summarized into a "TSM Action Evaluation Summary" sheet, as shown.

The cost-effectiveness plot for the two alternatives looked like this:

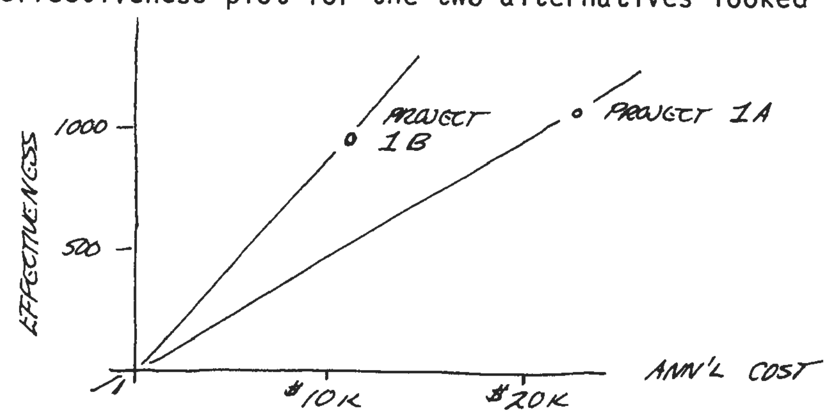


FIGURE 3-1. TSM ACTION EVALUATION WORKSHEET

			Problem No: 1A Action: EXCLUSIVE BUS LANES					Problem No: 1B Action: ONE-WAY STREETS				
Performance Measure	Level	Base Value	Revised PM	% Diff.	Sign	Wt.	Eff	Revised PM	% Diff.	Sign	Wt.	Eff
BUS SPEED	ROUTE	9.2 MPH	12.2 MPH	33	+	10		12.4 MPH	35	+	10	
COST/VEH-MIS		930/585.6 = $1.58	$1.33	16	+	15		$1.31	17	+	15	
PASS/VEH-MIS		523/585.6 = 0.89	1.06	19	+	15		0.94	6	+	15	
HC/PASS-MIS		3514/1308 = 2.69 GR	1.88	30	+	5		1.75	35	+	5	
NOX/PASS-MIS		14640/1308 = 11.19 GR	8.66	23	+	5		9.28	17	+	5	
			Total Effectiveness			+	1120	Total Effectiveness			+	955
Capital Cost			$154,000					$72,800				
Annualized Capital Cost			$22,950					$10,850				
Annual Operating Cost			~					~				
Total Annual Cost			$22,950					$10,850				

FIGURE 3-2. TSM ACTION EVALUATION SUMMARY

		Problem Number: 1A Action: EXCLUSIVE BUS LANES, ROUTE 2	Problem Number: 1B Action: ONE-WAY STREETS, ROUTE 2	Problem Number: Action:
		Capital Cost:$150,000	Capital Cost:$ 72,800	Capital Cost:$
		Life: 10 Years	Life: 10 Years	Life: Years
		Salvage Value:$ ~	Salvage Value:$ ~	Salvage Value:$
		Interest Rate: 8 %	Interest Rate: 8 %	Interest Rate: %
Performance Measure	Base Value	Revised Performance Measure Value	Revised Performance Measure Value	Revised Performance Measure Value
BUS SPEED	9.2 MPH	12.2 MPH	12.4 MPH	
COST PER VEH-MILE	$1.58	$1.33	$ 1.31	
PASS PER VEH-MILE	0.89	1.06	0.94	
HC PER PASS-MILE	2.69 GR	1.88 GRAMS	1.75 GRAMS	
NOX PER PASS-MILE	11.19 GR	8.66 GRAMS	9.28 GRAMS	
Annualized Capital Cost		$ 22,950	$ 10,850	
Annual Project Operating Cost		~	~	
Change in Operating Cost		~	~	
Total Annual Cost		$ 22,950	$ 10,850	
Effectiveness		+ 1120	+ 955	
Cost Effectiveness		$ 20.49	$ 11.36	

Project 1B turns out to be the more cost-effective of the two, so would most likely be selected over 1A for inclusion in the TSM program.

The next step in the analysis would be to prepare worksheets for all the candidate projects and rank them in cost-effectiveness order. These results, which can be presented in the "Summary" form, are input into the final selection process for projects to be included in the TSM program.

APPENDIX E: REFERENCES

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