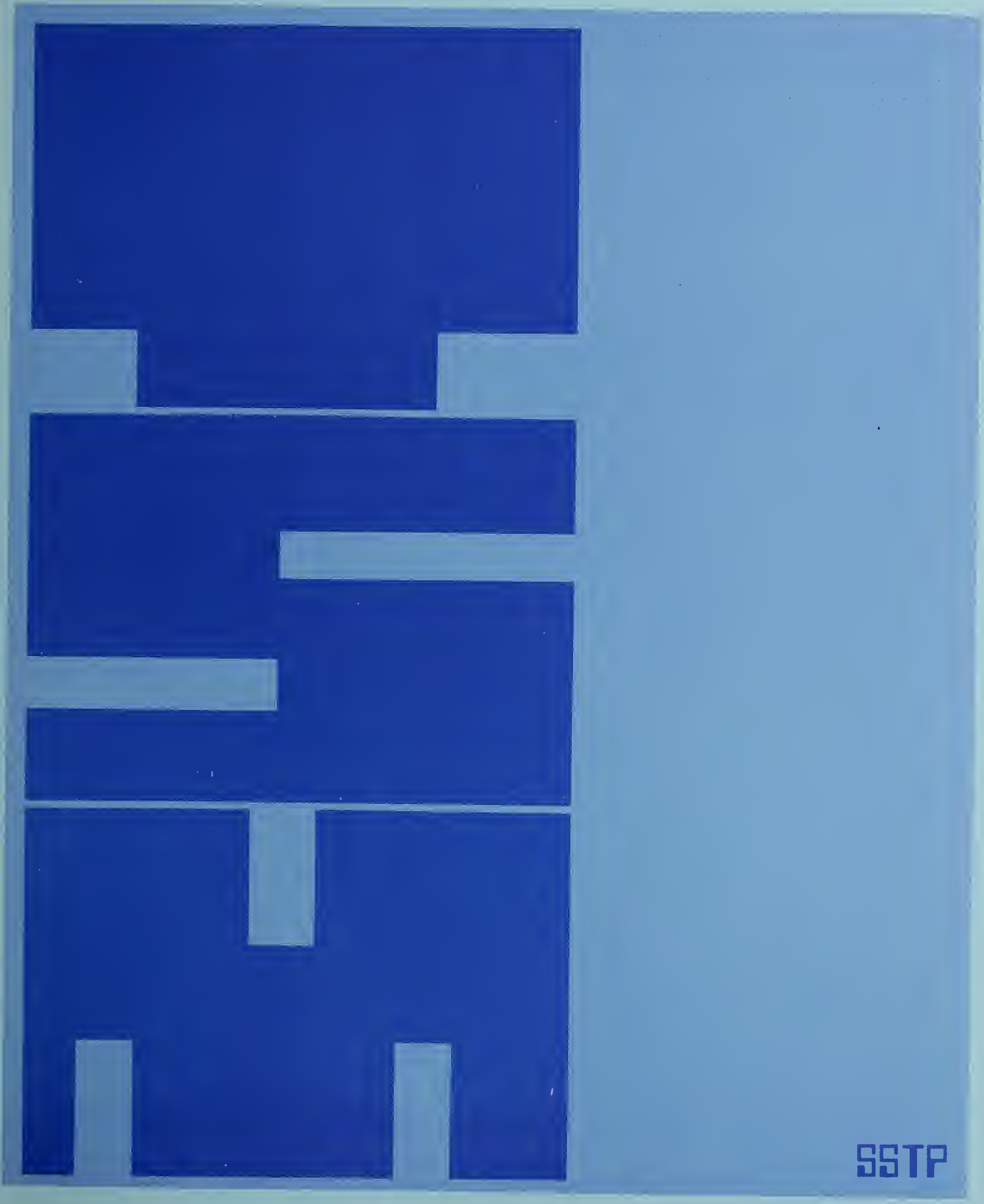
U.S. Department of Transportation

October 1981

Energy Impacts of Transportation Systems Management Actions



SSTP

Energy Impacts of Transportation Systems Management Actions

Final Report
October 1981

Prepared by
Transportation Data and Analysis Section
New York State Department of Transportation
Albany, New York

Prepared for
Office of Planning Assistance
Urban Mass Transportation Administration
U.S. Department of Transportation
Washington, D.C. 20590

In Cooperation with
Technology Sharing Program
Office of the Secretary of Transportation

DOT-I-82-4

FOREWORD

During the 1970's, transportation system users faced significant increases in energy prices. These increases have made energy efficiency an important goal for transportation planners. Transportation System Management (TSM) activities have been identified as being particularly effective in reducing energy consumption. However, to this point it has been difficult to assess the energy implications of TSM actions due to the complexity of existing analysis techniques.

This report is designed to make energy-use impact analyses for TSM-type projects much simpler. It provides a set of easy-to-apply manual methods to calculate energy consumption in areas where TSM-type activities are proposed. The methods use data normally available in the project development process. We believe this manual will prove useful to planners at all levels who are interested in assessing the energy impacts of TSM-type projects.

Additional copies of this report are available from the National Technical Information Service, Springfield, Virginia 22161. Please refer to UMTA-NY-09-8007-82-1 in your request.

Charles H. Graves
Director, Office of Planning Assistance
Urban Mass Transportation Administration
U.S. Department of Transportation
Washington, D. C. 20590

Alfonso B. Linhares
Director, Office of Technology and
Planning Assistance
Office of the Secretary
U.S. Department of Transportation
Washington, D. C. 20590

Abstract

Recent federal regulations have placed greater emphasis on analysis of energy issues in the Urban Transportation Planning Process. Part of these requirements include analysis of energy savings resulting from Transportation Systems Management (TSM) actions.

This document is a handbook of simple analysis methods that can be used to assess the direct energy impact of TSM actions. It contains step-by-step instructions to complete worksheets that have been included. Sample case studies are also included which demonstrate the use of the analysis procedures.

This methods discussed should appeal to a variety of user groups by requiring minimum data input; reasonable staff time and expertise; and no computer use.

TABLE OF CONTENTS

1. Introduction

Transportation Systems Management (TSM) has been an important element of the Urban Transportation Planning process for a number of years. (1) TSM planning challenges decision makers to maximize the efficient use of the existing transportation system through the development of policies and programs which maintain a high level of mobility within the constraints presented by limited funding.

TSM Actions can be broadly classified into four categories (2):
- actions that reduce demand for vehicle travel.
- actions that enhance highway supply.
- actions that reduce demand for vehicle travel and reduce highway supply.
- actions that enhance highway supply and reduce vehicle travel demand.

In each of these categories the emphasis is on low cost investments which encourage mode shifts, reduce travel demand, or improve vehicular flow.

Purpose

Recent energy supply shortfalls and price increases have required the TSM planner to evaluate the direct energy implications of a variety of actions. Federal regulations concerning the urban transportation planning process have emphasized the need for assessment of energy impacts in an atmosphere of uncertainty. (3).

The purpose of this document is to provide procedural guidance to TSM planners charged with evaluating the energy impact of TSM actions. The procedures discussed in the handbook are designed to appeal to a variety of user groups by requiring minimum data input, reasonable staff time and expertise and no computer use. The methods are flexible enough to be applied to a range of urban area policies yet still provide reasonable estimates of energy impact. The use of simple manual methods as presented in this text is consistent with recent shifts in transportation analysis.

The last decade has witnessed a change in analysis approaches from long-range data-intensive highway planning to "quick response" multimodal planning. This document has been developed as a user-oriented handbook for a range of TSM actions. Each section presents brief background information concerning the action step-by-step instructions and an analysis worksheet. Also contained is a case study describing the application of each energy analysis procedure.

Important Energy Analysis Factors

Several important tables are summarized below which are the basis for many of the procedures developed in this handbook. Throughout the text, these tables will be cited many times to provide important basic information.

Table 1.1 - Fuel Consumption Rates at Selected Cruise Speeds.

Research has shown that the rate (measured in gallons per mile) of fuel consumption is a function of speed and vehicle type. This table contains estimates of fuel consumption at selected cruise speeds for autos and trucks. The consumption rates are based on figures compiled for the following composite auto: large cars, 20%; standard cars, 65%; compact cars, 10% and small cars, 5%. For trucks the composite car is: pickup and panel trucks, 54%; two-axle six-tire trucks, 6%; and tractor semi-trailer truck combinations, 40%.

Table 1.2 - Adjustment for Change in Automobile Fuel Economy by Year.

The data concerning fuel consumption for autos outlined above is based on data collected in the early 1960's. Since this time Federal fuel economy standards have resulted in a reduction in the rates. Therefore, the composite auto estimates must be adjusted to reflect this improvement in fuel economy. This is accomplished by multiplying the fuel consumption rate for a selected cruise speed, by the appropriate adjustment factor for a particular year.

Table 1.3 - Passenger Car Fleet Fuel Economy

As mentioned previously, Federal fuel economy standards have resulted in an improvement to fuel consumption rates for passenger vehicles. This table reflects the improvement to "over the road" fuel economy resulting from these standards. "Over the road" operation represents typical driving conditions experienced by passenger vehicles and is, therefore, useful in determining consumption of fuel over a specified distance. For example, in several procedures developed in this handbook estimates of VMT saving will be developed. These estimates can be divided by the factors in this table to find gallons of fuel saved.

Table 1.4 - Excess Fuel Consumed Per Speed Change Cycle

As vehicles decelerate from a constant speed and accelerate back to that speed from a stopped condition, excess fuel is consumed. Estimates of the direct energy impact of these speed change cycles are outlined in this table. The auto values have to be adjusted by the appropriate factor in Table 1.2 to reflect improved fuel economy.

Table 1.5 - Additional Standard Factors

Any estimated savings in vehicle miles of travel (VMT) resulting from a mode shift (i.e. drive alone auto to shared ride or transit) will be offset by VMT generated by the "car left home". In cases where work trip VMT is reduced by a TSM action, this savings can be multiplied by a factor of 0.6 to account for the increase in VMT generated by the "car left home" (4).

In many cases, it will be desirable to convert estimates of daily energy impact to yearly impacts to provide consistent estimates of yearly impact, standard factors are provided. In the case of strategies which influence work trips, 250 is used and in cases where strategies influence all trip types, 330 is used.

Table 1.1

Fuel Consumption Rates at Selected Cruise Speeds

	Fuel Consumption (Gals/Mile)	
Speed (MPH)	Auto	Truck
10	.072	.177
15	.058	.136
20	.050	.112
25	.045	.100
30	.044	.095
35	.045	.095
40	.046	.099
45	.048	.107
50	.052	.119
55	.055	.132
60	.058	.142
65	.062	.169

Source: (5)

Table 1.2

Adjustment to Fuel Economy by Year

Year	Adjustment
1974	1.000
1975	1.000
1976	0.980
1977	0.955
1978	0.931
1979	0.902
1980	0.871
1981	0.831
1982	0.791
1983	0.747
1984	0.748
1985	0.670
1986	0.638
1987	0.612
1988	0.592
1989	0.576
1990	0.565
1991	0.556
1992	0.550
1993	0.546
1994	0.542
1995	0.540
1996	0.540
1997	0.540
1998	0.538
1999	0.538
2000	0.538

Source: J. A. Apostolos et al; Energy and Transportation Systems (NCHRP 20-7); (6) CALTRANS; December, 1978

Table 1.3

Passenger Car Fleet Fuel Economy

Year	MPG
1978	15.95
1979	16.5
1980	17.0
1981	17.7
1982	18.5
1983	19.5
1984	20.6
1985	21.7
1986	22.7
1987	23.6
1988	24.5
1989	25.2
1990	25.8

Source: U.S. Department of Transportation, *Automotive Fuel Economy Program Fifth Annual Report to the Congress*, Washington, D.C., USDOT, Jan. 1981.

Table 1.4

Excess Fuel Consumed Per Speed Change Cycle

Speed Reduced From and Returned to (MPH)	Gallons/Cycle	
	Auto	Truck
10	.0016	.0069
15	.0044	.0142
20	.0066	.0216
25	.0082	.0301
30	.0097	.0386
35	.0112	.0499
40	.0128	.0595
45	.0148	.0895
50	.0168	.1082
55	.0188	.1082
60	.0208	.1308
65	.0225	.1461

Source: (5)

Table 1.5

Additional Standard Factors

1. Car Left Home = 0.60
2. No. work days/yr. = 250
3. No. travel days/yr. = 330

Use of the Report and Worksheets

As noted in the Table of Contents, each section of this report deals with a specific TSM action. In order to make this report easy to use, page end markings on the Table of Contents are matched to markings on the page at the beginning of the corresponding section and on the page at the sample worksheet detailing the methodology. This allows the analyst to locate relevant sections and worksheets conveniently.

Concluding Remarks

The purpose of this document is to present a handbook of energy analysis techniques to evaluate the direct energy impact of TSM actions. The text contains sample worksheets and step-by-step instructions that allow the application of these procedures by a wide range of user groups.

This document will hopefully help enhance the ability of TSM planners to assess the energy implications of TSM policies and programs in a timely fashion.

REFERENCES

1. Federal Register, Vol. 40, No. 181, Wednesday, September 17, 1975, pg. 42729
2. Fred A. Wagner and Keith Gilbert, Transportation Systems Management: An Assessment of Impacts, Interim Report, Alan M. Voorhees, Inc., McLean, Virginia, 1978.
3. Federal Register, Vol. 46, No.12, Monday, January 19, 1981, pg. 5702.
4. Janis M. Gross, "The Car Left Home" Preliminary Research Report 168, NYSDOT, Planning and Research Unit, Albany, New York, August, 1979.
5. Nathan S. Erlbaum, "Procedures for Estimating Energy Consumption in Transportation Projects, " Preliminary Research Report 174, New York State Department of Transportation, Planning and Research Unit, Albany, New York, June 1980.
6. J.A. Apostolos et. al. Energy and Transportation Systems, (NCHRP-20-7), CALTRANS, December, 1978.
7. U.S. Department of Transportation. Automotive Fuel Economy Program Fifth Annual Report to Congress, Washington, D.C. USDOT, Jan. 1981.

2. Traffic Operations

The purpose of this discussion is to present a methodology which can be used to assess the energy impacts of traffic engineering roadway improvements. It is suggested that direct energy consumption is a function of traffic flow conditions (number and duration of stops; number of acceleration-deceleration cycles; and average vehicle cruise speed) and that this knowledge can be used to analyze the impact of highway capacity improvements on fuel consumption.

Introduction

Traffic engineering is concerned with improving the safety and efficiency of travel. Many traffic engineering projects are aimed specifically at expanding the ability of the roadway to accomodate vehicular traffic.

The "direct" energy impact of these capacity improvements can have positive energy benefits by reducing delay and stopping while increasing vehicle speed. Greater understanding of these concepts can be found in the following discussion.

Motor Vehicle Energy Conservation

The direct energy consumed by a motor vehicle is influenced by a number of factors, including vehicle characteristics (size, weight, engine displacement, etc.), ambient conditions (temperature, altitude, etc.), trip length/cold start, driver habits, road conditions (grade, surface, etc.), and traffic flow conditions (number and duration of stops, number of acceleration-deceleration cycles, vehicle speed) (1).

Data bases have been developed to identify the energy consumption patterns of vehicles under various road and traffic flow conditions (2,3). This research indicates that vehicle fuel efficiency (miles per gallon) is maximized at a constant speed between 30-35 mph. It also finds that any deviation from this pattern (stopping, delay, lower or higher speeds) will lower fuel economy (3). These principles can be used to estimate the energy impact of traffic engineering improvements.

The first section of this paper describes in more detail the energy consumption factors that can be used to estimate fuel consumption at various cruise speeds and stopping cycles. The data described in this section is applied in the methods described below. The analyst is referred to this earlier section for more detail.

Roadway Elements

For purposes of energy analysis it is useful to distinguish between two vehicle operating conditions resulting from the nature of th roadway segment under evaluation. These conditions may be termed uninterrupted flow (vehicle not required to stop while traversing a segment) and interrupted flow (vehicle required to stop because of intersection controlled by traffic signal or stop sign, etc.). The assessment of energy consumption during uninterrupted conditions requires estimates of the vehicle cruise speed. Interrupted flow analysis requires additional information on stopping frequency and delay as well as cruise speed.

The following discussion presents methodologies for both these conditions. In the case of uninterrupted flow, total fuel consumption from cruise speed shifts is estimated. The interrupted flow method estimates the total excess fuel consumed from stops and delay above that which would be consumed at a constant cruise speed.

A. Energy Analysis for Intersections

As mentioned above, traffic engineering improvements are designed to improve the capacity of selected roadway elements. It is common practice to expand the capacity of intersections by upgrading signalization, eliminating parking, adding turn lanes, or prohibiting turns. These improvements can reduce delay and stopping frequencies, resulting in an associated improvement in direct energy consumption. A worksheet is included to analyze improvements at uninterrupted flow segments.

Instructions for Worksheet Intersection Analysis

It is useful to provide information concerning the background of the proposed improvement. Evaluation can be based on any particular time during a day; however, peak hour comparisions are suggested because this is the time when the greatest travel demand and congestion occurs.

Step 1: Record the traffic demand during the time period under analysis. The demand is classified into trucks and autos.
Step 2: Estimate the approach speed. If not known, use speed limit.
Step 3: Estimate the percent vehicles that must stop on the approach. The method contained in JHK and Associates (4) is recommended.
Step 4: Multiply the percent stopping (Step 3) by the demand volume (step 1) to obtain the number of vehicles stopping.
Step 5: From Table 1.4 find the excess fuel consumed from stopping using the approach speed (Step 2).
Step 6: Multiply Step 4 (number stopping) by Step 5 to find excess gallons consumed by stopping vehicles.
Step 7: Record the average delay per stopping vehicle. See JHK and Associates (4) for methodology.

Step 8: Multiply Step 4 (number stopping) by Step 7 to find total vehicle seconds of delay. Divide this by 3600 to find total vehicle hours of delay on the approach.

Step 9: Multiply Step 8 by idling rate of fuel consumption
auto - 0.58 gallons per vehicle hour
truck - 0.61 gallons per vehicle hour
to find excess fuel consumed by delay (Claffey (2)).

Step 10: Add Step 6 and Step 9 to find total gallons consumed per analysis period.

Step 11: Multiply the fuel consumed during the analysis period by the number of analysis periods per day to find the daily fuel consumption and then multiply this daily estimate by 250 to find the total yearly unadjusted fuel consumption.

Step 12: From Table 1.2 find the adjustment factor for the analysis year to account for improved vehicle fuel efficiency for autos. Multiply this factor by the estimate of auto fuel consumption in Step 11.

Step 13: Sum the adjusted yearly fuel consumption estimates (auto and truck) for each approach to find total yearly fuel consumption for the intersection.

The worksheet is used twice: first, based on "before" conditions and next, based on information describing "after" conditions. The difference ("before" minus "after") in gallons provides an estimate of the net energy savings.

TSM
ENERGY ANALYSIS
WORKSHEET

TRAFFIC OPERATIONS: INTERSECTION ANALYSIS

A. BASE DATA

	APPROACH VOLUME		% STOPPING		TOTAL STOPPING		AVG. DELAY (SEC)				TOTAL DELAY (HR)
A		X		=		X		÷	3600	=	
T		X		=		X		÷	3600	=	

	APPROACH SPEED (MPH)		
A		T	

B. FUEL CONSUMPTION

	TOTAL DELAY		FCR		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
A		X	.58	X		=	
T		X	.61			=	
	TOTAL STOPPING		FCR (TABLE 1.4)				
A		X		X		=	
T		X				=	

SUBTOTAL [ ] DAILY FUEL CONSUMPTION

X [250] WORKDAYS PER YEAR

TOTAL [ ] ANNUAL FUEL CONSUMPTION

A = AUTO
T = TRUCK
FCR = FUEL CONSUMPTION RATE (GALLONS PER VEHICLE HOUR)

Example

An example has been included to demonstrate the use of the worksheet. The base data is summarized below and was obtained from field observations recorded in Dale (5).

A number of improvements were made at an intersection that included signal upgrading, channelization, and other geometric changes. Before and after data are contained in Table 2.1 and are used to determine the change in fuel consumption.

Results of Analysis

After using the worksheet, it is revealed that the improvement will result in a net decrease in direct energy consumption of 6,450 gallons. This represents the change in "excess" fuel consumed above uninterrupted flow operation through the intersections.

Table 2.1

Base Data

	North	East	South	West
	Approach Volume			
A.M. (2 Hr.)	890	860	640	630
P.M. (2 Hr.)	1080	1040	1500	1200
Other Hours	5690	5820	5120	5510
	7660	7720	7260	7340
	Percent Stopping			
Before				
A.M.	80	52	71	85
P.M.	95	67	86	100
Other Hours	70	50	61	75
After				
A.M.	57	50	59	73
P.M.	72	64	68	67
Other Hours	50	50	50	55
	Average Delay per Stopped Vehicle (Seconds)			
Before				
A.M.	30.2	14.1	30.8	73.4
P.M.	41.4	19.3	42.2	100.5
Other Hours	27.7	12.7	28.3	67.3
After				
A.M.	23.7	27.3	28.5	35.1
P.M.	35.7	35.1	31.4	41.2
Other Hours	23.9	23.5	21.0	27.6

Source: REF (4).

BEFORE
NORTH APPROACH

TSM
ENERGY ANALYSIS
WORKSHEET

TRAFFIC OPERATIONS: INTERSECTION ANALYSIS

A. BASE DATA 5% TRUCKS PM PEAK

	APPROACH VOLUME		% STOPPING		TOTAL STOPPING		AVG. DELAY (SEC)				TOTAL DELAY (HR)
A	1026	x	95	=	975	x	41.4	÷	3600	=	11.21
T	54	x	95	=	51	x	41.4	÷	3600	=	0.59

	APPROACH SPEED (MPH)		
A	35	T	30

B. FUEL CONSUMPTION

	TOTAL DELAY		FCR		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
A	11.21	x	.58	x	.831	=	5.40
T	0.59	x	.61			=	0.36

	TOTAL STOPPING		FCR (TABLE 1.4)				
A	975	x	.0112	x	.831	=	9.07
T	51	x	.0386			=	1.97

SUBTOTAL 16.80 DAILY FUEL CONSUMPTION

x 250 WORKDAYS PER YEAR

TOTAL 4200 ANNUAL FUEL CONSUMPTION

A = AUTO
T = TRUCK
FCR = FUEL CONSUMPTION RATE (GALLONS PER VEHICLE HOUR)

BEFORE
EAST APPROACH

TSM
ENERGY ANALYSIS
WORKSHEET

TRAFFIC OPERATIONS: INTERSECTION ANALYSIS

A. BASE DATA 5% TRUCKS - PM PEAK

	APPROACH VOLUME		% STOPPING		TOTAL STOPPING		AVG. DELAY (SEC)				TOTAL DELAY (HR)
A	988	x	67	=	662	x	19.3	÷	3600	=	3.55
T	52	x	67	=	35	x	19.3	÷	3600	=	0.19

	APPROACH SPEED (MPH)		
A	35	T	30

B. FUEL CONSUMPTION

	TOTAL DELAY		FCR		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
A	3.55	x	.58	x	.831	=	1.71
T	0.19	x	.61			=	0.12

	TOTAL STOPPING		FCR (TABLE 1.4)				
A	662	x	.0112	x	.831	=	6.16
T	35	x	.0386			=	1.35

SUBTOTAL 9.34 DAILY FUEL CONSUMPTION

x 250 WORKDAYS PER YEAR

TOTAL 2,335 ANNUAL FUEL CONSUMPTION

A = AUTO
T = TRUCK
FCR = FUEL CONSUMPTION RATE (GALLONS PER VEHICLE HOUR)

BEFORE
SOUTH APPROACH

TSM
ENERGY ANALYSIS
WORKSHEET

TRAFFIC OPERATIONS: INTERSECTION ANALYSIS

A. BASE DATA 5% TRUCKS - PM PEAK

	APPROACH VOLUME		% STOPPING		TOTAL STOPPING		AVG. DELAY (SEC)				TOTAL DELAY (HR)
A	1,425	X	86	=	1,226	X	42.2	÷	3600	=	14.4
T	75	X	86	=	65	X	42.2	÷	3600	=	.76

	APPROACH SPEED (MPH)		
A	35	T	30

B. FUEL CONSUMPTION

	TOTAL DELAY		FCR		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
A	14.4	X	.58	X	.831	=	6.94
T	0.76	X	.61			=	0.46

	TOTAL STOPPING		FCR (TABLE 1.4)				
A	1,226	X	.0112	X	.831	=	11.41
T	65	X	.0386			=	251

SUBTOTAL 21.32 DAILY FUEL CONSUMPTION

A = AUTO
T = TRUCK
FCR = FUEL CONSUMPTION RATE (GALLONS PER VEHICLE HOUR)

X 250 WORKDAYS PER YEAR

TOTAL 5,330 ANNUAL FUEL CONSUMPTION

BEFORE
WEST APPROACH

TSM
ENERGY ANALYSIS
WORKSHEET

TRAFFIC OPERATIONS: INTERSECTION ANALYSIS

A. BASE DATA 5% TRUCKS - pm PEAK

	APPROACH VOLUME		% STOPPING		TOTAL STOPPING		AVG. DELAY (SEC)				TOTAL DELAY (HR)
A	1,140	x	100	=	1,140	x	100.5	÷	3600	=	31.83
T	60	x	100	=	60	x	100.5	÷	3600	=	1.68

	APPROACH SPEED (MPH)		
A	35	T	30

B. FUEL CONSUMPTION

	TOTAL DELAY		FCR		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
A	31.83	x	.58	x	.831	=	15.34
T	1.68	x	.61			=	1.02

	TOTAL STOPPING		FCR (TABLE 1.4)				
A	1,140	x	.0112	x	.831	=	10.61
T	60	x	.0386			=	2.32

SUBTOTAL	29.29	DAILY FUEL CONSUMPTION
x	250	WORKDAYS PER YEAR
TOTAL	7,323	ANNUAL FUEL CONSUMPTION

A = AUTO
T = TRUCK
FCR = FUEL CONSUMPTION RATE (GALLONS PER VEHICLE HOUR)

ALL APPROACHES
19,188

AFTER
NORTH APPROACH

TSM
ENERGY ANALYSIS
WORKSHEET

TRAFFIC OPERATIONS: INTERSECTION ANALYSIS

A. BASE DATA 5% TRUCKS - PM PEAK

	APPROACH VOLUME		% STOPPING		TOTAL STOPPING		AVG. DELAY (SEC)				TOTAL DELAY (HR)
A	1,026	x	72	=	739	x	35.7	÷	3600	=	7.33
T	54	x	72	=	39	x	35.7	÷	3600	=	0.39

APPROACH SPEED (MPH)

A 35 T 30

B. FUEL CONSUMPTION

	TOTAL DELAY		FCR		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
A	7.33	x	.58	x	.831	=	3.53
T	0.39	x	.61			=	0.24

	TOTAL STOPPING		FCR (TABLE 1.4)				
A	739	x	.0112	x	.831	=	6.88
T	39	x	.0386			=	1.51

SUBTOTAL 12.16 DAILY FUEL CONSUMPTION

A = AUTO
T = TRUCK
FCR = FUEL CONSUMPTION RATE (GALLONS PER VEHICLE HOUR)

x 250 WORKDAYS PER YEAR

TOTAL 3,040 ANNUAL FUEL CONSUMPTION

AFTER
EAST APPROACH

TSM
ENERGY ANALYSIS
WORKSHEET

TRAFFIC OPERATIONS: INTERSECTION ANALYSIS

A. BASE DATA

5% TRUCKS . pm PEAK

	APPROACH VOLUME		% STOPPING		TOTAL STOPPING		AVG. DELAY (SEC)				TOTAL DELAY (HR)
A	988	x	64	=	632	x	35.1	÷	3600	=	6.16
T	52	x	64	=	33	x	35.1	÷	3600	=	0.32

	APPROACH SPEED (MPH)		
A	35	T	30

B. FUEL CONSUMPTION

	TOTAL DELAY		FCR		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
A	6.16	x	.58	x	.831	=	2.97
T	0.32	x	.61			=	0.20

	TOTAL STOPPING		FCR (TABLE 1.4)				
A	632	x	.0112	x	.831	=	5.88
T	33	x	.0386			=	1.27

SUBTOTAL		10.32	DAILY FUEL CONSUMPTION
	x	250	WORKDAYS PER YEAR
TOTAL		2,580	ANNUAL FUEL CONSUMPTION

A = AUTO
T = TRUCK
FCR = FUEL CONSUMPTION RATE (GALLONS PER VEHICLE HOUR)

AFTER
SOUTH APPROACH

TSM
ENERGY ANALYSIS
WORKSHEET

TRAFFIC OPERATIONS: INTERSECTION ANALYSIS

A. BASE DATA

5% TRUCKS - pm PEAK

	APPROACH VOLUME		% STOPPING		TOTAL STOPPING		AVG. DELAY (SEC)				TOTAL DELAY (HR)
A	1,425	x	68	=	969	x	31.4	÷	3600	=	8.45
T	75	x	68	=	51	x	31.4	÷	3600	=	0.44

	APPROACH SPEED (MPH)		
A	35	T	30

B. FUEL CONSUMPTION

	TOTAL DELAY		FCR		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
A	8.45	x	.58	x	.831	=	4.07
T	0.44	x	.61			=	0.27

	TOTAL STOPPING		FCR (TABLE 1.4)				
A	969	x	.0112	x	.831	=	9.02
T	51	x	.0386			=	1.97

SUBTOTAL	15.33	DAILY FUEL CONSUMPTION
x	250	WORKDAYS PER YEAR
TOTAL	3,833	ANNUAL FUEL CONSUMPTION

A = AUTO
T = TRUCK
FCR = FUEL CONSUMPTION RATE (GALLONS PER VEHICLE HOUR)

AFTER
WEST APPROACH

TSM
ENERGY ANALYSIS
WORKSHEET

TRAFFIC OPERATIONS: INTERSECTION ANALYSIS

A. BASE DATA 5% TRUCKS - pm PEAK

	APPROACH VOLUME		% STOPPING		TOTAL STOPPING		AVG. DELAY (SEC)				TOTAL DELAY (HR)
A	1,140	x	67	=	764	x	41.2	÷	3600	=	8.74
T	60	x	67	=	40	x	41.2	÷	3600	=	0.46

	APPROACH SPEED (MPH)		
A	35	T	30

B. FUEL CONSUMPTION

	TOTAL DELAY		FCR		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
A	8.74	x	.58	x	.831	=	4.21
T	0.46	x	.61			=	0.28

	TOTAL STOPPING		FCR (TABLE 1.4)				
A	764	x	.0112	x	.831	=	7.11
T	40	x	.0386			=	1.54

SUBTOTAL 13.14 DAILY FUEL CONSUMPTION

x 250 WORKDAYS PER YEAR

TOTAL 3,285 ANNUAL FUEL CONSUMPTION

ALL APPROACHES
12,738

A = AUTO
T = TRUCK
FCR = FUEL CONSUMPTION RATE (GALLONS PER VEHICLE HOUR)

B. Energy Analysis For Uninterrupted Flow

In cases where vehicles operate at a continuous speed, free from intersection control, a different energy analysis is suggested. This method simply compares the average vehicle speed "before" and "after" an improvement to a segment. This estimate is the net direct energy savings over the segment.

Typical improvements in this category include road widening, removal of parking, and reconstruction.

A worksheet outlines the energy impact methodology.

Instructions for Worksheet

Step 1: Identify the segment under investigation, normally segments must exhibit some constant cruise speed free from "stop and go" traffic signal interference.
Step 2: Segment length (mile).
Step 3: Identify direction of flow.
Step 4: Identify demand volume, by direction, for each segment.
Step 5: Determine the average speed by direction for the segment under investigation.
Step 6: Enter Table 1.1 above to estimate the fuel consumption rate over the segment.
Step 7: Multiply the demand volume by segment length by the fuel consumption rate to determine total fuel consumption (gallons) for the segment.
Step 8: Adjust the auto fuel consumption for the analysis year from Table 1.2.
Step 9 Multiply Step 8 by Step 7 to find total adjusted fuel consumption. This result may be multiplied by any number of days appropriate for the analysis (i.e. annually = Step 9 x 330, annual peak hour = Step 9 x 250, etc...)

TSM
ENERGY ANALYSIS
WORKSHEET

TRAFFIC OPERATIONS: UNINTERRUPTED FLOW

A. BASE DATA

	DEMAND VOL.		SEGMENT LENGTH (MI)		DAILY VMT	SPEED (MPH)
AUTO		X		=		
TRUCK		X		=		

B. FUEL CONSUMPTION

	VMT		FCR (GPM) (TABLE 1.1)		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
AUTO		X		X		=	
TRUCK		X		X		=	

SUBTOTAL		DAILY FUEL CONSUMPTION
X	250	WORKDAYS PER YEAR
TOTAL		ANNUAL FUEL CONSUMPTION

Example

The procedure discussed above for uninterrupted flow is designed to be applied in cases where vehicle operation is free from the influence of signalized intersections. This would include freeway or expressway segments and arterial segments which have signalized intersections at a spacing of more than one mile.

An example is presented below describing some improvements to a hypothetical expressway. This discussion outlines the application of the worksheet.

Base Information

A two mile long suburban expressway with two lanes in each direction currently accommodates a peak hour volume (P.M.) of 4,000 vehicles per hour in each direction. This volume is forecasted to increase to 6,000 vehicles per hour in 20 years. The current average speed is 35 miles per hour during the peak hour. With no additional lanes, this speed will decrease to 20 miles per hour in 20 years. Using the information summarized in Table 2.2 and the worksheet the direct energy impact of the "null" condition and widening to six lanes is presented for the 20 year planning horizon.

Table 2.2

20 Year Design Alternatives-

Condition	P.M. Demand Volume	No. Lanes	Average Speed (MPH)
"Null"	6000	4	20
Widen to Six Lanes	6000	6	35

After completion of worksheet B, it is shown that under the null condition 343 gallons will be consumed per P.M. peak compared to 307 gallons under the proposed widening. If this savings of 36 gallons is multiplied by 250 days per year, a yearly savings of 9,000 gallons is indicated.

Summary and Limitations

The purpose of this section has been to present a discussion of the project level direct energy impact of general traffic operations improvements. It has been shown that it is necessary to collect field data including delay, stopping, and average speed information in order apply the procedures outlined. The method outlined for interrupted flow conditions provides an estimate of the change in excess fuel consumed for the project. The uninterrupted flow method calculates the total fuel consumed over the project.

TSM
ENERGY ANALYSIS
WORKSHEET

NULL OPTION

TRAFFIC OPERATIONS: UNINTERRUPTED FLOW

Pm PEAK - EACH DIRECTION - 5% TRUCKS

A. BASE DATA

	DEMAND VOL.		SEGMENT LENGTH (MI)		DAILY VMT	SPEED (MPH)
AUTO	5700	x	2	=	11400	20
TRUCK	300	x	2	=	600	20

B. FUEL CONSUMPTION

	VMT		FCR (GPM) (TABLE 1.1)		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
AUTO	11400	x	.050	x	.538	=	307
TRUCK	600	x	.112	x	.538	=	36

SUBTOTAL 343 DAILY FUEL CONSUMPTION

x 250 WORKDAYS PER YEAR

TOTAL 85,750 ANNUAL FUEL CONSUMPTION

TSM
ENERGY ANALYSIS
WORKSHEET

WIDEN
OPTION

TRAFFIC OPERATIONS: UNINTERRUPTED FLOW

pm PEAK - EACH DIRECTION - 5% TRUCKS

A. BASE DATA

	DEMAND VOL.		SEGMENT LENGTH (MI)		DAILY VMT	SPEED (MPH)
AUTO	5700	x	2	=	11400	35
TRUCK	300	x	2	=	600	35

B. FUEL CONSUMPTION

	VMT		FCR (GPM) (TABLE 1.1)		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
AUTO	11400	x	.045	x	.538	=	276
TRUCK	600	x	.095	x	.538	=	31

SUBTOTAL	307	DAILY FUEL CONSUMPTION
x	250	WORKDAYS PER YEAR
TOTAL	76,750	ANNUAL FUEL CONSUMPTION

Project level analysis of traffic engineering improvements has been a topic of great interest. The literature contains many references which may be of use in developing and understanding energy impact methods. For further informations, the analyst is referred to the literature (6, 7, 8).

References

1. Cambridge Systematics, Inc. Analytical Procedures for Urban Transportation Energy Conservation, prepared for U.S. Department of Energy, Washington, D.C. 1979.
2. Claffey, Paul "Running Costs of Motor Vehicles as Affected by Road Design and Traffic, " NCHRP Report 111, Highway Research Board, Washington, D.C. 1971.
3. Winfrey, Roger Economic Analysis for Highways, International Textbook Company, 1968.
4. JHK and Associates. A Technique for Measurement of Delay at Intersections. San Francisco, CA, JHK & Assoc., Sept. 1976, 3 Vols.
5. Dale, Charles W., "Evaluation of 2 Traffic Engineering Improvements," Transportation Research Board, Record No. 528, Washington, D.C., 1974, pp. 15-19.
6. Davis, Charles W. Procedures for Estimating Highway User Costs, Fuel Consumption and Air Pollution, prepared for U.S. D.O.T., Washington, D.C. 1980.
7. AASHTO, A Manual on User Benefit Analysis of Highway and Bus Transit Improvements. American Association of State Highway and Transportation Officials, Washington, D. C. 1977.
8. Winfrey, R. and C. Zeller, "Summary and Evaluation of Economic Consequences of Highway Improvements." NCHRP 122, Transportation Research Board, Washington, D.C. 1971.
9. Apostolos, J. et al. Energy and Transportation Systems Final Report, prepared for NCHRPR Project 20-7, Task 8, CALTRANS, December 1978.

3. Computerized Signal System

The adaptation of computer technology to traffic control has been an important development in traffic engineering. These systems are designed to manage traffic flow on the surface street system so that travel time, delay, and "Stop and Go" driving cycles are minimized. Such systems can be implemented to a range of roadway configurations including arterial control and network or area wide control.

Wagner (1) suggests that the analysis of energy savings associated with computerization will depend on the nature of the existing control system. Table 3.1 presents a summary of experience documented by Wagner (1) which demonstrates this idea. The largest improvement in travel time will result in a change from non-interconnected pretimed signals to advanced computer based control. (+25%)

These estimates can be used to provide the analyst with a basis for determining an order of magnitude of improvement in travel time. The procedure below suggests how this knowledge can be incorporated into an energy analysis methodology.

Analysis Method

The following steps are suggested to estimate energy savings from computerized signal systems. The method requires estimates of the existing travel time on the proposed system and improvements resulting from implementation of a computer based control system.

TABLE 3.1

SUMMARY OF EXPERIENCE

Before	After	Improvement Percent in Travel Time
Non-interconnected pretimed signals Old timing plans	Advanced computer based control	+25%
Interconnected pretimed signals Old timing plans	Advanced computer based control	+17.5%
Non-interconnected signals Traffic activated	Advanced computer based control	+8%
Interconnected pre-timed signals Various forms of master control and various timing plans	Optimization of signal timing plans No change in hardware	+12%

Source: Wagner, (1) pp. 20

Control System.
Instructions for Worksheet

Step 1 - Determine vehicle miles of travel (VMT) and Vehicle Hours of Travel (VHT) over the proposed computer system.

Step 2 - From Table 3.1, estimate the improved travel time (%) that results from the proposed computer system.

Step 3 - Calculate base line energy consumption from the formula:

$$FTOT = 0.0425 (VMT) + 0.60 (VHT)$$

Where
FTOT = Total fuel consume (Gallons) for analysis period
VMT = Vehicle Miles of Travel
VHT = Vehicle Hours of Travel

Source: Wagner (1)

Step 4 - Estimate revised daily VHT and VMT. In most cases VMT will not change in the short range. It is possible that additional VMT will occur over the system because of improved travel times.

Step 5 - Estimate revised daily fuel consumption using the above formula.

Step 6 - Subtract Step 5 from Step 3 to find the difference in energy consumption ("Energy Impact").

Step 7 - From Table 1.2 find fuel economy adjustment factor for analysis year.

Step 8 - Multiply Step 6 X Step 7 to find adjusted daily energy impact.

Step 9 - Multiply Step 8 X 330 to find yearly adjusted yearly energy.

TSM
ENERGY ANALYSIS
WORKSHEET

COMPUTERIZED SIGNALIZATION

	BASE DAILY VMT		BASE DAILY VHT		UNADJUSTED FUEL CONSUMPTION		FUEL ECONOMY ADJ (TABLE 1.2)		GALLONS OF GASOLINE	
0.0425	☐	+ 0.6	☐	=	☐	X	☐	=	☐	BASE DAILY FUEL CONSUMPTION
									−	
	REVISED DAILY VMT		REVISED DAILY VHT		UNADJUSTED REVISED FUEL CONSUMPTION					
0.0425	☐	+ 0.6	☐	=	☐	X	☐	=	☐	REVISED DAILY FUEL CONSUMPTION

☐ DAILY ENERGY SAVINGS

X 330 TRAVEL DAYS PER YEAR

= ☐ ANNUAL ENERGY SAVINGS

Example

The following discussion outlines a hypothetical example applying the above methodology.

Given:

.Urban radial arterial 3.7 miles long
.Non interconnected pretimed signals
.Signal spacing as shown on segments outlined below
.Speed/Delay over the system estimated for average of peak and off-peak time periods and summarized below
.Average daily volume (2-way) as shown below

Find:

.Daily vehicle miles of travel (VMT)
.Daily vehicle hours of travel (VHT) (Existing and Proposed)
.Current energy consumption and revised energy consumption as a result of installation of an advanced based computer control system. (Gallons per day and per year).

BASE CONDITION

Segment	Length (Miles)	ADT	VMT/Day	Ave. Travel Time (Hrs.)	VHT/Day
A-B	0.227	25,300	5,743	.00892	226
B-C	0.379	25,500	9,665	.01639	418
C-D	0.295	28,000	8,260	.61278	358
D-E	0.326	27,000	8,829	.02028	547
E-F	0.322	18,500	5,957	.02220	411
F-G	0.504	14,100	7,106	.02440	345
G-H	0.652	12,600	8,215	.03861	486
H-I	0.144	11,500	1,656	.01528	176
I-J	0.578	12,500	7,225	.04194	524
J-K	0.300	7,100	2,130	.03139	223
			64,786 VMT/Day		3,714 VHT/Day

TSM
ENERGY ANALYSIS WORKSHEET

COMPUTERIZED SIGNALIZATION

	BASE DAILY VMT		BASE DAILY VHT		UNADJUSTED FUEL CONSUMPTION		FUEL ECONOMY ADJ (TABLE 1.2)		GALLONS OF GASOLINE	
0.0425	64786	+ 0.6	3714	=	4982	x	.831	=	4140	BASE DAILY FUEL CONSUMPTION
									−	
	REVISED DAILY VMT		REVISED DAILY VHT		UNADJUSTED REVISED FUEL CONSUMPTION					
0.0425	64786	+ 0.6	2785	=	4424	x	.831	=	3676	REVISED DAILY FUEL CONSUMPTION
									464	DAILY ENERGY SAVINGS
								x	330	TRAVEL DAYS PER YEAR
								=	153,120	ANNUAL ENERGY SAVINGS

Results and Limitations

From the above, it is estimated that the installation of an advanced based computer control system on this arterial will result in a savings of 153,120 gallons of fuel per year.

The simplified manual technique outlined above is designed to provide reasonable estimates of travel time and energy consumption with a minimum of base data and analysis time. The results obtained must, therefore, be reviewed in this context.

Energy advanced based computer control system is generally tailored to local needs and specifications. The above method is intended to provide a general approach to this analysis. It is recommended that local data or experience be applied wherever possible.

References

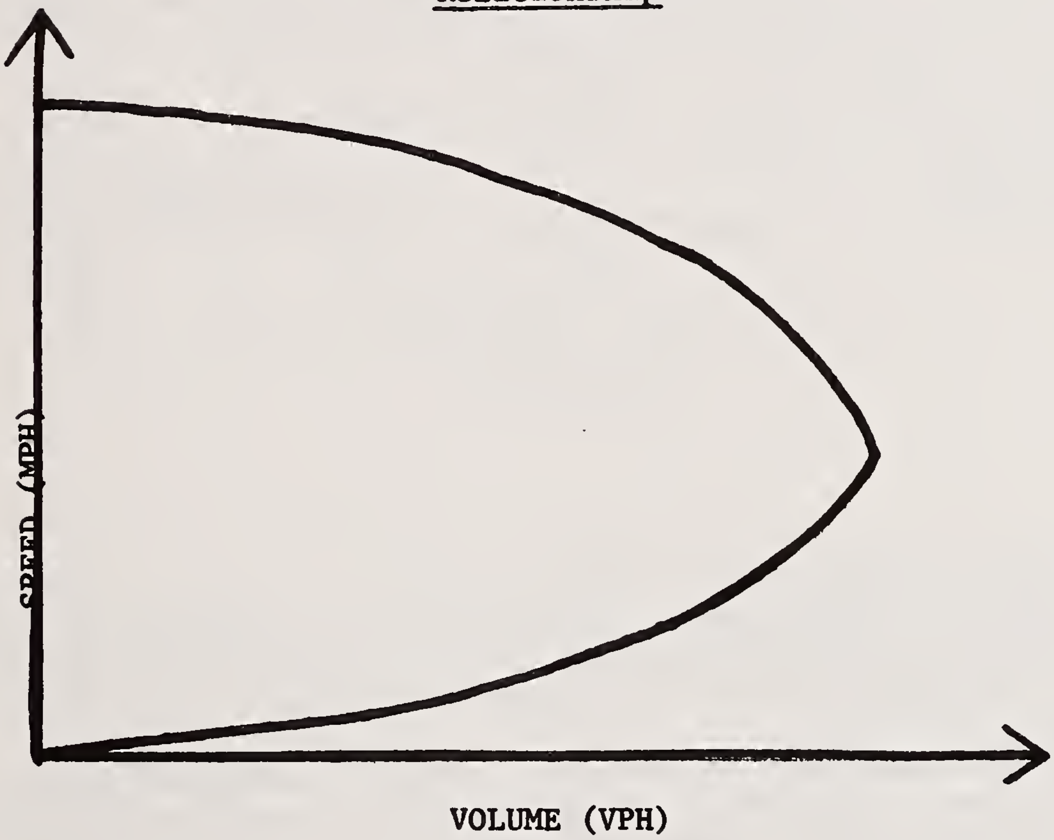
1. Wagner, Fredrick A., Traffic Control System Improvements: Impacts and Costs, prepared for FHWA, U.S. Department of Transportation, Washington, D.C. March, 1980.
2. Traffic Control Systems Handbook, Prepared for F.H.W.A., U.S. Department of Transportation, Washington, D.C., June, 1976.

4. Freeway Ramp Metering

In cases where freeway segments experience severe peak hour congestion, metering of vehicles entering at ramp junctions has proven to be an effective strategy to improve average travel speeds (1). A review of the relationships between speed and volume shows that as the demand volume on a freeway segment increases, speed decreases (Figure 4.1.).

Figure 4.1

Speed - Flow Relationship

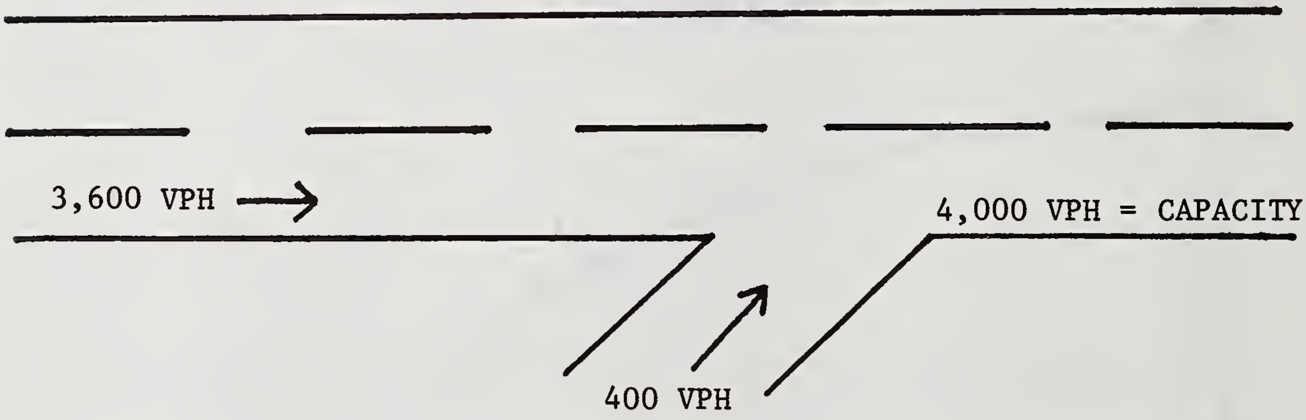


Ramp metering attempts to control the volume on a segment so that an acceptable speed can be maintained.

Consider a two lane freeway segment with a peak hour capacity of 4,000 vehicles per hour (one direction) and a single lane entrance ramp with a peak hour demand of 400 vehicles per hour. The peak hour demand upstream from the ramp is 3,600 vehicle per hour (see Figure 4.2). As a result, the volume/capacity ratio downstream from the ramp approaches 1.0 during peak hours.

Under such conditions, "Metering" of the entering ramp vehicles can reduce the volume to capacity ratio and improve the quality of flow along the segment.

Figure 4.2



Direct energy consumed by the traffic stream is a function of the volume, traffic mix, and vehicle speed. Table 1.1 of this handbook outlines the fuel consumed by vehicles at various constant speeds. Generally, optimum fuel consumption occurs at a speed of 30-35 miles per hour.

Wagner (2) has summarized the results of ramp metering projects in several urban areas. Improvement in average travel speed during peak hours in the range of 14% to 27% have been observed when ramp metering is combined with computerized freeway surveillance (2).

Analysis of energy savings resulting from speed increases due to ramp metering can become very complex.

Generally, such projects are implemented in very heavily congested travel corridors which includes a number of ramp junctions. Computer programs such as <u>FREQ6PE</u> have been developed to aid in such analysis (4).

Ramp metering is usally a part of a comprehensive freeway surveillance and control system designed to meet the local needs of a specific corridor. Therefore, manual analysis methods may not be appropriate because of the complexity of such a system. A simplified method for analysis of a single ramp has been developed to demonstrate the principles of such analysis. An example is included to illustrate the application of such a method for information purposes.

Instructions for Worksheet

Step 1: Identify the analysis period which will be impacted by the project. Normally A.M. peak and P.M. peak hour traffic will be included.
Step 2: Identify the length of the segment in miles.
Step 3: Identify the demand for the analysis period in vehicles per hour, autos and trucks.
Step 4: Identify average speed for the analysis period.
Step 5: Estimate the improvement in average speed that results from ramp metering; literature indicates that this improvement may range from 10% to 30% (2).
Step 6: With the base average speed and the revised speed enter Table 1.1 to find corresponding fuel consumption rates in gallons per mile. Subtract the revised rate from the base to find the difference. This value is the number of gallons conserved per mile.
Step 7: Multiply Step 2 x Step 3 x the number of analysis periods, i.e. peak hours per day, x Step 6 to find the unadjusted daily fuel consumption, in gallons.
Step 8: From Table 1.2, find fuel adjustment factor for analysis year.
Step 9: Multiply Step 8 x 250 to find yearly savings in gallons.

TSM
ENERGY ANALYSIS
WORKSHEET

RAMP METERING

A. BASE DATA

	DEMAND VOLUME		SEGMENT LENGTH (MI)		DAILY VMT
AUTO		X		=	
TRUCK		X		=	

	SPEED (MPH)
BASE	
REVISED	

B. FUEL CONSUMPTION

	ΔFCR (TABLE 1.1)		VMT		FUEL ECONOMY ADJ (TABLE 1.2)		ENERGY SAVINGS (GALLONS)
AUTO		X		X		=	
TRUCK		X				=	

SUBTOTAL		DAILY ENERGY SAVINGS
X	250	WORKDAYS PER YEAR
TOTAL		ANNUAL ENERGY SAVINGS

Example

Given: A two lane urban freeway 6 miles long, peak hour speed and volume information outlined below:

		Peak Hour Volume (VPH)		Average Peak Hour Speed (MPH)	
Before Ramp Metering		A.M.	P.M.	A.M.	P.M.
	auto	3300	3300	15	15
	Truck	300	300	15	15
After Ramp Metering					
	Auto	3300	3300	20	20
	Truck	300	300	20	20

Find: 1981 Energy savings resulting from ramp metering project which results in an increase of 30% in the average speed.

Results and Limitations

After applying the worksheet, it is found that the ramp metering project results in an annual savings of 87,250 gallons of fuel.

The simplified method outlined below represents only a cursory analysis of energy savings associated with ramp metering. For a more complete discussion of analysis methods, consult the literature (1).

TSM
ENERGY ANALYSIS
WORKSHEET

RAMP METERING

Am + Pm PEAK

A. BASE DATA

	DEMAND VOLUME		SEGMENT LENGTH (MI)		DAILY VMT
AUTO	6600	x	6	=	39600
TRUCK	600	x	6	=	3600

	SPEED (MPH)
BASE	15
REVISED	20

B. FUEL CONSUMPTION

	ΔFCR (TABLE 1.1)		VMT		FUEL ECONOMY ADJ (TABLE 1.2)		ENERGY SAVINGS (GALLONS)
AUTO	-.008	x	39600	x	.831	=	263
TRUCK	-.024	x	3600			=	86

SUBTOTAL	349	DAILY ENERGY SAVINGS
x	250	WORKDAYS PER YEAR
TOTAL	87250	ANNUAL ENERGY SAVINGS

References

1. Traffic Control Systems Handbook, prepared for FHWA, U.S. Department of Transportation, Washington, D.C. June 1976
2. Wagner, Frederick A., Traffic Control System Improvements - Impacts and Costs, prepared for FHWA, U.S. Department of Transportation, Washington, D.C. March 1980.
3. Claffey, Paul, "Running Costs of Motor Vehicles as Affected by Road Design and Traffic," NCHRP Report 111, Highway Research Board, Washington, D.C. 1971.
4. Jovanis, Paul P., A.D. May, and Waiki Yip, FREO6PE - A Freeway Priority Entry Control Simulation Model, Research Report No. 78-8, Institute of Transportation Studies, University of California, Berkeley, 1978.

5. One-Way Streets

Introduction

Many documents are available which summarize the operational aspects of one-way streets. (Enustun (1), HRB (2), Pignataro (3).) Experience indicates that establishment of one-way operation can increase street capacity by 20% to 50% (depending on street width, parking characteristics, etc...), and reduce travel times by as much as 25% (improved signal coordination, removal of left turn conflicts, etc...).

These changes contribute to improved energy consumption by reducing vehicle delay and stopping cycles (see section 2, traffic engineering). However, this savings is offset to some degree by additional vehicle miles of travel caused by increased trip circuity.

In order to estimate the energy impact of conversion to one-way operation it is necessary to have information concerning the improvement in average speed and the added vehicle miles of travel. Speed improvements can be estimated from methods outlined in HRB (4). However, the incremental VMT increase is more difficult to estimate.

Additional vehicle miles of travel is a product of many variables including location, block lengths, and volume. Block circling maneuvers can be estimated from "before" and "after" observations. It is not always possible to collect such data so simplifying assumptions are required.

An estimate of incremental VMT made by Enustun (1) can be used when "after volume data is not available. He developed a theoretical estimate of 10% additional VMT which was then found to compare favorably with an actual observation of 8%. In lieu of sufficient volume data, the procedure outlined below uses this 10% estimate.

Instructions for Worksheet

Step 1 - Outline the study area of the proposed one-way system. Estimate existing vehicle miles of travel (VMT) by direction. If no after data is available, add 10% to the base VMT to represent the VMT in the after condition.

Step 2 - Determine the average speed in minutes per miles, for the "before" and "after" condition.

Step 3 - Fuel consumption rate, FCR, in gallons per mile, can be estimated from the equation given by Wagner (5).

Step 4 - Multiply Step 3 x Step 1 to find daily fuel consumed, gallons.

Step 5 - From Table 1.2, find appropriate adjustment factor for auto fuel economy improvement.

Step 6 - Multiply Step 4 x Step 5 to find adjusted daily fuel consumption.

Step 7 - Multiply Step 6 x 330 to find yearly fuel consumption, gallons, for the "before" and "after" condition. The difference represents the net energy impact.

This method is designed to evaluate the energy implications of one-way street conversions for a single pair of streets. It is outlined to provide assessment of "before" and "after" conditions on a single worksheet.

TSM
ENERGY ANALYSIS
WORKSHEET

ONE-WAY STREETS

A. BASE DATA

	DEMAND VOLUME		SEGMENT LENGTH (MI)		DAILY VMT
BEFORE		X		=	
		X		=	
AFTER		X		=	
		X		=	

B. FUEL CONSUMPTION

	VMT			TRAVEL TIME RATE (MIN/MI)		UNADJUSTED FUEL CONSUMPTION (GAL)		FUEL ECONOMY ADJUSTMENT (TABLE 1.2)		DAILY FUEL CONSUMPTION (GALLONS)
BEFORE		X	[.0425 + .01 X		] =		X		=	
		X	[.0425 + .01 X		] =		X		=	

TSM
ENERGY ANALYSIS
WORKSHEET

ONE-WAY STREETS (CONT'D)

	VMT		TRAVEL TIME RATE (MIN/MI)		UNADJUSTED FUEL CONSUMPTION (GAL)		FUEL ECONOMY ADJUSTMENT (TABLE 1.2)		DAILY FUEL CONSUMPTION (GALLONS)
AFTER		x [.0425 + .01 x		] =		x		=	
		x [.0425 +.01 x		] =		x		=	

CONSUMPTION BEFORE		CONSUMPTION AFTER		DAILY ENERGY SAVINGS (GAL)		TRAVEL DAYS PER YEAR		ANNUAL ENERGY SAVINGS (GAL)
	–		=		x	330	=	

Example

A one-way pair has been implemented in the downtown of a major city. "Before" and "After" speed and volume data has been collected and is outlined below. Using the worksheet, determine net annual energy savings.

Base Data
Street

	Main		Central	
	Before	After	Before	After
Speed	9.3 MPH	14.8 MPH	10.8 MPH	13.1 MPH
Volume	16,400	19,600	17,200	19,800

Main - 6.5 miles long
Central - 5.7 miles long

Results and Limitations

Application of the worksheet show that a net energy savings of approximately 132,660 gallons per year will result from conversion to one-way operation in this particular case.

Analysis of one-way street conversions may be done in a variety of ways. It is possible to use a detailed "before" and "after" study approach to analyze speed and volume. It is also possible to follow a simple method such as the one outlined above.

The "Quick-Response" method presented above can be applied when a simple broad based estimate is required. On the other hand, when possible, a detailed study of speed and volume data can be undertaken. It is up to the discretion of the individual analyst as to what procedure should be followed.

TSM
ENERGY ANALYSIS
WORKSHEET

ONE-WAY STREETS

A. BASE DATA

		DEMAND VOLUME		SEGMENT LENGTH (MI)		DAILY VMT
MAIN	BEFORE	16,400	x	6.5	=	106,600
CENTRAL		17,200	x	5.7	=	98,040
MAIN	AFTER	19,600	x	6.5	=	127,400
CENTRAL		19,800	x	5.7	=	112,860

B. FUEL CONSUMPTION

		VMT				TRAVEL TIME RATE (MIN/MI)		UNADJUSTED FUEL CONSUMPTION (GAL)		FUEL ECONOMY ADJUSTMENT (TABLE 1.2)		DAILY FUEL CONSUMPTION (GALLONS)
MAIN	BEFORE	106,600	x	[.0425 + .01	x	6.45	] =	11,406	x	.831	=	9,478
CENTRAL		98,040	x	[.0425 + .01	x	5.56	] =	9,618	x	.831	=	7,993
												17,471

TSM
ENERGY ANALYSIS
WORKSHEET

ONE-WAY STREETS (CONT'D)

		VMT		TRAVEL TIME RATE (MIN/MI)		UNADJUSTED FUEL CONSUMPTION (GAL)		FUEL ECONOMY ADJUSTMENT (TABLE 1.2)		DAILY FUEL CONSUMPTION (GALLONS)
MAIN	AFTER	127,400	x [.0425 + .01 x	4.05	] =	10,574	x	.831	=	8,787
CENTRAL		112,860	x [.0425 +.01 x	4.58	] =	9,966	x	.831	=	8,282
										17,069

CONSUMPTION BEFORE		CONSUMPTION AFTER		DAILY ENERGY SAVINGS (GAL)		TRAVEL DAYS PER YEAR		ANNUAL ENERGY SAVINGS (GAL)
17,471	-	17,069	=	402	x	330	=	132,660

Reference

1. Enustun, N. "Study of The Operational Aspects of One-Way and Two-Way Streets: Report TSD-NO-219-72, Michigan State Highway Department, October 1972.
2. Highway Research Board "Improved Street Utilization Through Traffic Engineering" Special Report 93, HRB, Washington, D.C., 1967.
3. Pignatano, L.J. Traffic Engineering Theory and Practice, Prentice Hall, 1973.
4. Highway Research Board "Highway Capacity Manual" Special Report 87, HRB, Washington, D.C., 1965.
5. Wagner, F.J. Traffic Control System Improvements: Impacts and Costs prepared for FHWA, Washington, D.C. 1980.

6. Ridesharing

Ridesharing is a form of paratransit that involves the prearranging of shared rides for persons with similar travel patterns. Included in this category are carpooling, vanpooling and special express bus service. Transportation Systems Management actions are aimed at encouraging the establishment and expansion of ridesharing programs. Strategies of this nature include employer-based car and vanpool matching services, various incentive tactics such as financial and preferential parking privileges, and work hour flexibility. Mass distribution of public information is a facet of promotion that will increase public awareness and aid in altering negative attitudes toward ridesharing.

Ridesharing arrangements will result in significant energy savings derived from reductions in vehicle miles of travel (VMT) by those participating in the program. If a substantial amount of VMT is eliminated, it follows that this will have a beneficial effect on congestion, thereby resulting in an additional savings. An offsetting factor is the negative savings associated with the car left home now available to be used for travel by other family members.

The procedure for estimating the total energy savings resulting from ridesharing programs is divided into two sections:

- . savings resulting from VMT reductions;
- . savings resulting from increased travel speeds.

Savings From VMT Reductions

Many techniques are available for evaluating ridesharing programs. In choosing among the methodologies, the extensive research done by C.C. Miesse on the reduction of VMT associated with car and vanpool programs (1) was both straightforward and accurate, and easily adaptable for the purpose of this analysis. In previous work done by New York State Department of Transportation, Miesse's formula was evaluated for accuracy, by comparing his results to its own Carpool Coordination Demonstration Project (2). The report concluded that, based on these findings, it appears that Miesse's formula can be used even in settings less metropolitan than Washington, D.C. (2).

The technique itself is based on an auto occupancy model developed by R.H. Pratt Associates (3) and is a function of employee residential distribution and income.

Miesse's formula to compute the daily change in vehicle-miles of travel is as follows:

$$\Delta \text{VMT per day} = (.1728)\ (\text{EMP } 1.306)$$

Where: EMP = the number of employees

To compute the annual change in VMT:

ΔVMT per year = ΔVMT per day x 250 workdays/year.

The annual gasoline savings in gallons =

$$\frac{\Delta \text{VMT per Year}}{\text{MPG}}$$

Additionally, the negative savings resulting from the "car left home," that must now be used for discretionary travel must be evaluated. The procedure to determine the number of gallons lost due to incremental travel is provided by New York State Department of Transportation (4). The additional travel is estimated to be 40% of the daily VMT saved. Therefore, the actual savings is only 60% of potential savings.

Speed Related Savings

If VMT reductions are substantial enough, then congestion will also be reduced resulting in an increase in average network speeds. The additional energy savings that will accrue due to this factor can be estimated as follows:

S = VMT peak x Δ Speed x Δfuel consumption x # of peaks x # of days x Adjustment Factor

where: VMT peak = the average peak hour vehicle miles of travel on any given workday

ΔSpeed = the absolute difference between the "before ridesharing" speed and the "after ridesharing" speed.

The "after" speed may be computed by increasing "before" speed by 1/4% (2) if no other data is available.

Δfuel Consumption = the savings (in gallons/mile) per speed change, which can be derived from Table 1.1.

# of peaks = the number of peak periods per day, (this is usually 2)

# of days = the number of days a year that ridesharing will be utilized (this is usually 250)

Adjustment Factor = factor used to adjust for yearly improvements in the vehicle mix (Table 1.2)

The total savings due to ridesharing actions is then the sum of the savings due to VMT reductions and the savings due to congestion relief (i.e., speed increases).

TSM
ENERGY ANALYSIS
WORKSHEET

RIDESHARING

A. ΔSPEED AND VMT

	EMPLOY		DAILY ΔVMT		CAR LEFT HOME FACTOR		WORKDAYS PER YEAR		ANNUAL ΔVMT
.1728		$^{1.306}$ =		x	.60	x	250	=	

BASE NETWORK SPEED (MPH)		SPEED ADJUSTMENT FACTOR		ΔSPEED
	x	.0025	=	

B. FUEL CONSUMPTION

ANNUAL ΔVMT		AUTO MPG (TABLE 1.3)		ANNUAL ENERGY SAVINGS (GAL)
	÷		=	

ΔFCR (TABLE 1.1)		BASE VMT		PEAKS/DAY		WORKDAYS/YEAR		FUEL ECON. ADJUSTMENT (TABLE 1.2)		
	x		x		x		x		=	

TOTAL

Example

In February, 1978 the New York State Department of Transportation established a pilot Carpool Coordination Demonstration. The study consisted of two groups (1) the uptown campus and (2) the Nelson A. Rockefeller Plaza (downtown). The evaluation in this example will examine only one agency; the Department of Transportation. The total employment for this agency is 1727 (5). The network speed for the upstate campus before any program was implemented was 18.50 mph (2). The peak hour VMT is 407,403 miles (2).

Limitations

Although comparisons of Miesse's results with other data proved favorable, possible limitations and adjustments should be noted. The computation of his formula is based upon the round-trip length of 23 miles for the Washington, DC metropolitan area. Adjustments should be made to account for either much greater or smaller trip lengths. Additionally, the formula implies a variable success rate of ridesharing program falling within a range based on the size of employment organizations. If there is reason to believe that the success rate (number of additional employees carpooling as a percent of all employees of an organization) is vastly different from 15%, then a further adjustment may be necessary. Reference 2 contains a more detailed discussion of these limitations and the methods to adjust the results appropriately.

TSM
ENERGY ANALYSIS WORKSHEET

RIDESHARING

A. ΔSPEED AND VMT

	EMPLOY	1.306	DAILY ΔVMT		CAR LEFT HOME FACTOR		WORKDAYS PER YEAR		ANNUAL ΔVMT
.1728	1,727	=	2,920	x	.60	x	250	=	438,000

BASE NETWORK SPEED (MPH)		SPEED ADJUSTMENT FACTOR		ΔSPEED
18.5	x	.0025	=	.05

B. FUEL CONSUMPTION

ANNUAL ΔVMT		AUTO MPG (TABLE 1.3)		ANNUAL ENERGY SAVINGS (GAL.)
438,000	÷	15.95	=	27,461

ΔFCR (TABLE 1.1)		BASE VMT		PEAKS/DAY		WORKDAYS/YEAR		FUEL ECON. ADJUSTMENT (TABLE 1.2)		
-.00008	x	407,403	x	2	x	250	x	.931	=	15,172

TOTAL 42,633

References

1. C.C. Miesse, "Reductions in Vehicle Travel by Use of Car and Vanpools in Major Metropolitan Areas," Environmental Protection Agency, Philadelphia, PA, published in TRB Special Report #184, 1979.
2. Janis M. Gross, Daniel K. Boyle, Gerald S. Cohen, Nathan S. Erlbaum, Michael A. Kocis, K. W. Peter Koeppel, "Energy Impacts of Transportation Systems Management Actions in New York State, 1978-1980," New York State Department of Transportation, Preliminary Research Report 151, May 1979.
3. "Development and Calibration of Washington Mode-Choice Models," R.H. Pratt, Associates, Bethesda, MD, Technical Report 8, June 1973.
4. Janis M. Gross, "The Car Left Home," New York State Department of Transportation, Preliminary Research Report 168, August 1979.
5. Joanna M. Brunso and David T. Hartgen, "Carpool Coordinator Demonstration Study: Overview and Analysis of "Before" Survey Data," New York State Department of Transportation, Preliminary Research Report 150, May 1979.

7. Priority Treatment for High Occupancy Vehicles

Background

Recent transportation policy has emphasized the need to move people rather than vehicles. High occupancy vehicle (HOV) priority treatments are designed to fulfill this goal by enhancing the "person carrying capacity" of the urban transportation system.

Many types of HOV strategies have been implemented. Wagner (1) suggests the following classification:

1. Non-separate concurrent flow freeway lanes
2. Contra-flow freeway reserved lanes
3. Metered ramp bypass lanes
4. Exclusive freeway ramps
5. Physically separated freeway priority lanes
6. Reserved bus lanes on arterials
7. Reserved bus lanes on CBD streets
8. Bus priority signal systems

HOV Impacts

The planning, design, and operation of high occupancy vehicle treatments is documented elsewhere (2, 3, 4). In general, most treatments are implemented to serve peak-hour work trip demand. However, selected strategies (i.e., CBD busways, bus priority signal systems ...) are designed to improve the reliability and travel speed of high occupancy vehicles throughout the entire day.

Priority treatments offer improved average speeds to HOV's. This increase in speed (i.e., reduced travel time) encourages mode shifts and impacts the direct energy consumed by changing the rate at which fuel is used (i.e., gallons per mile) by the HOV.

The dedication of space for priority vehicles on a highway facility can be accomplished by "adding" lanes or "taking" lanes. Travel lanes can be taken in the priority direction (concurrent flow) or in the non-priority direction (contra-flow) by removing them from use by non-priority vehicles.

Physically "adding" lanes for HOV's will not reduce the average speeds of non-priority vehicles. However, the "taking" of travel lanes will impact the average speed on non-HOV's. This change in speed (i.e., reduced travel time) will encourage mode shifts. In addition, it can reduce or improve fuel economy of non-priority vehicles.

Suggested Energy Impact

The most important variable in the procedure developed below is the improved travel time offered to HOV users. Knowledge of this savings can be used with estimates of travel time elasticities to determine mode shifts.

The direct energy consumed by HOV's and non-priority vehicles is changed to some degree by HOV treatments. The method presented below does not include explicit treatment of speed changes on direct vehicular energy consumption. This is done to keep the procedure simply, yet flexible enough to apply to a full range of HOV priority treatments. At the discretion of the reader, estimates of speed change impact on energy consumption can be determined through comparing average speeds "before" and after" project implementation. This additional information can be added to the procedure outlined below by comparing the change in fuel economy at various speeds presented in Table 1.1.

The following discussion outlines a method which is designed to be applied "artfully". It allows for flexibility on the part of the analyst to examine energy impacts for a variety of HOV treatments. It is suggested that such a generic methodology can best serve the needs of a full range of scenarios while still providing a framework for reasonalbe estimates of energy consumption patterns. In many ways, this method serves as a "sketch planning" approach that can be used for preliminary analysis before more detailed evaluation and design is completed.

Instructions for Worksheet

Step 1: Identify total one-way person trips for the selected analysis period. The analysis period may include any combination of peak-hours or total daily hours appropriate for a particular strategy. The analyst may select any level of analysis including areawide, corridor or facility.
Step 2: Base market shares for each mode. These are expressed in decimal form and sum to 1.0.
Step 3: Total daily trips by mode, base condition. Step 1 x Step 2.
Step 4: Identify average trip length for each mode corresponding to the appropriate analysis period.
Step 5: Estimate vehicle occupancy by mode.
Step 6: Multiply Step 3 x Step 4 and divide by Step 5 to find base vehicle miles of travel by mode.
Step 7: Estimate the percent change in line-haul travel time from the selected HOV treatment. For purposes of this procedure, only the travel time of vehicles in the peak direction will be of interest. It is recognized that certain HOV treatments will impact the offpeak direction volumes. Such impacts will be ignored in this analysis. One result of this is that the energy savings estimated may be overstated to some degree.
Step 8: Direct travel time elasticities are required to estimate the change in VMT by mode. An elasticity is a measure of the responsiveness of trip demand to change in an independent variable. For example, trip demand (expressed in person trips) by mode will decrease an in-vehicle travel time

increases. Knowledge of elasticities can be used to estimate the mode change resulting from improved travel times for transit and shared ride modes caused by HOV strategies. Default values are shown. These estimates were obtained from Chan (6) and Gross (8). For further information on the use and limitations of elasticities, see CRA (5), Chan (6), and Pucher (7).

Step 9: Multiply Step 7 x Step 8 to find the change in market share by mode.

Step 10: Multiply Step 2 x Step 9 and add to Step 2 to find revised market shares. These estimates are normalized to add to 1.0.

Step 11: Multiply Step 1 x Step 10 x Step 4 and divide by Step 5 to find revised vehicle miles of travel by mode.

Step 12: Subtract Step 6 from Step 11 to find the change in vehicle miles of travel by mode.

Step 13: Step 12 is multiplied by 0.6 to account for the car left home. This factor is only applied to drive alone and shared ride shares which show a decrease in vehicle miles of travel.

Step 14: Adjust Step 12, change in vehicle miles of travel by mode, for car left home factor.

Step 15: Divide Step 14 by the appropriate over the road fuel economy estimate (Table 1.3) for the analysis year. For transit use 5.0 mpg of diesel fuel.

Step 16: Divide Step 14 by Step 15 to find daily energy consumption change in gallons.

Step 17: One gallon of diesel yields the equivalent of 1.104 gallons of gasoline in energy. This step adjusts the diesel savings to gasoline gallons.

Step 18: Multiply transit in Step 16 x Step 17.

Step 19: Add daily change in gasoline consumption per day for each mode to find total change, in gallons.

Step 20: Multiply Step 19 x 250 to find annual estimated savings.

TSM
ENERGY ANALYSIS
WORKSHEET

HIGH OCCUPANCY VEHICLES

A. BASE DATA

	DAILY TRIPS		BASE MKT SHARE (%)		TRIP LENGTH (MI)		VEHICLE OCCUPANCY		BASE VMT
DA		X		X		÷		=	
SR		X		X		÷		=	
TR		X		X		÷		=	

B. CHANGE IN MARKET SHARE

	%Δ LINE HAUL TRAVEL TIME		e_{TT}		BASE MARKET SHARE (%)		%Δ MARKET SHARE
DA		X	-.50	X		=	
SR		X	-.35	X		=	
TR		X	-.35	X		=	

TSM
ENERGY ANALYSIS
WORKSHEET

HIGH OCCUPANCY VEHICLES (CONT'D)

C. CHANGE IN VMT

	%ΔMARKET SHARE		BASE MARKET SHARE		DAILY TRIPS		TRIP LENGTH		OCCUPANCY		REVISED VMT
DA	(	+	)	X		X		÷		=	
SR	(	+	)	X		X		÷		=	
TR	(	+	)	X		X		÷		=	

D. FUEL CONSUMPTION

	ΔVMT		CAR LEFT HOME FACTOR		FUEL ECONOMY (MPG) BY MODE (TABLE 1.3)		DIESEL-GASOLINE CONVERSION FACTOR		ENERGY SAVINGS (GAL)
DA		X	0.6	÷				=	
SR		X	0.6	÷				=	
TR				÷	5.0	X	1.104	=	

SUBTOTAL		DAILY ENERGY SAVINGS
X	250	WORKDAYS PER YEAR
TOTAL		ANNUAL ENERGY SAVINGS

DA - DRIVE ALONE
SR - SHARED RIDE
TR - TRANSIT

e_{TT} - ELASTICITY OF IN-VEHICLE TRAVEL TIME

ΔVMT = BASE VMT - REVISED VMT

Example

A concurrent flow reserved lane on a radial urban freeway has been proposed. The lane will operate during the two hour a.m. peak. Given the base data summarized below, find the direct energy impact.

Base Data	
a.m. peak-hour person trips, total peak direction only	30,000
Base Mode Shares	
Auto Drive Alone	0.70
Shared Ride	0.20
Transit	0.10
Average Trip Length	
Auto Drive Alone	7.0 miles
Shared Ride	9.0
Transit	6.5
Percent Change in Line-Haul Travel Time	
Auto Drive Alone	+.22
Shared Ride	-.15
Transit	-.15

TSM
ENERGY ANALYSIS WORKSHEET

HIGH OCCUPANCY VEHICLES

A. BASE DATA

	DAILY TRIPS		BASE MKT SHARE (%)		TRIP LENGTH (MI)		VEHICLE OCCUPANCY		BASE VMT
DA	30,000	x	70	x	7.0	÷	1.0	=	147,000
SR	30,000	x	20	x	9.0	÷	2.5	=	21,600
TR	30,000	x	10	x	6.5	÷	60.0	=	325

B. CHANGE IN MARKET SHARE

	%Δ LINE HAUL TRAVEL TIME		e TT		BASE MARKET SHARE (%)		%Δ MARKET SHARE
DA	+.22	x	-.50	x	70	=	-7.7
SR	-.15	x	-.35	x	20	=	+1.1
TR	-.15	x	-.35	x	10	=	+0.5

TSM
ENERGY ANALYSIS
WORKSHEET

HIGH OCCUPANCY VEHICLES (CONT'D)

C. CHANGE IN VMT

NORMALIZED

	%MARKET SHARE		BASE MARKET SHARE		DAILY TRIPS		TRIP LENGTH		OCCUPANCY		REVISED VMT
DA	-7.7 66.3	+	70	x	30,000	x	7.0	÷	1.0	=	139,230
SR	+1.1 22.5	+	20	x	30,000	x	9.0	÷	2.5	=	24,300
TR	+0.5 11.2	+	10	x	30,000	x	6.5	÷	60.0	=	364

D. FUEL CONSUMPTION

	ΔVMT		CAR LEFT HOME FACTOR		FUEL ECONOMY (MPG) BY MODE (TABLE 1.3)		DIESEL-GASOLINE CONVERSION FACTOR		ENERGY SAVINGS (GAL)
DA	-7,770	x	0.6	÷	17.7			=	263
SR	+2,700	x	0.6	÷	17.7			=	(153)
TR	+39			÷	5.0	x	1.104	=	(9)

SUBTOTAL	101	DAILY ENERGY SAVINGS
x	250	WORKDAYS PER YEAR
TOTAL	25,250	ANNUAL ENERGY SAVINGS

DA - DRIVE ALONE
SR - SHARED RIDE
TR - TRANSIT

e_{TT} - ELASTICITY OF IN-VEHICLE TRAVEL TIME

ΔVMT = BASE VMT - REVISED VMT

Results and Limitations

After applying the worksheet, it is found that the action will result in an annual savings of 25,250 gallons.

The elasticity-based analysis method is designed to generate estimates of energy impacts. The analyst is required to provide relevant data for the appropriate level of analysis (areawide, corridor, facility) concerning person trips and line-haul travel time impacts. This strategy is appropriate for predicting impacts on proposed HOV treatments.

In cases where the analyst is studying the actual changes of a project that has been implemented, then the suggested methodology may be adjusted slightly. In a "before" and "after" approach actual mode shifts and speed changes may be observed. This would preclude the use of travel time elasticities. In these cases the measured changes in VMT can be used to evaluate the gallons saved for the analysis period under consideration.

A more detailed micro level energy analysis may also be completed in the design phase of HOV treatments. These should provide the analyst with speed changes for both peak and off peak directions. This data can be used in conjunction with mode shift estimates to evaluate the energy impacts on a project level basis.

References

1. Wagner, Frederick A., "Transportation Impacts of Priority Treatments", Working Paper Number 13, TSM Institutional and Planning Research, 1979.
2. JHK and Associates, Selection of High Occupancy Vehicle Priority Treatments, prepared for FHWA, Washington, D.C., 1980.
3. Levinson, Herbert S. et al, "Bus Use of Highways," NCHRP Report 143, Highway Research Board, Washington, D.C., 1973.
4. Levinson, Herbert S. et al, "Bus Use of Highways: Planning and Design Guidelines," NCHRP Report 155, Highway Research Board, Washington, D.C., 1975.
5. Charles River Associates, Inc., "Methods for Analyzing Fuel Supply Limitations on Passenger Travel," NCHRP Report 229, Transportation Research Board, Washington, D.C., 1980, pp. 39.
6. Chan, Y and F.L Oh, A Tabulation of Demand Elasticities for Urban Travel Forecasting, Pennsylvania Transportation Institute, August 1977.
7. Pucher, J.R. and J. Rothenberg, Pricing in Urban Transportation: A Survey of Empirical Evidence on the Elasticity of Travel Demand, Center for Transportation Studies, MIT, 1976.
8. Gross, Janis et al, "Energy Impact of Transportation Systems Management Actions in New York State, 1978-1980," Preliminary Research Report No. 151, New York State Department of Transportation, 1979.

8. Pedestrian Travel

Transportation System Management actions that improve and encourage pedestrian travel include the construction and restoration of facilities such as overpasses, underpasses, malls, and skywalks.

Pedestrian trips accounted for 4.7% of total national work trips in 1975 (1). Of these trips, 91.4% were less than one mile long and 99.7% were no more than two miles in length (1). In contrast the mean distance to work in the United States is 8.5 miles (1).

Studies in the Southwest Washington Area (2) and the suburbs of Virginia (3) indicate that the most frequent trip purposes for pedestrian travel are shopping and recreational trips, comprising about 60% of all pedestrian trips in Washington and 69% in Virginia. In contrast, work trips only accounted for 5% of pedestrian travel in Virginia and about 11% in Washington. Data from these surveys on pedestrian trip length by trip purpose revealed a fairly uniform distribution of lengths walked for all purposes. The majority of trips exhibited a maximum walking distance of 1/2 mile.

It should be indicated that both the number of pedestrian trips, the distance of these trips and the destinations are dependent to a large degree on the geographic characteristics of a locality. Characteristics such as residential patterns, terrain features, weather, and physical limitations will influence pedestrian travel.

Methodology

The potential energy savings is realized through mode shifts from auto to walking, thereby causing a reduction in vehicle miles of travel. The trips that have the highest propensity to shift are those that are short in length. The following procedure can generally be applied to compute the maximum gasoline savings attributable to pedestrian strategies.

The methodology assumes a 100 percent mode shift from auto trips that are less than one mile in length to walking. The computed savings resulting from this assumption must be reduced in order to ascertain the true savings. Each area will have a different reduction dependent on residential and population patterns, terrain features, and weather. It is left to each locale to determine this variable.

Additionally, the procedure requires each locale to determine which trip purposes are most likely to be affected by this action and therefore will be most prone to shift modes to walking. For example, a pedestrian walkway constructed in the CBD area will affect trip purposes such as work to shop trips, shop to shop trips, and personal business trips. In contrast, the same facility constructed in a residential setting, perhaps for the purpose of providing access between two neighborhoods, will affect a different set of users which could be for recreational use or special trips. The trips which have the highest potential to switch to walking are the only purposes that will be considered.

Lastly, it has been assumed that the construction or rehabilitation of a pedestrian facility will impact the travel characteristics only in the immediate area surrounding the facility. A radius of one mile has been designated as the maximum distance that will be affected. This distance was specified because the majority of pedestrian trips do not exceed this length. Only trips with origins and destinations within these bounds will be included in this analysis.

The necessary inputs for the technique are:

1. The key trip purpose(s) considered most affected by the pedestrian strategy.
2. For each purpose determine the total number of auto trips for the area that are within a one mile radius of the pedestrian facility that have origins and destinations within the affected zone and have trip lengths less than one mile long. This will permit estimation of the total number of potential new pedestrian trips per day.
3. The average pedestrian trip length (if no other estimate is available 0.5 may be substituted).
4. The average annual automobile fleet fuel efficiency factor in miles per gallon (Table 1.3 may be utilized if data are unavailable).
5. The number of days per year that pedestrian travel will take place. This factor should reflect the geographic variation in climate. For example, a warmer, drier climate will have a greater number of days suitable for walk trips.

The procedure is as follows:

<ins>Step 1:</ins> Multiply the number of potential walk trips per day by the average pedestrian trip length to obtain the vehicle miles of travel eliminated daily.
<ins>Step 2:</ins> Divide the eliminated VMT by the average annual fuel efficiency rate to derive the daily gasoline savings in gallons.
<ins>Step 3:</ins> Multiply the daily savings by the number of days a year that pedestrian travel is possible, reflecting the weather factors. This is the total annual gasoline savings in gallons attributable to pedestrian strategy.

TSM
ENERGY ANALYSIS
WORKSHEET

PEDESTRIAN TRAVEL

TRIP PURPOSE	POTENTIAL AUTO TRIPS AFFECTED

		AVG PED TRIP LENGTH		AUTO MPG (TABLE 1.3)		GALLONS	
	x	0.5	÷		=		DAILY ENERGY SAVINGS
					x		FAVORABLE DAYS PER YEAR
							ANNUAL ENERGY SAVINGS

Example

The Rochester area has constructed a pedestrian walkway, the Genesee Crossroads Bridge, connecting the business district to downtown shopping area. The facility provides new access serving as a bridge over the Genesee River. The Rochester Home Interview Survey of 1974 was utilized to determine the affected area which consists of seven zones.

TSM
ENERGY ANALYSIS WORKSHEET

PEDESTRIAN TRAVEL

TRIP PURPOSE	POTENTIAL AUTO TRIPS AFFECTED
EAT ↔ WORK	454
HOME ↔ SHOP	280
HOME ↔ WORK	462

1,196 x 0.5 (AVG PED TRIP LENGTH) ÷ 17.7 (AUTO MPG (TABLE 1.3)) = 33.8 (GALLONS) DAILY ENERGY SAVINGS

x 178 FAVORABLE DAYS PER YEAR

6,016 ANNUAL ENERGY SAVINGS

Limitations

Encouragement of pedestrian travel may be less important as a strategy by itself than as a component of other strategies, such as attracting transit ridership (4). Safe, attractive, clearly-labeled pedestrian access to rapid transit stations, bus stops, and intermodal transfer points should not be overlooked as part of a comprehensive program to improve transit service and promote transit's image (4). Although these facilities may not attract many new potential walkers, their absence may discourage those who may otherwise have switched.

References

1. U.S. Bureau of the Census, "The Journey to Work in the United States: 1975" Special Studies P-23, No. 99, Current Population Reports, July 1979.
2. Gary E. Maring, "Pedestrian Travel Characteristics," in Pedestrian Protection, Highway Research Record 406, 1972.
3. Michael J. Demetsky and Michael A. Perfater, "Assessment of Pedestrian Attitudes and Behavior in Suburban Environments," in Urban Accident Patterns, Transportation Research Record 540, 1975.
4. Roman Krzyczkowski, S.S. Henneman, C.L. Hudson, E.S. Putman, D.J. Thiesen, "Joint Strategies for Urban Transportation, Air Quality and Energy Conservation Volume 1: Joint Actions Programs," Interplan Corporation, prepared for UMTA, EPA, December 1974.
5. Janis M. Gross, Daniel K. Boyle, Gerald S. Cohen, Nathan S. Erlbaum, Michael A. Kocis, K.-W. Peter Koeppel, "Energy Impacts of Transportation Systems Management Actions in New York State, 1978-80, Preliminary Research Report 151, New York State Department of Transportation, May 1979.

9. Bicycle Facilities

Description and Impacts

The bicycle is one of the most energy efficient modes of transportation. A cyclist can pedal over a thousand miles on the energy equivalent of one gallon of gasoline (1). It is even more efficient than walking, as a pedestrian can only walk 250 miles on the energy equivalent of a gallon of gasoline (1). Numerous actions can be taken to encourage mode shifts to increase bicycle usage. The promotion of bicycling can be achieved by removing the obstacles (such as lack of bicycle provisions, incomplete access routes, lack of shower facilities and motorist hostility) that prevent the unobstructive use of bicycles. The development of a safe network of bicycle routes and the installation of adequate and secure parking facilities would increase the number of riders. Many studies have been written on the energy savings that can be achieved assuming that the potential mode shift is fulfilled (1,2,3). In summary, an increase of bicycle usage in the range of between 50 and 100 percent would induce a daily national reduction in vehicle miles of travel of between 8.3-16.5 million miles. If this goal is attained, it will result in a gasoline savings of 7.9 to 15.0 million barrels per year (2). A study in New York City revealed that the impacts of an auto-to-bicycle mode shift of one percent of total vehicle miles of travel would save 2.8 million gallons of gasoline on an annual basis (1).

While the potential does exist, there are several arguments suggesting that the changes in mode are likely to be small, as are the gasoline savings attributable to these changes. Despite the many social and private benefits gained through bicycling, experience has shown that construction or designation of bikeways in congested urban areas, in itself, may not be enough to cause a significant number of persons to switch to bicycle use, or even to assure reasonable use of routes (4).

In addition, supporting evidence from Everett (5) and Floyd (6) indicate that the dollar savings from a modal shift (generally $100 to $300 per year) are really too small to induce such a shift (7). Other factors that are not conducive to widespread shifts to bicycles are:

1. Weather - for many of the regions of the United States, dangerous weather conditions, such as ice and snow, make bicycle use virtually impossible for significant portion of the year.
2. General absence of shower facilities at the trip destination.
3. General absence of orderly and reasonable theft-proof bicycle storage facilities at the trip destination.
4. Residential patterns - the typical one-way bike trip is around 3 miles long, few are longer than 5 miles. In contrast, the average work trip is substantially longer.

5. Safety, circuity and recognition of the bike route - while all but signed bike routes tend to improve the perceived safety of the bicyclist considerable, circuity is the major reason cited by bicyclists for not using a facility which would take them out of their way by up to two blocks (7).

Further evidence supporting this argument is summarized by Floyd's (6) description of the potential demand for bicycle trips:

1. It is highly doubtful that commuting trips to work by bicycle will ever constitute a significant portion of total commuting trips in the United States except in very specialized situations.
2. Commuting trips to schools appear to offer the greatest potential benefits to bikeway users, in terms of both economy and safety. This potential is particularly great in communities having large college student populations.
3. Bicycle shopping trips offer little potential for expansion in most communities and should be considered as an incidental factor in bikeway planning.

The evidence presented above suggests that the potential energy savings attributable to bicycle strategies would be very small. Therefore, the methodology that will be outlined will be of a very general nature. It should serve as a guideline for those who choose to further investigate the energy savings attributed to bicycling as a mode of transportation.

Methodology

The methodology utilizes a number of assumptions which should be noted. The technique will evaluate the maximum energy savings that could be obtained through the increased use of the bicycle as a mode of transportation to and from work. The procedure is overly optimistic since it assumes that the mode shift to bicycles will occur for all automobile work trips two miles or less in length. National data (8) reveals that approximately 24.4% of automobile work trips fall under this range, with a mean distance of 1.4 miles. However, this may be an over-estimation of the total energy savings in the respect that some of the shortest trips (.6 miles) may be diverted to walking rather than bicycling. Additionally, a 100% mode shift is unlikely to be obtained. Therefore, this methodology should be viewed as an indicator of the uppermost limit of the range of savings. The procedures is as follows:

Step 1: Multiply the number of automobile work trips by the percent of automobile work trips that are two miles or less in length. This will yield the number of potential auto work trips diverting to bicycling per day.
Step 2: Multiply the number of diverted trips by the average bicycle trip length; this is the daily VMT eliminated.

<u>Step 3:</u> Multiply the daily VMT eliminated by the number of days per year that a bicycle can be used as a mode of transportation to work (this factor should reflect climatic variation) to obtain the annual VMT eliminated.
<u>Step 4:</u> Divide the annual VMT eliminated by the Statewide fuel efficiency rate in miles per gallon to obtain the annual gasoline savings in gallons (Table 1.3).
<u>Step 5:</u> Adjust these savings to account for the VMT savings reinvested as travel by the car left at home. Multiply the savings by 0.60 to account for this new travel. This yields the total yearly savings due to bicycle actions.

TSM
ENERGY ANALYSIS
WORKSHEET

BICYCLE FACILITIES

DAILY WORK TRIPS LESS THAN 2 MILES LONG		AVERAGE BICYCLE TRIP LENGTH (MI)		FACTOR FOR CAR LEFT HOME		AUTO MPG (TABLE 1.3)		GALLONS	
	X		X	0.6	÷		=		DAILY ENERGY SAVINGS
							X		FAVORABLE DAYS PER YEAR
							TOTAL		ANNUAL ENERGY SAVINGS

Example

Suppose that the Rochester area implements bicycle strategies to encourage the use of this mode. Utilizing the Home Interview Survey of 1974, it was determined that 27.8% of all auto work trips were 2 miles or less in length and that the average national bicycle trip length is 1.4 miles (8).

Limitations

As noted above, the assumptions involved in the methodology tend to overestimate energy savings. The results of the example worksheet are, therefore, an optimistic estimate of savings due to bicycle facilities.

TSM
ENERGY ANALYSIS
WORKSHEET

BICYCLE FACILITIES

DAILY WORK TRIPS LESS THAN 2 MILES LONG		AVERAGE BICYCLE TRIP LENGTH (MI)		FACTOR FOR CAR LEFT HOME	AUTO MPG (TABLE 1.3)		GALLONS	
67,763	x	1.4	x	0.6	17.7	=	3,216	DAILY ENERGY SAVINGS
						x	178	FAVORABLE DAYS PER YEAR
						TOTAL	572,448	ANNUAL ENERGY SAVINGS

References

1. "Bikeway Planning and Policy Guidelines for New York City," prepared by: Edwards and Kelcey in association with Transportation Alternatives, Inc., prepared for: New York City Department of Transportation, July 1978.
2. "Bicycle Transportation for Energy Conservation," U.S. Department of Transportation, Office of the Secretary, Washington, D.C., April 1980.
3. Marda Fortmann Mayo, "Bicycling and Air Quality Information Document," prepared by: Abt Associates Inc., prepared for: Environmental Protection Agency, Office of Transportation and Land Use Policy, U.S. Department of Transportation, September 1979.
4. Barbara Ibarra Keyani, Evelyn S. Putman, "Transportation Systems Management: State of the Art, February 1977." Interplan Corporation, prepared for: The Office of Policy and Program Development UMTA, USDOT, September 1976.
5. Michael Everett, "Commuter Demand for Bicycle Transportation in the United States," Traffic Quarterly, October 1974.
6. Charles F. Floyd, "The Future of the Bicycle as a Mode of Transportation in the U.S.," Traffic Quarterly, January 1977.
7. Janis M. Gross, Daniel K. Boyle, Gerald S. Cohen, Nathan S. Erlbaum, Michael A. Kocis, K.-W. Peter Koeppel, "Energy Impacts of Transportation Systems Management Actions in New York State, 1978-80," Preliminary Research Report 151, New York State Department of Transportation, May 1979.
8. U.S. Bureau of the Census, "The Journey to Work in the United States: 1975," Current Population Reports, Special Studies P-23, No. 99, July 1979.

10. Parking Management Programs

Description

Parking Management Programs are actions taken to alter the supply, operation and/or parking demand of an area's parking system to further the attainment of local transportation, economic, environmental, and other objectives (1). The TSM strategies affecting parking include three categories:

- Pricing Policies
- Supply Management
- Parking Permit Systems

The general objectives of all three of these tactics are "to improve transportation service and to increase the general cost of using a single-occupant automobile so as to encourage a mode shift to either transit or high-occupancy vehicles" (2). The effectiveness of a given parking strategy can be enhanced by implementing complementary TSM actions; for example, improved transit service and preferential treatment for high occupancy vehicles will contribute to diverting auto users to other modes.

The regulation of the price of parking facilities includes the following actions:

- parking taxes
- parking surcharge
- increased parking rates
- revised parking rate structures and differential rates

Parking charges can be used to regulate the number of vehicles entering the CBD and the trip purposes they serve (3). These actions have the potential for targeting the group impacted by the charge by setting specifications of area, hours, facilities and duration (2).

Limiting the supply of both on- and off-street parking can be accomplished by:

- Parking restrictions - such as prohibitions on parking before specified hours, peak period restrictions or limiting duration of parking.
- Physically removing spaces
- Preferential parking for high occupancy vehicles

These actions utilize supply limitations to make the use of automobiles less attractive, thereby reducing congestion and promoting the use of high-occupancy vehicles.

Residential parking permit programs are a response to the excessive amount of parking demand of persons not living in neighborhoods but parking thier vehicle there for various purposes. This method prevents long-term parking in residential neighborhoods by commuters

(1). Permits are sold, to residents only, by the municipality for for fees ranging from $5-$10. Communities that have implemented residential parking permit programs have been generally satisfied by the effect it has had on alleviating local parking problems.

Impacts

The effects of parking management and regulation are far-reaching and widespread. Both the auto user and the transit industry are affected. The physical areas that will be impacted include the CBD and the residential neighborhoods adjacent to the CBD. Short-term parkers (generally commuters) will be targets of the various actions. The impacts associated with each of these topics must be considered and determined in assessing the energy conservation attributable to parking management programs. However, the emphasis of this effort will be on the effects that parking management programs will have on long-term commuter parking in the CBD.

The primary goal of these actions is to reduce automobile use in congested areas, thus achieving energy conservation by a reduction in the number of vehicle-miles of travel. This reduction is induced by either a mode shift, or the rerouting of trips. Changes in modal choice can be attributed to parking of autos becoming less attractive financially or less convenient. In addition to a mode shift, it is assumed that a certain amount of rerouting of autos also results from the regulation of parking. Those individuals who continue to park may decide to increase their walking distance in order to save the additional expense of parking closer. In making this adjustment, it is expected that those who relocate their parking sites will park, if possible, closer to their homes rather than park further from both work and home and will therefore drive a shorter distance each day. Additionally, travel, as measured by VMT, is also affected by the reduction in cruise time associated with finding an available parking space since less vehicles will park in congested areas as a result of an increase in price.

A reduction in the supply of parking can have an adverse affect on cruise time. Fewer spaces available will cause an increase in the amount of search time necessary to find a space. This factor is not evaluated in the section on supply management because it is assumed that any increases in cruise time will be short-lived. For example, a person driving daily into the CBD will find it very difficult to find a space and thus be forced to leave the CBD in search of available parking. It is assumed that after a short period of time the driver will quickly learn that he cannot find a space within the CBD and will seek an alternative solution to the problem.

The reduction in VMT will have a positive affect on both auto and transit travel times, assuming that parking strategies will reduce congestion, increase average network speeds, and improve the traffic flow (4).

In summary, well designed parking management programs can:

1. discourage the use of autos (especially solo drivers)
2. increase transit usage
3. reduce congestion in the CBD
4. reserve limited parking in the CBD fringe for the residents of the area; and
5. limit long-term commuter parking.

However, to achieve the goal of energy conservation certain conditions not directly related to parking must be present to complement parking strategies to achieve the maximum effect. These complementary conditions include:

- Fast, dependable, convenient, and reasonably priced alternate means of transportation.
- Ability to impose substantial price changes (price elasticities for parking are very low -.15 to -.29).
- Ability to control all or most of the parking facilities (5).

In formulating a strategy, consideration must be given to the potential impact on downtown retail sales and professional services. Good strategies should limit the use of parking for work trips, but encourage the use of the limited available space for shoppers and other short-term parkers.

10.1 Supply Management

Methodology

The supply management actions that were previously reviewed can be aggregated into two categories: those actions which restrict parking to improve traffic flow and those that reduce auto accessibility. The former includes actions such as peak period restrictions, duration limitations, and hourly prohibitions. The latter encourages mode shifts from solo drivers to either transit or other high-occupancy vehicles. The actions in this category include space removal and preferential parking programs. The two separate types of restrictions will be evaluated individually because their impacts on energy savings and travel parameters vary considerably.

Evaluating Restrictions to Improve Traffic Flow

Actions which improve traffic flow directly affect traffic speeds; therefore, the analysis must evaluate the energy savings that would accrue due to the change in this parameter. The procedure used in this study is obtained from Gross et al (5). The basic formula that is utilized is:

$$\underline{S = VMT \times \Delta FC \times ADJUST \times DAYS \times PP}$$

where:

S = the number of gallons of gasoline saved annually.
VMT = the number of vehicles miles of travel that is affected by the restriction.
ΔFC = The change in gasoline consumption rate in gallons per mile corresponding to the change in speed after parking restrictions are implemented (Table 1.1).
ADJUST = The appropriate yearly adjustment factor that adjusts the auto energy consumption for improvements due to vehicle efficiency improvements. If statewide fleet mix is unknown, Table 1.2 can be used.
DAYS = the number of days per year that a parking program is applicable; generally, for work purposes, this is 250 days/yr, subtracting weekends, vacation time and holidays.
PP = the number of peak periods a day, which is generally 2.

The necessary inputs for the procedure are:

1. Peak hour traffic volumes.
2. Length of the affected road segment in miles.
3. Speed before parking restriction implementation.

<u>Step 1:</u> Multiply the traffic volume by the road length to get vehicle miles of travel affected.
<u>Step 2:</u> Obtain the speed after parking restriction:
Speed after = 1 mph + 1.4 x speed before (5)
<u>Step 3:</u> Obtain the corresponding consumption rates for (a) the before speed and (b) the after speeds from Table 1.1.
<u>Step 4:</u> To find the change in fuel consumption:
Subtract before speed (Step 3a) consumption - after speed (Step 3b) consumption.
<u>Step 5:</u> Multiply VMT (Step 1) by the change in consumption rate (Step 4) to get the unadjusted gasoline savings in gallons.
<u>Step 6:</u> Multiply the unadjusted savings (Step 5) by the yearly adjustment factor from Table 1.2 to get the actual gasoline savings per peak period.
<u>Step 7:</u> Multiply the actual savings per peak period (Step 6) by 250 days/year to get the annual gasoline savings.
<u>Step 8:</u> (Optional depending on project) Multiply the annual savings (Step 7) by 2 peak periods/day to get annual savings per year for 2 peak periods a day.

TSM
ENERGY ANALYSIS
WORKSHEET

PARKING: PARKING REMOVAL

A. BASE DATA

DEMAND VOLUME		SEGMENT LENGTH		BASE VMT
	X		=	

BEFORE SPEED (MPH)		ADJUSTMENT FACTORS				AFTER SPEED (MPH)
	X	1.4	+	1.0	=	

B. FUEL CONSUMPTION

ΔFCR (TABLE 1.1)		BASE VMT		FUEL ECONOMY ADJ (TABLE 1.3)			
	X		X		=		DAILY ENERGY SAVINGS (GAL)
					X	250	WORKDAYS PER YEAR
					=		ANNUAL ENERGY SAVINGS (GAL)

Hypothetical Example:

Orange County: 24 hour parking restrictions on Route 17, in the Village of Sloatsburg, three continuous areas of parking restriction, reducing a four lane, undivided highway to a three lane highway. The restrictions are, going from north to south:

1200 ft. - right hand side restricted
5300 ft. - left hand side restricted
2600 ft. - right hand side restricted

Peak hr. volume:

Morning (southbound): 710/hour (7-9 am)
Evening (northbound): 690/hour (4-9 pm)

Inputs

1. Peak period traffic volume = 1420 am
   1380 pm
2. Length of the affected segments = .227 mile
   1.004 mile
   .492 mile
3. Speed before parking restriction implementation = 20 mph.

TSM
ENERGY ANALYSIS
WORKSHEET

PARKING: PARKING REMOVAL

Am PEAK

A. BASE DATA

DEMAND VOLUME		SEGMENT LENGTH		BASE VMT
1420	x	.227 1.004 .492	=	322 1,426 699

BEFORE SPEED (MPH)		ADJUSTMENT FACTORS				AFTER SPEED (MPH)
20	x	1.4	+	1.0	=	29

B. FUEL CONSUMPTION

ΔFCR (TABLE 1.1)		BASE VMT		FUEL ECONOMY ADJ (TABLE 1.3)			
.006	x	2,447	x	0.831	=	12.2	DAILY ENERGY SAVINGS (GAL)
					x	250	WORKDAYS PER YEAR
					=	3,050	ANNUAL ENERGY SAVINGS (GAL)

TABLE 10.1

PREDICTED AREAWIDE IMPACTS OF PARKING AVAILABILITY AND COST STRATEGIES: WASHINGTON, D.C.

STRATEGY	PERCENT CHANGE						
	WORK-TRIP MODAL SHARES (PERCENT):			VMT (MILES/DAY):			FUEL CONSUMPTION (GAL/DAY)
	Drive-Alone	Shared-Ride	Transit	Work	Non-Work	Total	
Base Values*	52.9	25.4	14.5	10.4	16.7	27.1	2.6
Preferential Parking	10.7	22.1	0.4	-3.4	1.0	-0.6	-0.6
Preferential Parking + Shared-Ride Parking Subsidies	-22.3	43.8	4.6	-9.8	2.5	-2.2	-1.8
Base Parking Cost (Areawide):							
+ $1	-5.1	4.5	10.6	-3.3	0.7	-0.8	-0.7
+ $2	-10.4	9.3	21.6	-6.6	1.5	-1.7	-1.4
+ $3	-15.6	13.9	32.6	-10.2	2.3	-2.5	-2.1
Base Parking Cost (CBD Only)**:							
+ $1	-2.2	1.0	6.3	-1.4	0.3	-0.3	-0.3
+ $2	-4.4	2.0	12.5	-2.7	0.7	-0.6	-0.5
+ $3	-6.5	3.0	17.8	-4.0	1.0	-0.9	-0.8
Reduced Parking Supply in Ring 0:							
DA*** Walk Time: + 7.5 min.	-3.2	3.8	5.0	-1.3	0.4	-0.3	-0.2
DA Walk Time: + 15 min.	-5.6	6.8	8.5	-2.3	0.7	-0.5	-0.4
DA Alternative Estimated	-14.8	16.7	24.8	-12.2	3.1	-2.8	-2.2

*Excluding weekend travel
**Rings 0 and 1
***DA = Drive-Alone

Source (6)

TABLE 10.2

PREDICTED IMPACTS OF REDUCED CBD CORE PARKING SUPPLY ON HOUSEHOLDS WITH WORK TRIPS DESTINED TO THE AFFECTED AREA: WASHINGTON, D.C.

STRATEGY	PERCENT CHANGE						
	WORK-TRIP MODAL SHARES (PERCENT):			VMT (MILES/DAY):			FUEL CONSUMPTION (GAL/DAY)
	Drive-Alone	Shared-Ride	Transit	Work	Non-Work	Total	
Base Values*	39.0	29.4	25.0	10.8	15.0	25.8	2.5
Reduced Parking Supply in Ring 0:							
DA** Walk Time: + 7.5 min.	-14.2	10.6	9.6	-5.7	1.9	-1.3	-1.1
DA Walk Time: + 15 min.	-24.9	19.3	16.2	-10.6	3.5	-2.4	-2.1
DA Alternative Eliminated	-65.8	47.2	47.1	-55.8	16.2	-13.9	-11.0

*Excluding weekend travel
**DA = Drive-Alone

Source (6)

TABLE 10.3

PREDICTED AREAWIDE IMPACTS OF CARPOOL STRATEGIES: BIRMINGHAM, ALABAMA[†]

STRATEGY	PERCENT CHANGE						
	WORK-TRIP MODAL SHARES (PERCENT):			VMT (MILES/DAY):			FUEL CONSUMPTION (GAL/DAY)
	Drive-Alone	Shared-Ride	Transit	Work	Non-Work	Total	
Base Values*	67.7 (52.9)	23.9 (25.4)	8.0 (14.5)	8.0 (10.4)	14.0 (16.7)	22.0 (27.1)	2.1 (2.6)
Base Parking Cost + $1.00 Areawide	-3.9 (-5.1)	6.6 (4.5)	14.1 (10.6)	-3.2 (-3.3)	0.8 (0.7)	-0.7 (-0.8)	-0.5 (-0.7)
CBD Only	-1.0 (-2.2)	1.2 (1.0)	4.9 (6.3)	-0.7 (-1.4)	0.2 (0.3)	-0.1 (-0.3)	-0.1 (-0.3)
Preferential Parking	-6.3 (-10.7)	18.2 (22.1)	0.2 (0.4)	-1.9 (-3.4)	1.0 (1.0)	-0.1 (-0.6)	-0.02 (-0.6)
Preferential Parking + Shared-Ride Parking Subsidies**	-19.2 (-22.3)	51.5 (43.8)	12.6 (4.6)	-10.3 (-9.8)	3.5 (2.5)	-1.6 (-2.2)	-1.1 (-1.8)
Employer Incentives	-4.4 (-3.9)	16.1 (16.7)	-9.9 (-5.0)	-2.1 (-1.8)	0.8 (0.5)	-0.3 (-0.4)	-0.2 (-0.2)
Auto-Restricted Zones***	-0.7 (-1.7)	-2.3 (-4.8)	12.5 (14.6)	-0.5 (-1.0)	0.2 (0.3)	-0.1 (-0.2)	-0.1 (-0.2)
Increased Frequency of Bus Service to CBD Wait Time -20%	-0.3 (-0.9)	-1.4 (-2.2)	6.8 (7.2)	-0.3 (-0.6)	0.1 (0.2)	-0.05 (-0.1)	-0.04 (-0.1)
Express Bus Service to CBD Combined with Increased Frequency (both in-vehicle and out-of-vehicle travel times reduced by 20%)	-0.5 (-1.7)	-1.8 (-4.1)	9.2 (13.5)	-0.7 (-1.7)	0.2 (0.3)	-0.1 (-0.3)	-0.06 (-0.3)
Base Value****	67.7 (52.9)	23.9 (25.4)	8.0 (14.5)	8.0 (10.4)	23.0 (27.6)	31.0 (38.0)	3.0 (3.7)
Gasoline Price x 2	-1.0 (-1.4)	1.6 (1.6)	4.1 (2.4)	-1.2 (-1.4)	-6.7 (-6.6)	-5.6 (-5.1)	-4.8 (-4.7)

[†] Birmingham x.x
Washington (x.x)
*Excluding weekend travel
**Drive-Alone parking charge = $2.00
***Drive-Alone and Shared-Ride walk time increased by 7.5 minutes
****Including weekend travel

Source (6)

The procedure is as follows:

Step 1: Multiply the base volume by the mode shift to get the number of trips eliminated.
Step 2: Multiply round trip length by the trips eliminated to get the VMT saved.
Step 3: Divide VMT saved by statewide fuel efficiency (Table 1.3) to get the number of gallons saved daily by VMT reduction.
Step 4: Multiply by 250 days/year to get the yearly savings.

Computing the Speed-Related Savings

A reduction in vehicle miles of travel will bring about an increase in travel speed; hence the gasoline consumption rate per auto will decrease and energy will be conserved. The inputs to the procedure are:

1. remaining VMT (i.e. VMT "not saved")
2. before implementation speed

The procedure is:

Step 1: Obtain the after implementation speed by the following formula:
Speed after = 1 mph + 1.4 x speed before (5)
Step 2: Obtain the corresponding consumption rates for (a) the before speed and (b) the after speeds from Table 1.1.
Step 3: To find the change in fuel consumption, subtract before speed consumption from after speed consumption.
Step 4: Multiply the VMT "not saved" by the change in consumption rate to obtain the unadjusted gasoline savings per peak period in gallons.
Step 5: Multiply the gallons saved per peak period by the yearly adjustment factor from Table 1.2. This factor is "used to adjust energy consumption rates for improvements in vehicle efficiency" (12).
Step 6: Multiply the adjusted savings by the number of days on which the restriction is effective (usually 250) to obtain the yearly savings in gallons for one peak period.
Step 7: This step is optional depending on the individual project that is implemented.
Multiply the yearly savings x 2 peak periods a day.

Computing the Negative Savings Due to an Auto Being Left at Home

It is assumed that parking restrictions of this nature will induce a mode shift. Those that do shift to alternate means of travel will be leaving an automobile at home that can be utilized for travel purposes other than work. The additional travel is estimated to be about 40% of the work VMT saved (5).

Therefore, multiply the fuel savings due to VMT reduction by 60% to get the adjusted savings.

The total savings due to parking restrictions that reduce auto accessibility is:

$$\text{Savings} = (\text{VMT savings} \times 60\%) + \text{Speed Savings}$$

TSM
ENERGY ANALYSIS
WORKSHEET

PARKING: REDUCE CBD PARKING

A. BASE DATA

BASE AUTO VOLUME		AVERAGE ROUND TRIP LENGTH		BASE VMT		Δ% DRIVE ALONE		ΔVMT
	X		=		X		=	

BASE NETWORK SPEED (MPH)		ADJUSTMENT FACTORS				REVISED NETWORK SPEED (MPH)
	X	1.4	+	1.0	=	

B. FUEL CONSUMPTION

ΔFCR (GPM) (TABLE 1.1)		BASE VMT		ΔVMT		FUEL ECONOMY ADJ (TABLE 1.2)		ENERGY SAVINGS (GAL)	
	X [		+		] X		=		FROM SPEED-RELATED CHANGES

ΔVMT		AUTO FUEL ECONOMY (TABLE 1.3)		CAR LEFT HOME FACTOR			
	÷		X	0.6	=		FROM VMT-RELATED CHANGES

SUBTOTAL		DAILY ENERGY SAVINGS
X	250	WORKDAYS PER YEAR
TOTAL		ANNUAL ENERGY SAVINGS

Example

A study performed on the Washington, DC central business district indicated that a reduction in the parking supply of the core area would induce an additional 7.5 minutes of walk times for trips destined for work and would decrease the drive alone mode by 14.2%. The base value for alone drivers was 39.0%, hence this action will decrease this percentage to 33.5% (6). The base volumes on the CBD network for the average weekday was 445,201. This was determined by cordon counts done by the Metropolitan Council of Governments (13). The average network speed before action implementation is 15 mph.

TSM
ENERGY ANALYSIS
WORKSHEET

PARKING: REDUCE CBD PARKING

A. BASE DATA

BASE AUTO VOLUME		AVERAGE ROUND TRIP LENGTH		BASE VMT		Δ% DRIVE ALONE		ΔVMT
445,201	x	16.8	=	7,479,377	x	-14.2	=	-1,062,072

BASE NETWORK SPEED (MPH)		ADJUSTMENT FACTORS				REVISED NETWORK SPEED (MPH)
15	x	1.4	+	1.0	=	22

B. FUEL CONSUMPTION

ΔFCR (GPM) (TABLE 1.1)		BASE VMT		ΔVMT		FUEL ECONOMY ADJ (TABLE 1.2)		ENERGY SAVINGS (GAL)	
-.010	x	[7,479,377	+	-1,062,072]	x	.631	=	53,328	FROM SPEED-RELATED CHANGES

ΔVMT		AUTO FUEL ECONOMY (TABLE 1.3)		CAR LEFT HOME FACTOR			
-1,062,072	÷	17.7	x	0.6	=	36,002	FROM VMT-RELATED CHANGES

SUBTOTAL	89,330	DAILY ENERGY SAVINGS
x	250	WORKDAYS PER YEAR
TOTAL	22,332,500	ANNUAL ENERGY SAVINGS

Limitations

In summary a comparison of parking supply restrictions to other TSM actions reveals a great potential for conserving large amounts of gasoline. The procedures utilized to assess these savings is relatively straightforward and precise.

A drawback that is noteworthy for the methodology used for restrictions to improve traffic flow is that it does not lend itself to easy application in the case of areawide restrictions. If a large number of road segments are involved in the analysis then the procedure can become quite cumbersone although it can still be utilized.

10.2 Pricing Policies

Methodology

The energy savings resulting from parking pricing policies can be attributed to the impact that such a program has upon vehicle miles of travel and travel speeds. The change in vehicle miles of travel is a function of three variables: mode shifts, the rerouting of trips by those wishing to avoid the parking expense (which may increase VMT), and the reduction of cruise time necessary to find an available parking space. In addition, a decline in vehicles miles of travel will diminish congestion, producing an increase in average network speeds thereby reducing fuel consumption per vehicle. The analysis is broken down in this fashion. Figure 10.1 illustrates this classification.

The most important factor determining the extent of the effectiveness of such programs is the availability of adequate transit services. Studies on parking pricing actions in Chicago and Washington, DC found a correlation between these factors (14). Other conditions relating to effectiveness are substantial facility coverage and significant cost increase.

The methodology involved in estimating the total energy savings is segmented into two parts: the savings associated with a reduction in vehicle miles of travel; and the speed-related savings.

VMT-Related Savings

In determining the savings attributable to VMT reductions, one must speculate on the behavioral effects resulting from pricing actions. The majority of drivers will most likely persist in parking, merely changing the location of the area parked in. This reaction to the policy can significantly affect the amount of VMT reduced, possibly resulting in the largest energy savings (providing that the trips do not increase in length in comparison to before the pricing action). The number of modal shifts away from single-occupant vehicles is a function of each individual locale. Depending on this number, the energy savings will vary considerably. Those who basically go unaffected by the increase in parking costs and continue to park in the affected zone will spend less time searching for a parking space, presumably reducing VMT. It should be noted that this effect is very dependent on the number of mode shifts. If the percent switching modes is small, it is likely that a significant saving from "cruise time" reductions will not accrue.

Figure 10.1

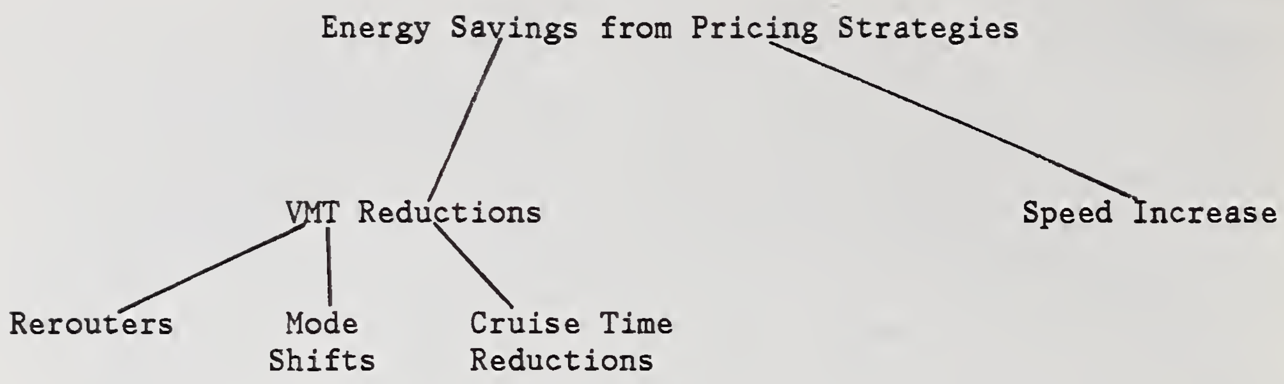
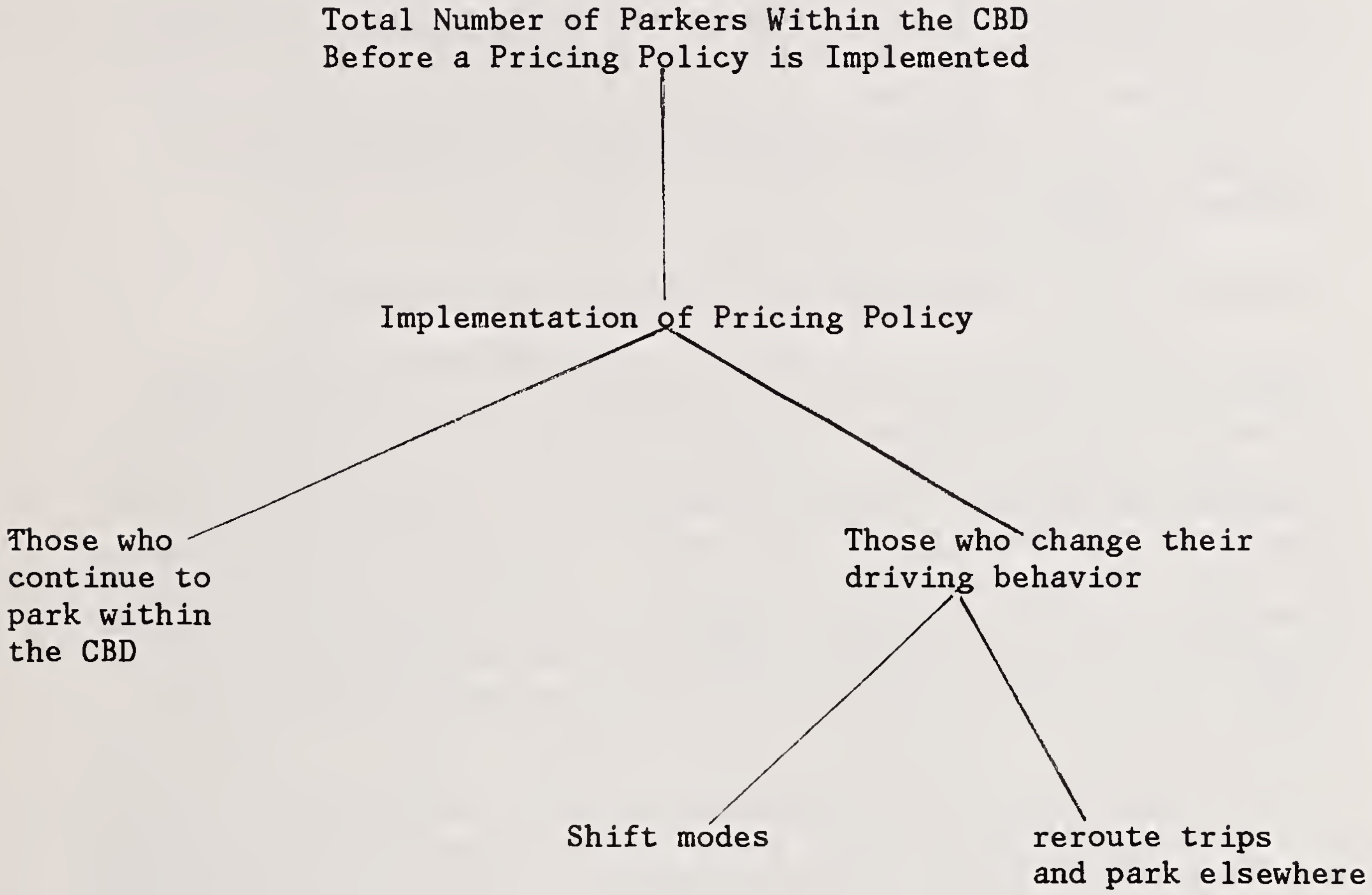

Energy Savings from Pricing Strategies
VMT Reductions
Speed Increase
Rerouters
Mode Shifts
Cruise Time Reductions

Figure 10.2

The Impact of Pricing Strategies on Driver Behavior



The procedure utilized in this analysis attempts to present the savings for all trip purposes for the duration of an average weekday for a CBD area. The analysis is simplified by segmenting the savings resulting from VMT reductions into the three sections: (1) the savings resulting from those who reroute their trips to park in areas unaffected by the charge; (2) the associated savings that occurs because less search time is now necessary to find a parking space by those who continue to park in the affected areas; and (3) the savings resulting from mode shifts away from single-occupant vehicles. Figure 10.2 illustrates the basic impacts associated with these policies.

Estimating the Gasoline Savings Resulting from Rerouting

It has been assumed that an increase in the cost of parking by any of the pricing policies will yield either one of two consequences on the behavior of drivers. Drivers will attempt to avoid the cost by either diverting to another mode of travel or by rerouting their trips to enable them to park their vehicles outside the area of the charge, thereby trading off convenience. The effect of rerouting can have a positive or a negative effect on vehicle miles of travel depending on whether a driver parks closer or further from his home. The assessment of the impacts on VMT and the corresponding gasoline savings associated with rerouting is based on either the increase or decrease of this distance. For the purpose of this analysis it is assumed that the affected drivers will park closer to their homes rather than further from home and work, thus saving energy. It should be noted that the relocation of parking may actually increase VMT if the trips made are longer in length. Hence this is an optimistic approach. However, the procedure that is developed can also be utilized to compute the negative savings that may accrue. A reasonable estimate of the distance saved by parking closer to home is about 1/2 mile. This is based solely on the knowledge that the majority will not consider walking distances greater than this length. The initial inputs to the procedure are:

1. The number of vehicles entering the CBD on any weekday before policy implementation. It is assumed that all vehicles entering this area will be parking and does not consider the minimal amount of through traffic.
2. The daily price of parking before and after the pricing policy is effective.
3. The parking price elasticity of demand with respect to the number of parked vehicles (Default value -0.22) (5).
4. The percent mode shift away from single-occupant vehicles resulting from a pricing policy.
5. The average annual statewide automobile fuel efficiency in miles per gallon.
6. The number of days a year that a pricing policy will be effective.
7. Average distance saved by parking closer to home (Default value = 1/2 mile).

The methodology proceeds as follows:

1. Compute the percent change in demand corresponding to the change in the price of parking.

$$\frac{\text{After Price - Before Price}}{\text{Before Price}} \qquad X -.22$$

2. Multiply the percent change in demand by the number of autos no longer parking within the CBD
3. Apply the percent mode shift away from single-occupant vehicles to the number of autos no longer parking to obtain the number of auto drivers shifting modes.
4. Subtract from the number of autos no longer parking the number of vehicles shifting to obtain the number of automobiles rerouting.
5. Multiply the number of automobiles rerouting by the average distance being saved daily to obtain the VMT eliminated daily because of the relocation of trips.
6. Divide the VMT eliminated by the average annual statewide fuel efficiency to obtain the number of gallons of gasoline saved daily.
7. Multiply the daily savings by the number of days per year that a pricing policy will be effective (usually 250 work days per year); this will yield the annual gasoline savings in gallons.

Estimating the Gasoline Savings Resulting from Mode Shifts

Mode shifts account for a significant proportion of total fuel saving attributable to pricing policies. The evaluation of the reduction of vehicle miles of travel and the associated energy savings centers around the computation of the percent change in mode shares after the imposition of a pricing mechanism. This variable is determined to a great extent by characteristics of the transit service in each individual locality. In situations where alternative modes are characterized by relatively poor levels of service, people are more resistant to change from auto. For example, in Fort Worth, a city with relatively poor transit service (indicated by an initial transit share of 2% for worktrips), the response to an areawide increase in parking cost was a 0.9 percent decrease in VMT. In San Francisco, however, a city with good transit service (as reflected by an initial transit share of 15%) this measure resulted in 1.8 percent decrease in VMT (8). It is assumed that this information is readily available; howver, if it is necessary, a variety of sources contain detailed accounts on methods to compute mode shifts (6,7,8,9) and the calibration of base splits (10).

The initial inputs for the procedure are:

1. The average round trip, work trip length to the CBD.
2. The average annual automobile fuel efficiency rate in miles per gallon (Table 1.3 may be utilized):

3. The number of days per year that a pricing action will be effective (This is usually 250).

The procedure utilizes the previously calculated number of vehicles no longer being driven due to mode shifts:

1. Multiply the number of autos no longer being driven by the average round trip length to ascertain the vehicle miles of travel eliminated per day.
2. Divide the VMT eliminated daily by the average annual efficiency rate in miles/gallon to obtain the number of gallons of gasoline saved daily.
3. Multiply the daily gasoline savings by the number of days a year that a pricing action will be effective. This is the annual gasoline savings in gallons attributed to mode shifts.
4. Multiply the annual savings by 0.60 to account for the car left home factor thus yielding the total savings.

Estimating the Gasoline Savings Resulting from Decreased Cruise Time

Those individuals who choose to bear the additional expense of a pricing policy and continue to park without changing their behavior will indirectly affect vehicle miles of travel. Those who either rerouted or switched modes contributed to the lessening of congestion in the CBD. Fewer vehicles will be parked and there will be a greater abundance of available spaces for those who continue to park in the CBD. The increase in this availability will given rise to a decrease in the necessary amount of search time required to find a place to park. A corresponding decline in vehicle miles of travel will occur as a result of this reduction in "cruise time".

Available literature evaluating the impacts of this variable is scarce. The procedure will utilize the formula: Rate x Time = Distance; where:

Rate = the average speed driven when searching for a parking space in miles per hour.
Time = the average time-savings in hours attributed to a reduction in search time necessary to find a parking space.

This measure of distance will then be multiplied by a fuel consumption rate corresponding to the "Rate" to yield an unadjusted gasoline savings per vehicle. The initial figures used to represent time-savings are estimates based solely on professional judgement.

The necessary data to compute the gasoline savings is as follows:

1. The travel time saved in hours resulting from a reduction in cruise time.
2. The average speed driven when searching for a space.

3. The fuel consumption rate associated with the average speed driven when searching for a space (Table 1.1 may be used if data is unavailable).
4. The yearly adjustment factor to account for increases in vehicle fuel efficiency (Table 1.2 may be substituted for unavailable data).

The procedure is as follows:

1. Utilizing the data and calculations from rerouters: subtract from the number of autos entering the CBD the number no longer parking to obtain the number who will continue to park despite the increase in price.
2. Multiply: travel speed in mph by travel time saved in hours to obtain the number of miles saved per auto per day.
3. Multiply: the number of miles saved by the fuel consumption rate in gallon/mile. This is unadjusted gasoline savings in gallons/vehicle/day.
4. Multiply: the unadjusted savings by the yearly adjustment factor to calculate the adjusted savings in gallons/vehicle/day.
5. Multiply: the adjusted savings by the number of vehicles that continue parking. This is the total savings in gallons for all vehicles in one day.
6. Multiply: the total savings by 250 days/year to yield the total annual gasoline savings for all vehicles in the CBD.

The Speed Related Savings

The procedure used to estimate the savings resulting from increased travel speeds is the same as previously defined in the section on Evaluating Restrictions that Reduce Auto Accesibility. The initial inputs are vehicle miles of travel not saved and the "before implementation" speed. The vehicle miles of travel saved can be retrieved from the preceding sections on rerouting, cruise times and mode shifts by simply adding the vehicle miles of travel saved by each segment. The method itself will not be repeated to avoid redundancy.

Speed related savings will not be significant if the amount of VMT eliminated is not substantial.

Total Savings

The overall evaluation of the energy savings resulting from pricing policies can be computed by summing each part of the analysis calculated in the preceding sections. The total savings is:

Energy Savings = (Savings from rerouting + savings from decreased cruise time + savings from mode shifts) + speed related savings.

TSM
ENERGY ANALYSIS WORKSHEET

PARKING: PRICING POLICIES

A. BASE DATA

AUTOS ENTERING CBD		AVG. ROUND TRIP LENGTH		VMT BEFORE
	X		=	

AUTOS ENTERING CBD		% Δ PARKING PRICE (PP)		PERCENTAGE CONVERSION		e_{PP}		Δ PARKED AUTOS IN CBD
	X		÷	100	X	-0.22	=	

B. VMT SAVINGS - MODE SHIFT

Δ PARKED AUTOS IN CBD		% MODE SHIFT AWAY FROM AUTO FOR DRIVE-ALONES (SEE TABLE 10.1)		PERCENTAGE CONVERSION		Δ PARKED AUTOS DUE TO MODE SHIFT		AVG. ROUND TRIP LENGTH		FACTOR FOR CAR LEFT HOME		Δ VMT_1
	X		÷	100	=		X		X	0.6	=	

C. VMT SAVINGS - REROUTING

	Δ PARKED AUTOS IN CBD		Δ PARKED AUTOS DUE TO MODE SHIFT		AVG VMT/AUTO ELIMINATED		Δ VMT_2
(		-		) X		=	

D. VMT SAVINGS - CRUISE TIME

	AUTOS ENTERING CBD		Δ PARKED AUTOS IN CBD		Δtt CRUISING FOR SPACE (HR)		AVG. CRUISE SPEED (MPH)		Δ VMT_3
(		+		) X		X		=	

E. ENERGY SAVINGS

VMT BEFORE		Δ VMT (Σ Δ VMT_i)		VMT AFTER		FCR (GPM) (TABLE 1.1)		ADJUSTMENT FACTOR (TABLE 1.2)		DAILY SPEED RELATED ENERGY SAVINGS (GAL)
	+		=		X		X		=	

Δ VMT (Σ Δ VMT_i)		AUTO MPG TABLE 1.3)		DAILY VMT RELATED (ENERGY SAVINGS (GAL)
	÷		=	

DAILY SPEED RELATED ENERGY SAVINGS		DAILY VMT RELATED ENERGY SAVINGS		DAILY ENERGY SAVINGS		WORKDAYS PER YEAR		ANNUAL ENERGY SAVINGS
	+		=		X	250	=	

Example

The city of Washington, DC has imposed a $1.00 surcharge on all downtown facilities. The number of automobiles entering the core area during the course of a weekday is 445,201 (13). The average travel speed before the application of the charge is estimated to be 15 miles per hour. The price elasticity with respect to the number of parkers is assumed to be -.22 (5). The analysis will not include a savings resulting from decreases in search time required to find a parking space because mode shifts and parking relocation outside the CBD only amounts to about 5% total indicating that 95% of automobiles will still be parked within the CBD limits. After the surcharge imposition, average speed is 22 mph.

Limitations

The computed savings is based to a large extent on speculation of the drivers' response to pricing controls.

In the section on the rerouting of travel, two assumptions were made: (1) drivers will park closer to their homes and (2) this distance will be 1/2 mile closer to their homes. If either of these assumptions are violated, the savings will be overestimated.

Estimates of the gasoline savings as a result of decreases in search time is subject to variation. In actuality there may not be a savings. Data to assess this impact was unavailable; however, it is reasonable to assume that if mode shifts are not substantial then a savings resulting from this impact will also be small.

In light of this, the procedure should be viewed as a simplified process to allow for the assessment of the energy savings attributable to pricing strategies.

TSM
ENERGY ANALYSIS WORKSHEET

PARKING: PRICING POLICIES

A. BASE DATA

AUTOS ENTERING CBD		AVG. ROUND TRIP LENGTH		VMT BEFORE
445,201	x	16.8	=	7,479,377

AUTOS ENTERING CBD		% Δ PARKING PRICE (PP)		PERCENTAGE CONVERSION		e PP		Δ PARKED AUTOS IN CBD
445,201	x	22.2	÷	100	x	-0.22	=	-21,744

B. VMT SAVINGS - MODE SHIFT

Δ PARKED AUTOS IN CBD		% MODE SHIFT AWAY FROM AUTO FOR DRIVE-ALONES (SEE TABLE 10.1)		PERCENTAGE CONVERSION		Δ PARKED AUTOS DUE TO MODE SHIFT		AVG. ROUND TRIP LENGTH		FACTOR FOR CAR LEFT HOME		Δ VMT$_1$
21,744	x	-2.2	÷	100	=	-478	x	16.8	x	0.6	=	-4,818

C. VMT SAVINGS - REROUTING

Δ PARKED AUTOS IN CBD		Δ PARKED AUTOS DUE TO MODE SHIFT		AVG VMT/AUTO ELIMINATED		Δ VMT$_2$
(-21,744	-	-478)	x	1.0	=	-21,266

D. VMT SAVINGS - CRUISE TIME

AUTOS ENTERING CBD		Δ PARKED AUTOS IN CBD		Δtt CRUISING FOR SPACE (HR)		AVG. CRUISE SPEED (MPH)		Δ VMT$_3$
(—	+	—)	x	—	x	—	=	—

E. ENERGY SAVINGS

VMT BEFORE		Δ VMT ($\Sigma \Delta$ VMT$_1$)		VMT AFTER		FCR (GPM) (TABLE 1.1)		ADJUSTMENT FACTOR (TABLE 1.2)		DAILY SPEED RELATED ENERGY SAVINGS (GAL)
7,479,377	+	-26,084	=	7,453,293	x	-.010	x	.831	=	-61,937

Δ VMT ($\Sigma \Delta$ VMT$_1$)		AUTO MPG TABLE 1.3)		DAILY VMT RELATED (ENERGY SAVINGS (GAL)
-26,084	÷	17.7	=	-1,474

DAILY SPEED RELATED ENERGY SAVINGS		DAILY VMT RELATED ENERGY SAVINGS		DAILY ENERGY SAVINGS		WORKDAYS PER YEAR		ANNUAL ENERGY SAVINGS
61,937	+	1,474	=	63,411	x	250	=	15,852,750

10.3 Residential Parking Permit Systems

Methodology

Energy conservation resulting from the establishment of permit systems can be achieved through either mode shifts from auto to transit or through the rerouting of travel.

Data on the impacts of this strategy on commuter behavior is ascertained from an empirical study of the Alexandria, Virginia parking districts (15). The results of a telephone interview survey of commuters in this area indicated that the most likely response to this restriction is the rerouting of travel, where the auto user will attempt to avoid the problem area by parking in a different location but simultaneously trading off convenience. It was found that 76% of respondents changed their parking locations. The specific changes in parking patterns amoung respondents who formerly parked in on-street spaces are given below:

New Parking Location	Respondents %
Off street	29
On street	
In districts	20
Out of districts	20
Metered space in districts	1
Dropped off	1
No regular parking pattern	5
Total	76

Source: (15)

Twelve percent of commuters reported a change in mode and the rest continued to park within the districts changing their parking spaces frequently during the day to avoid exceeding the three hour parking limitations for nonresidents. The study concluded that the establishment of a permit system may in fact be increasing vehicle usage as a result of 20-40 percent of commuters are forced to drive more to search for a space or move their cars around.

The study did not indicate whether or not these commuters, when changing their parking location, were parking closer to their homes (which would decrease VMT) or further (expending more vehicle miles). The methodology presented assumes an optimistic approach to the establishment of a permit system from an energy perspective. It is assumed that when the rerouting of trips occur, the commuters will park closer to their homes rather than further from home and work. However, the methodology does take into account those who increase their trip lengths by extending their travel from the fringe area into the CBD and parking in higher priced facilities, thereby expending more energy than previously.

The inputs to the procedure are:

1. The number of parking spaces currently used by commuters, who will no longer be able to park in this location because of the permit system.
2. The percentage of the "displaced" users that will:
   (a) reroute and park closer to their homes
   (b) shift to an alternate mode of travel
   (c) increase their trip lengths by extending their travel into the CBD to find available parking facilities.
3. The average daily savings in miles per vehicle that a "displaced" user will contribute by parking in a different location closer to the point of origin.
4. The average daily cost in miles per vehicle that a "displaced" user will expend when driving further into the CBD to park a vehicle.
5. The number of days a year that a residential parking permit system will be effective (usually about 250 days).
6. The average annual fleet fuel efficiency (Table 1.3 may be used if necessary).
7. The average one way work trip, trip length.

The general formula is:

Energy Savings = ((Savings due to rerouters + savings from mode shifts) - the cost from those driving into the CBD to park)

The procedure is as follows:

<u>Step 1</u>: Multiply the number of spaces no longer being occupied by commuters by the percent of "displaced" users that reroute and park closer to their homes. This will yield the total number of rerouters. .

<u>Step 2</u>: Multiply the number of rerouters by the average daily savings in miles per vehicle that a rerouter will no longer travel by parking in a different location. This will yield the daily VMT eliminated by rerouters.

<u>Step 3</u>: Multiply the daily VMT eliminated by the fuel consumption rate in gallons/mile to obtain the daily gasoline savings attributable to rerouters.

<u>Step 4</u>: Multiply the number of spaces no longer being occupied by the percent shifting to an alternate mode. This will yield the total number of shifters.

<u>Step 5</u>: Multiply the number of shifters by the round trip, work trip, trip length, to obtain the daily VMT eliminated by mode shifts.

Step 6: Divide the daily VMT eliminated by the fuel consumption rate in miles/gallon to obtain the daily gasoline savings attributable to mode shift.
Step 7: Multiply the daily savings by 60% to account for the car left home factor. This will yield the true savings due to mode shifts.
Step 8: Multiply the number of spaces no longer being occupied by the percent of displaced users that will extend their trip and continue to drive into the CBD. This will yield the total number that will continue to drive into the CBD.
Step 9: Multiply the number that continue to drive into the CBD by the additional distance in miles that a "displaced" user will travel on a daily basis to find parking within the CBD. This is the additional daily VMT due to drivers extending their trips to find parking within the CBD.
Step 10: Multiply the additional VMT by the fuel consumption rate in gallons/mile to obtain the negative gasoline savings attributable to those who drive into the CBD to park, which is in fact further than the location previously parked in before the permit system.
Step 11: Add together the savings from rerouters and shifters and subtract the gasoline cost from those driving further to obtain the total daily savings attributable to the imposition of residential parking permit system.
Step 12: Multiply the daily savings by the number of days a year that a permit system will affect commuter parking. This is the total annual gasoline savings.

TSM
ENERGY ANALYSIS
WORKSHEET

PARKING: RESIDENTIAL PERMIT SYSTEMS

SPACES NO LONGER OCCUPIED BY COMMUTERS ☐

PROPORTION PARKING CLOSER TO HOME 0.6 × AVERAGE DAILY VMT SAVED PER AUTO ☐ = DAILY VMT REDUCTION, REROUTING ☐

\+

PROPORTION SHIFTING MODES 0.15 × ROUND TRIP WORK TRIP LENGTH ☐ × FACTOR FOR CAR LEFT HOME 0.6 = DAILY VMT REDUCTION, MODE SHIFT ☐

\-

PROPORTION DRIVING INTO CBD 0.25 × AVERAGE DAILY ADDITIONAL VMT PER AUTO ☐ = DAILY VMT INCREASE, CBD PARKING ☐

☐ DAILY VMT REDUCTION

DAILY VMT REDUCTION ☐ ÷ AUTO MPG (TABLE 1.3) ☐ = DAILY ENERGY SAVINGS (GAL) ☐ × WORKDAYS PER YEAR 250 = ANNUAL ENERGY SAVINGS (GAL) ☐

Example

The procedure to compute the total savings is best illustrated in the following example given from source (5). This is a very simplified procedure for determining the accrued energy savings. Suppose there are 500 parking spaces currently utilized by auto commuters who could not do so if a parking permit system were imposed. The drivers of the 500 cars might respond as follows: 60% would park in a different location, presumably one farther from the CBD but closer to their homes. It is plausible that on the average this location would be 1/2 mile closer to their homes. Thus, if the cars had a fuel efficiency of 16.5 mpg in 1979, they would consume .0606 gallons/mile and the daily savings by those people would be 500 x 60% x (1/2 + 1/2) mile x .0606 gallons/miles = 18.18 gallons.

It is also reasonable that approximately 25% of the people or 125 would drive to the CBD. If the CBD was 1/2 mile from the area where the auto drivers were currently parked, there would be an energy cost because of the additional VMT. The daily cost would be 125 x (1/2 + 1/2) x .0606 gallons/mile = 7.58 gallons.

Finally, 15% of the cars (75) will presumably not be used as the driver and passengers divert to transit. If, for example, the one-way work trip is 5 miles long, the daily energy savings would be 75 x 10 miles x .0606 gallons/mile = 45.45. After taking the car left home into account, the daily energy savings would be 27.27 Adding up the net effect of all 3 groups we obtain a daily figure for 500 spaces filled with cars of 18.18 -7.58 + 27.27 = 37.9 gallons. Thus, the yearly savings would be 250 business days x 37.9 gallons/day = 9,470 gallons.

TSM
ENERGY ANALYSIS WORKSHEET

PARKING: RESIDENTIAL PERMIT SYSTEMS

SPACES NO LONGER OCCUPIED BY COMMUTERS: 500

PROPORTION PARKING CLOSER TO HOME: 0.6 x AVERAGE DAILY VMT SAVED PER AUTO: 1.0 = DAILY VMT REDUCTION, REROUTING: 300

+

PROPORTION SHIFTING MODES: 0.15 x ROUND TRIP WORK TRIP LENGTH: 10.0 FACTOR FOR CAR LEFT HOME: 0.6 = DAILY VMT REDUCTION, MODE SHIFT: 450

-

PROPORTION DRIVING INTO CBD: 0.25 x AVERAGE DAILY ADDITIONAL VMT PER AUTO: 1.0 = DAILY VMT INCREASE, CBD PARKING: 125

DAILY VMT REDUCTION: 625

DAILY VMT REDUCTION: 625 AUTO MPG (TABLE 1.3): 16.5 = DAILY ENERGY SAVINGS (GAL): 37.9 x WORKDAYS PER YEAR: 250 = ANNUAL ENERGY SAVINGS (GAL): 9,470

Limitations

The procedure has limited accuracy in the respect that the results are dependent on estimates of the behavioral response of the "displaced" commuters. The two key assumptions concern what impact a permit system will have on those no longer able to park within the restricted neighborhood and the corresponding estimation of the eliminated VMT by these drivers. It is clear that although this procedure optimistically assumes that this action will save energy, the reverse could conceivably by true, providing that those "displaced" drivers increase their VMT in order to find parking spaces. Without available data this procedure will merely be an estimate of the actual energy impact of this action.

References

1. John F. DiRenzo, Bart Cima, and Edward Barber, "Study of Parking Management Tactics Volume 2: Overview and Case Studies," Peat, Marwick, Mitchell and Co., prepared for the Federal Highway Administration, Report No. FHWA-PL-79-021, December 1979.
2. Raymond H. Ellis, "Parking Management Strategies," in Transportation System Management, Transportation Research Board Special Report 172, The National Academy of Sciences, 1977.
3. Barbara Ibarra Keyani, Evelyn S. Putnam, "Transportation System Management: State of the Art," Interplan Corporation, prepared for the Office of Policy and Program Development, UMTA, September 1976.
4. Charles M. Abrams, John F. DiRenzo, "Measures of Effectiveness for Multimodal Urban Traffic Management Volume 2: Development and Evaluation of TSM Strategies," JHK and Associates/Peat, Marwick, Mitchell and Company, prepared for the Office of Research and Development, FHWA, USDOT, Report No. FHWA-RD-79-113, December 1979.
5. Janis Gross, Daniel Boyle, Gerald Cohen, Nathan Erlbaum, Michael Kocis, Peter Koeppel, "Energy Impacts of Transportation Systems Management Actions in New York State, 1978-80," New York State Department of Transportation, Preliminary Research Report 151, May 1979.
6. "Carpool Incentives: Analysis of Transportation and Energy Impacts," The Federal Energy Administration, Report No. FEA/D-76/391, June 1976.
7. Harry S. Cohen, Joseph R. Stowers, Michael P. Petersilia, "Evaluating Urban Transportation System Alternatives," System Design Concepts, Inc., prepared for the Office of the Assistant Secretary for Policy and International Affairs, USDOT, Report No. DOT-P-30-78-44, November 1978.
8. "Urban Transportation Energy Conservation, Case City Applications of Analysis Methodologies Volume III," Cambridge Systematics, Inc., prepared for the U.S. Department of Energy, September 1978.
9. "Transportation Air Quality Analysis - Sketch Planning Methods, Volume I: Analysis Methods," Cambridge Systematics, Inc., prepared for the Office of Transportation and Land Use Policy, Envionmental Protection Agency, Report No. EPA 400/1-800-001a, December 1979.
10. "Evaluating Options in Statewide Transportation Planning Programming, Techniques and Appliations," Planning Environment International and System Design Concepts, Inc., NCHRP Report 199, March 1979.
11. "A Directory of Regularly Scheduled, Fixed Route, Local Public Transportation Service in Urbanized Areas Over 50,000 Population", USDOT, UMTA, August 1980.
12. Nathan S. Erlbaum, David T. Hartgen, and Gerald S. Cohen, "NYS Gasoline Use: Impact on Supply Restrictions and Embargoes," New York State Department of Transportation, Preliminary Research Report 142, August 1978.
13. Phone Conversation with John Williams of the Transportation Planning Board, Metropolitan Washington Council of Governments.

14. Richard H. Pratt, Neil J. Pedersen, Joseph J. Mather," Traveler Response to Transportation Systems Changes - A Handbook for Transportation Planners," R.H. Pratt Associates, Inc., prepared for USDOT, FHWA, February 1977.
15. Marie L. Olsson and Gerald K. Miller, "Impacts on Commuters of a Residential Parking - Permit Program in Alexandria, Virginia," Transportation Research Record 786, Parking, 1980.

11. Work Hour Policies

Work schedule strategies are included in the area of transportation systems management actions fulfilling the objectives under two categories: "Actions which insure efficient use of road space"; and "Actions which reduce vehicle use in congested areas". They intend to reduce congestion from major employment centers during the peak travel hours by increasing the time span in which commuting occurs (in effect, flattening out the peak) and ultimately contributing to energy conservation.

There are two distinct forms of alternate work schedules:

- Staggered Work Hours/Flextime
- Four Day Compressed Workweek

Staggered hours pertain to an adjustment of fixed schedules of beginning and ending hours away from the standard hours. Flextime, similarly, is a strategy in which the employees decide on their own start and finish times and are only limited in the respect that they must work a specified number of hours within a given time period and must be present during certain core hours (usually 10 a.m. to 3 p.m.). These two tactics have been grouped together because of their similar impacts and intentions. (1,2,3,4)

The four-day compressed workweek is a shortened week, converting from a eight-hour, five-day week schedule to a ten-hour, four-day week schedule. The principal objective of implementation is a reduction in total work trips, hence alleviating congestion problems and possibly vehicle miles of travel. This action is somewhat less popular and currently not as widely used as the staggered or flextime work schedules (1,2,3,4).

Impacts

The energy implications of these actions are realized by the potential impacts that the tactics have on two travel parameters - vehicle miles of travel and travel speed. The principal aim of staggered work hours and flextime is the reduction of the congestion during peak hours resulting in an increase in traffic speed for both participants and nonparticipants leading to an increase in energy efficiency. It is the purpose of this study to provide a simple procedure to assess the energy savings attributable to the implementation of work hour rescheduling for the network-wide system.

The compressed work schedule allows for a reduction of the number of daily work trips, affecting total VMT. If a reduction in VMT occurs, then a reduction in fuel consumption will follow. However, there is an offsetting factor which is the additional travel that is done due to a car left home for an additional day of the week. This factor is difficult to assess and not considered in this analysis. Discretionary travel that will result from a compressed workweek could be substantial, because this extra day a week (particularly if on a Friday or Monday) will give rise to additional social and recreational travel. Individuals conceivably could actually increase their total non-work vehicle miles of travel. The particular effects of this factor are yet inconclusive and lend themselves to further studies. One such study on the Denver Federal Employee Compressed Work Week (5) concludes that, contrary to earlier expectations that any decrease in work travel resulting from compressed work schedules would be offset to some extent by an increase in non-work travel, non-work travel, too, appears to have decreased. In light of this, the results should be viewed with caution.

An additional savings will accrue as a result of increased travel speed. Reduced VMT during the peak hours of travel will benefit non-participants by reducing congestion, hence increasing travel speeds during this period. Furthermore, it is likely that those participating will shift both their starting and finishing times to somewhere outside the peak due to the lengthening of the work day (from 8 hours to 10 hours). This will result in furthering gasoline savings for those now travelling in the off-peak at an increased rate of speed.

Methodology

The methodology involved in assessing the energy savings corresponding to the implementation of work schedules has been developed separately for staggered work hours/flextime and the compressed work-week. The initial inputs for the procedures can be divided into three groups consisting of the individual inputs of the specific area, travel parameters, and constants which are given. In all cases if data for the individual locality is available it should be used. Default values are included for those localities for which data is not available. The procedure itself makes a number of assumptions which are important to note. The journey-to-work trip is the only trip purpose taken into consideration. It is assumed that the most significant energy savings will result from the impacts that these actions have on automobile travel. Additionally it should be noted that all of these work trips occur during the peak period hours of the day (between 7-9 a.m. and 4-6 p.m.). Furthermore, it is assumed that there will not be a shift in modes.

The Data Necessary for the Analysis is Indicated Below:

A. Individual site specific - there are five values that must be used in this methodology. They are:

1. Population of the area.
2. Site-specific employment figure for the particular establishment being analyzed.
3. Number of employees participating in the work schedule program.

4. Average peak period speed before any program has been established.
5. Average speed outside the peak period.

B. Travel Parameters - these figures may be looked up in Tables 1.1, 1.2, 11.1, if no other information is available.

1. Trip length (Table 11.1).
2. Fuel consumption in gallons/mile for constant speeds (Table 1.1).
3. Adjustment factor for changes in auto fuel economy by year (Table 1.2).

C. Constants - to be used if no other local data is available.

1. The percent of auto drivers for work trips = 79.2% (6).
2. The number of work days in a year for the workweek consisting of 5 days, 8 hours/day minus vacations is 250 (50 x 5). Taking into account two trips per day (from home to work, from work to home) there are 500 trips made a year.
3. For the compressed workweek only 400 trips are made a year (50 x 4 x 2).

The procedure used to analyze the energy savings attributed to work hour policies is segmented into two separate areas of analysis, the computation of (1) the gasoline consumption before the implementation of any action (this will be the same for both staggered/flextime polices and the compressed workweek and (2) the gasoline consumption after the implementation of an action (the procedure to estimate the amount of consumption will vary for staggered/flextime hours and the compressed workweek). After these two factors have been estimated a total energy savings may be assessed by simply subtracting the After from the Before consumption

The procedure to calculate the gasoline consumption BEFORE the implementation of any action is:

Step 1: Multiply the proportion of work trips by automobile in urban areas x the average one-way work trip length x the employment figure to obtain the total daily one-way vehicle miles travelled between home and work in an urban area during the peak hours of travel.
Step 2: Multiply the daily peak perid VMT by the number of worktrips a year that are made by each employee to obtain the total annual VMT. (500 trips/year).
Step 3: Multiply the annual VMT by the average automobile fuel consumption rate in gallon per mile for an automobile traveling at the average peak period speed before action implementation. This yields the total number of gallons of gasoline consumed before the implementation of any work hour policy.

The procedure to calculate the gasoline consumption AFTER the im- of the COMPRESSED workweek and the energy savings attributable to this action:

Step 1: Subtract the number of participants from the total employment figure to obtain the number of employees who are not participating.
Step 2: Calculate the daily peak period VMT for those not participating by multiplying the number of employees not participating x the proportion of work trips by automobiles x average one-way, work trip length.
Step 3: Multiply the daily peak period VMT by 500 trips a year (which is the number of work trips a year that those not participating will make). This is the total annual VMT by those not participating.
Step 4: Multiply the annual VMT by the fuel consumption rate corresponding to the average travel speed after a compressed workweek has been initiated to obtain the total number of gallons of gasoline consumed annually by those not participating in the program.
Step 5: Calculate the daily off-peak hour VMT for those participating by multiplying the number of employees participating x the proportion of work trips by automobiles x the average one-way work trip length.
Step 6: Multiply the daily off-peak hour VMT by 400 trips a year (which is the number of work trips a year that those participating will make). This is the total annual VMT by those participating.
Step 7: Multiply the annual VMT by the fuel consumption rate corresponding to the "off-peak" speed to obtain the total number of gallons of gasoline consumed annually by those participating in the program.
Step 8: Add together the number of gallons of gasoline consumed by non-participants and the number of gallons consumed by participants to obtain the total number of gallons consumed after the implementation of a compressed workweek.
Step 9: Subtract the number of gallons consumed after from the number of gallons consumed before to obtain the total number of gallons of gasoline saved annually by implementing the compressed workweek.
Step 10: Multiply this savings by the appropriate annual adjustment factor to adjust for changes in auto fuel economy. This will yield the total adjusted savings.

The procedure to calculate the gasoline consumption AFTER the implementation of either staggered or flextime work schedules and the associated energy savings:

Step 1: Calculate the annual peak period VMT for employees not participating using the same procedure as for Step 2 and Step 3 in the "After compressed workweek" calculation.

Step 2: Multiply the annual peak period VMT for these employees by the fuel consumption rate corresponding to the "after" implementation speed to obtain the total number of gallons of gasoline consumed annually after the implementation of either staggered or flextime work hours during the peak.
Step 3: Calculate the daily off-peak period VMT for those participating by multiplying the number of employees participating x the proportion of work trips by automobiles x the average one-way trip length.
Step 4: Multiply the daily off-peak period VMT by 500 trips a year. This is the annual VMT occuring outside the peak period.
Step 5: Multiply the annual off-peak VMT by the fuel consumption rate corresponding to the "off-peak" speed to obtain the total number of gallons of gasoline consumed annually during the off-peak hours by those participating.
Step 6: Add together the number of gallons consumed annually by those not participating to the number of gallons consumed by the participants. This is the total annual gasoline consumption after the implementation of either staggered work hours or flextime.
Step 7: Subtract the number of gallons consumed after from the number of gallons consumed before to obtain the total number of gallons of gasoline saved annually by implementing staggered work hours or flextime.
Step 8: Adjust this savings by multiplying it by the appropriate annual adjustment factor to adjust for changes in the auto fuel economy. This will yield the total adjusted savings.

TSM
ENERGY ANALYSIS
WORKSHEET

WORK HOUR POLICIES

A. BASE DATA

EMPLOYMENT		PROPORTION DRIVING AUTOS		1-WAY TRIP LENGTH (TABLE 11.1)		WORK TRIPS PER YEAR		FCR, PEAK BEFORE (TABLE 1.1)		UNADJUSTED ANNUAL GASOLINE CONSUMPTION BEFORE (GAL)
	x	.792	x		x		x		=	

PEAK SPEED, BEFORE (MPH)		ADJUSTMENT FACTOR		PEAK SPEED, AFTER (MPH)		OFF PEAK SPEED (MPH)
	x	1.0025	=			

	EMPLOYMENT		# PARTICIPANTS IN GIVEN WORK-HOUR PROGRAM			PROPORTION DRIVING AUTOS		1-WAY TRIP LENGTH (TABLE 11.1)		WORK TRIPS PER YEAR		FCR, PEAK AFTER (TABLE 1.1)		UNADJUSTED ANNUAL FUEL CONSUMPTION NON-PARTICIPANTS (GAL)
(		-		)	x	.792	x		x	500	x		=	

B. COMPRESSED WORK WEEK

# PARTICIPANTS		PROPORTION DRIVING AUTOS		1-WAY TRIP LENGTH (TABLE 11.1)		WORK TRIPS PER YEAR, AFTER		FCR OFF PEAK (TABLE 1.1)		UNADJUSTED ANNUAL FUEL CONSUMPTION, CWW PARTICIPANTS
	x	.792	x		x	400	x		=	

C. STAGGERED HOURS/FLEXTIME

# PARTICIPANTS		PROPORTION DRIVING AUTOS		1-WAY TRIP LENGTH (TABLE 11.1)		WORK TRIPS PER YEAR, AFTER		FCR OFF PEAK (TABLE 1.1)		UNADJUSTED ANNUAL FUEL CONSUMPTION, SH/F PARTICIPANTS
	x	.792	x		x	500	x		=	

D. ENERGY SAVINGS

ANNUAL FUEL CONSUMPTION BEFORE			ANNUAL FUEL CONSUMPTION, CWW NON-PARTICIPANTS		ANNUAL FUEL CONSUMPTION, CWW PARTICIPANTS			FUEL ECONOMY ADJUSTMENT (TABLE 1.2)		ANNUAL ENERGY SAVINGS FROM COMPRESSED WORK WEEK
	-	(		+		)	x		=	

ANNUAL FUEL CONSUMPTION, BEFORE			ANNUAL FUEL CONSUMPTION, SH/F NON-PARTICIPANTS		ANNUAL FUEL CONSUMPTION, SH/F PARTICIPANTS			FUEL ECONOMY ADJUSTMENT (TABLE 1.2)		ANNUAL ENERGY SAVINGS FROM STAGGERED HOURS/FLEXTIME
	-	(		+		)	x		=	

Table 11.1

Mean Trip Length for Various Population Sizes

Population Size	Average Trip Length (Miles)
SMSA > 1.3 million	7.85
750,000-1,299,999	7.28
<750,000	6.30
Small Urban 1,000-2,500	11.70
Rural areas 1,000	14.50

Source: (6)

Example

A very large employer (New York State Office Campus in Albany, New York, with approximately 10,000 employees) introduces a staggered work hour policy which results in a net shift of 584 passenger vehicle trips to outside the peak hour. The network's "before" peak hour speed is 18.5 mph and its off-peak hour speed is 28.3 mph. (1).

TSM
ENERGY ANALYSIS
WORKSHEET

WORK HOUR POLICIES

A. BASE DATA

EMPLOYMENT		PROPORTION DRIVING AUTOS		1-WAY TRIP LENGTH (TABLE 11.1)		WORK TRIPS PER YEAR		FCR, PEAK BEFORE (TABLE 1.1)		UNADJUSTED ANNUAL GASOLINE CONSUMPTION BEFORE (GAL)
10,000	x	.792	x	6.30	x	500	x	.054	=	1,347,192

PEAK SPEED, BEFORE (MPH)		ADJUSTMENT FACTOR		PEAK SPEED, AFTER (MPH)		OFF PEAK SPEED (MPH)
18.5	x	1.0025	=	18.55		26.3

(	EMPLOYMENT		# PARTICIPANTS IN GIVEN WORK-HOUR PROGRAM	)		PROPORTION DRIVING AUTOS		1-WAY TRIP LENGTH (TABLE 11.1)		WORK TRIPS PER YEAR		FCR, PEAK AFTER (TABLE 1.1)	UNADJUSTED ANNUAL FUEL CONSUMPTION, NON-PARTICIPANTS (GAL)
(	10,000	-	584	)	x	.792	x	6.30	x	500	x	.053	= 1,245,025

B. COMPRESSED WORK WEEK

# PARTICIPANTS		PROPORTION DRIVING AUTOS		1-WAY TRIP LENGTH (TABLE 11.1)		WORK TRIPS PER YEAR, AFTER		FCR OFF PEAK (TABLE 1.1)		UNADJUSTED ANNUAL FUEL CONSUMPTION, CWW PARTICIPANTS
584	x	.792	x	6.30	x	400	x	.044	=	51,285

C. STAGGERED HOURS/FLEXTIME

# PARTICIPANTS		PROPORTION DRIVING AUTOS		1-WAY TRIP LENGTH (TABLE 11.1)		WORK TRIPS PER YEAR, AFTER		FCR OFF PEAK (TABLE 1.1)		UNADJUSTED ANNUAL FUEL CONSUMPTION, SH/F PARTICIPANTS
584	x	.792	x	6.30	x	500	x	.044	=	64,106

D. ENERGY SAVINGS

ANNUAL FUEL CONSUMPTION BEFORE		(	ANNUAL FUEL CONSUMPTION, CWW NON-PARTICIPANTS		ANNUAL FUEL CONSUMPTION, CWW PARTICIPANTS	)		FUEL ECONOMY ADJUSTMENT (TABLE 1.2)		ANNUAL ENERGY SAVINGS FROM COMPRESSED WORK WEEK
1,347,192	-	(	1,245,025	+	51,285	)	x	.831	=	42,283
ANNUAL FUEL CONSUMPTION, BEFORE		(	ANNUAL FUEL CONSUMPTION, SH/F NON-PARTICIPANTS		ANNUAL FUEL CONSUMPTION, SH/F PARTICIPANTS	)		FUEL ECONOMY ADJUSTMENT (TABLE 1.2)		ANNUAL ENERGY SAVINGS FROM STAGGERED HOURS/FLEXTIME
1,347,192	-	(	1,245,025	+	64,106	)	x	.831	=	31,629

Limitations

It shoud be emphasized that the conclusions drawn from the results of this methodology may be an overestimation. The previous example indicates that the establishment of a compressed workweek will save a greater number of gallons of gasoline than will either staggered hours or flextime. In theory this is a reasonable conclusion based on the fact that the compressed schedule will conserve energy in two respects: VMT reductions and a speed related savings, whereas staggered or flextime hours will only reduce consumption through speed increases. However, the effect of incremental travel done by those enjoying an additional day off (if in fact there is any) is not considered. In conclusion, the implementation of either staggered hours or flextime may in fact save as much energy as the compressed work schedule, depending on the travel behavior of individuals on their day off.

References

1. Barbara Ibarra Keyani, Evelyn S. Putnam, "Transportation Systems Management: State of the Art," Interplan Corporation, prepared for the Office of Policy and Program Development UMTA, USDOT, September 1976.
2. R.H. Pratt Associates, "Traveler Response to Transportation System Changes," prepared for USDOT, February 1977.
3. David W. Jones, Takuya Nakamoto, Matthys P. Cilliers, "Flexible Work Hours: Implications for Travel Behavior and Transport Investment Policy," Institute of Transportation Studies, prepared for USDOT Research and Special Programs Administration Report No. DOT/RSPA/DPB-50/78/29, December 1978.
4. Charles M. Abrams and John F. DiRenzo, "Measures of Effectiveness for Multimodal Urban Traffic Management - Appendix A," JHK and Associates and Peat, Marwick, Mitchell and Co., prepared for the Offices of Research and Development FHWA, USDOT Report No. FHWA-RD-79-113, December 1979.
5. Cambridge Systematics, "Denver Federal Employee Compressed Work Week Experiment: Evaluation of Transportation-Related Impacts," prepared for Denver Regional Council of Governments, September 1980.
6. U.S. Bureau of the Census "The Journey to Work in the United States: 1975", Special Studies No. 99, Current Population Reports, July 1979.
7. J. Gross, D. Boyle, G. Cohen, N. Erlbaum, M. Kocis, P. Koeppel, "Energy Impacts of Transportation Systems Management Actions in New York State, 1978-1980," Preliminary Research Report No. 151, New York State Department of Transportation, May 1979.

12. Urban Goods Movement

In 1978 an estimated $219 billion was expended on freight movement in the United States. 47% ($103 billion) was spent on long haul intercity shipping and 53% ($116 billion) on intracity Urban Goods Movement. Local trucking of urban goods used $100 billion of this total (1).

Urban goods movement is dominated by private trucking. Two thirds of the trucks used are under 10,000 pounds gross vehicle weight and 75% are gasoline powered. Most company fleets are small; only 5% have over 20 vehicles. (1).

A review of a typical truck trip will indicate areas where transportation systems management actions can improve urban goods movement. Pick up and delivery (PUD) activities include four specific elements: (1)

Terminal Activities - preparation of shipments, loading, transfer, etc.
Stem Driving - vehicle movement on the surface street system from the terminal to the delivery "zone" where the transfer of consignments will occur.
Zone Driving - vehicle movement within the delivery area.
Stop or Dwell Time Activities - Activities involved at shipping destination.

TSM actions can be implemented to improve traffic flow during stem driving and zone driving. In addition, actions can be pursued to improve terminal and dwell time activities to facilitate traffic flow on adjacent streets.

Table 12.1 presents several specific problems associated with goods movement as related to the surface street system. Table 12.2 suggests some TSM actions that can be used to ameliorate these problems. Four improvement areas are outlined: traffic flow improvements, curb use management, operational improvements and roads with restricted use.

Table 12.1

Characteristics of the Surface Street System Contributing to Urban Goods Movement Problems

Elements	Factors Contributing to Problems
Characteristics of Network en route to zone (stem driving and zone driving impacted)	. Street System Layout, Design and Capacity . Traffic Control Devices . Overhead and Ground Obstacles to Trucking
Characteristics of Transportation system at the shipping and receiving point (Terminal and Dwell Time Activities Impacted)	. Inadequate Off Street Loading . Inadequate Design and Access to Off-Street Loading Facilities . Inadequate On-Street Loading Facilities . Physical Obstacles to Loading

Source: University of Tennessee (2).

Table 12.2

Selected TSM Improvements for Urban Goods Movement

Types	Examples
General Traffic Flow Improvements	. Physical Street Improvements . One-Way Streets . Traffic Signal Improvements . Intersection Improvements
Curb Use Management	. Peak Period Curb Parking Prohibitions . Designate Curb Loading Areas . Off-Street Loading
Operational and Physical	. Vertical Clearance and Weight Restrictions . Remove Roadside Obstacles . Median Width Expansion
Roads with Restricted Use	. Truck Only . Truck Routes . Truck Restrictions

Energy Use by Urban Goods Movement

It has been estimated that urban goods movement consumes 6% of the total energy used by transportation (1). In addition, the presence of trucks in the traffic stream may account for an increase in auto fuel consumption of 650 million gallons per year (1).

Energy impact analysis for TSM improvements can be designed to evaluate the direct energy impact to vehicles involved in goods movement or the direct impact on energy consumption of the general traffic stream which is influenced by goods movement activities. Examples of the former include roads with restricted use and operational improvements. Examples of the latter include curb use management strategies and general traffic engineering improvements.

Suggested Impact Analysis Methodology

The following discussion presents an outline of analysis strategies that can be used to evaluate the energy impact of TSM strategies for urban goods movement. All categories of improvement are presented along with a framework for analysis.

General Traffic Flow Improvements

General traffic engineering projects provide improved service to both autos and trucks. Improvements in roadway elements that are implemented in areas of high urban goods movement activity (i.e. high truck volumes) can, indirectly, result in added efficiency to pick up and delivery activity.

In Section 2, (Traffic Engineering) of this handbook, energy analysis methods for traffic engineering projects are described. In this section, trucks are treated explicitly. These methods can be used, therefore, to describe the impact on urban goods movement for general traffic engineering improvements. This should provide a reasonable project level estimate of energy savings. The reader is referred to Section 2 for more details.

Operational and Physical Constraints

The scale of these projects is so small that it is unlikely that the energy impact will be great. No specific analysis method is suggested for these projects. Each improvement requires an individualized approach tailored to the type of improvement.

Important variables to consider include volume, speed, trip lengths and vehicle mix.

For example, to assess the energy impact of height restrictions, data concerning number of trucks diverted, trip lengths and average speed can be used to determine the excess energy consumed by vehicles that must use alternate routes.

Curb Use Management

One of the most common problems associated with pick up and delivery activities is the double parking of vehicles. This can impact the flow of the general traffic stream by reducing the capacity of the street. Double parking typically occurs along urban arterials on the fringe of downtown or directly in the CBD. Habib (3) has suggested an approach to evaluating the impact on traffic speed resulting from double parking incidents. Given information concerning the number of deliveries per hour, street type, and demand volume on the arterial, estimates of the reduction in speed to the general traffic stream can be made. This knowledge, in turn, can be used to determine the impact on energy consumption.

Instructions for Worksheet

Step 1: Identify arterial operation; one-way or two-way.
Step 2: Identify block length, in miles.
Step 3: Identify direction.
Step 4: Demand volume, total for each direction, in vehicles per hour of green (VPHG).
Step 5: Number of travel lanes in each direction. The procedure is developed for arterials with at least two lanes in each direction.
Step 6: Divide Step 4 by Step 5 to find vehicles per hour of green per lane (VPHGPL).
Step 7: From Figure 12.1 and the VPHGPL demand find the speed, MPH, that would be expected over the block with no pick up and delivery (PUD) activity.
Step 8: Identify the number of PUD's per hour on the blockface. This includes both sides on one-way streets but only one side on two-way streets.
Step 9: Enter Table 12.3 (one-way) or Table 12.4 (two-way) with the number of PUD's per hour and the demand (VPHGPL) to find the speed reduction in MPH from the "no blockface" speed (Step 7) that results from PUD activity.
Step 10: Subtract Step 7 from Step 9 to find the adjusted speed (MPH) that is a result of PUD activity.
Step 11: Estimate travel time rate in minutes per mile over the block from the unadjusted speed in Step 7.

$$\text{Travel time in minutes per mile} = \frac{1}{(\text{Speed})} \text{ X } (60)$$

Step 12: Estimate revised speed in minutes per mile from Step 10.
Step 13: From the formula:

$$\text{FCR} = .0425 + .01(\text{E}) \quad \text{Wagner (4)}$$

where FCR = Fuel consumption rate in gallons per mile,
E = Travel time rate (Step 11),

find the fuel consumption rate in gallons per mile with no blockage.

Step 14: Find the fuel consumption rate (Gallons per mile) resulting from the PUD activity, using the speed from Step 10.
Step 15: Find the fuel consumed over the block with no PUD activity (Step 13 x Step 2) gallons.
Step 16: Find revised fuel consumption, gallons, over the block (Step 14 x Step 2).
Step 17: Estimate the difference in fuel consumption, over the block resulting from PUD activity (Step 16-Step 15).
Step 18: Multiply the fuel consumption (Step 17) by demand volume for the analysis period (Step 4) to find the total excess fuel consumed over the block resulting from the PUD activity.
Step 19: Multiply the total excess fuel consumed per analysis period (typically one hour) by the number of analysis periods per day to find total daily excess fuel consumed.
Step 20: Multiply Step 19 by 250 to find yearly excess fuel consumption.
Step 21: From Table 1.2 find the adjustment factor corresponding to the analysis period to account for improvement in fuel economy. Since most of traffic is comprised of autos this adjustment factor should provide a reasonable estimate of savings.
Step 22: Multiply Step 20 by Step 21 to find adjusted yearly excess fuel consumption, gallons.

TSM
ENERGY ANALYSIS
WORKSHEET

URBAN GOODS MOVEMENT: CURB USE MANAGEMENT

A. BASE DATA

DEMAND VOLUME		NO. LANES		DEMAND VOL. VPHG/LN	DOUBLE PKG. VEH/HR	BLOCK LENGTH (MI)
	÷		=			

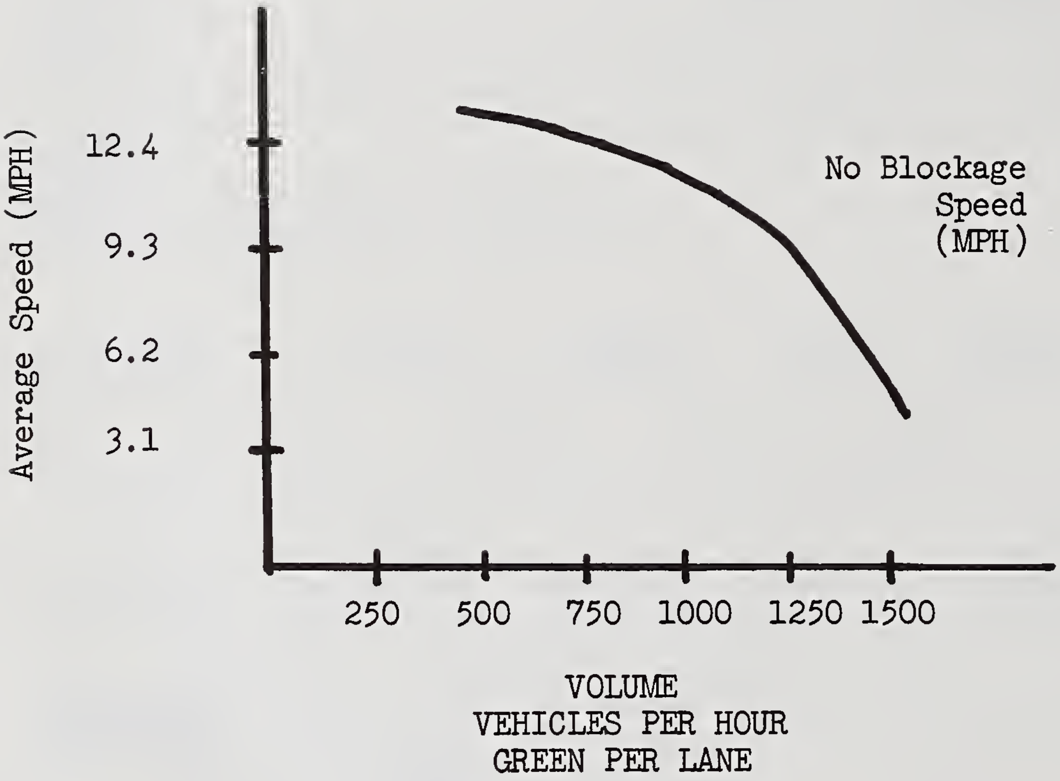
NO BLKG. SPEED (MPH) (FIGURE 12.1)		SPEED REDUCTION (TABLE 12.3 OR 12.4)		REVISED SPEED (MPH)
	–		=	

B. FUEL CONSUMPTION

		REVISED TRAVEL RATE		GALLONS PER MILE		BLOCK LENGTH (MI)		DEMAND VOL.		FUEL CONSUMPTION (GAL)
.0425 + .01	x		=		X		X		=	
									–	
		BASE TRAVEL RATE						DEMAND VOL.		
.0425 + .01	x		=		X		X		=	

EXCESS FUEL/DAY		
FUEL ECONOMY ADJ	X	
ADJUSTED EXCESS FUEL/DAY	=	
TRAVEL DAYS PER YEAR	X	
ADJUSTED EXCESS FUEL/YEAR	=	

FIGURE 12.1



SOURCE : HABIB (3)

Table 12.3

Speed Reduction for One-way Arterials For Various Level of PUD Double Parking Demand on Both Sides of the Street

Volume (Vehicles Per Hour of Green Per Lane)	Speed Reduction (MPH) By Number of PUD's Per Hour				
	6 PUDS	12 PUDS	24 PUDS	36 PUDS	48 PUDS
500	1.30	1.67	1.80	1.86	1.80
550	1.49	1.86	1.98	2.11	2.05
600	1.61	2.05	2.23	2.29	2.29
650	1.80	2.26	2.54	2.54	2.54
700	1.92	2.42	2.60	2.79	2.79
750	2.11	2.60	2.85	3.04	3.04
800	2.23	2.79	3.04	3.29	3.29
850	2.42	2.98	3.22	3.47	3.60
900	2.54	3.17	3.41	3.72	3.84
950	2.73	3.35	3.66	3.97	4.09
1000	2.91	3.41	3.66	4.03	4.22
1050	2.91	3.41	3.72	4.15	4.40
1100	2.85	3.41	3.78	4.28	4.59
1150	2.79	3.41	3.84	4.46	4.77
1200	2.79	3.41	3.84	4.59	5.02
1250	2.73	3.41	3.91	4.71	5.21
1300	2.67	3.41	3.97	4.84	5.39
1350	2.67	3.41	4.03	5.02	5.58
1400	2.60	3.41	4.01	5.10	5.77

Source: Habib (3).

Table 12.4

Speed Reduction for Two-Way Arterials for Various Levels of PUD Double Parking on One Side of the Street

Volume (Vehicles per Hour)	Speed Reduction (MPH) By Number of PUD's Per Hour				
	3 PUDs	6 PUDs	12 PUDs	18 PUDs	24 PUDs
500	.87	1.36	1.67	1.74	1.74
550	.99	1.49	1.86	1.98	1.98
600	1.12	1.67	2.11	2.23	2.23
650	1.18	1.80	2.29	2.42	2.48
700	1.30	1.98	2.48	2.67	2.73
750	1.43	2.11	2.67	2.91	2.98
800	1.49	2.23	2.85	3.10	3.22
850	1.61	2.42	3.10	3.35	3.47
900	1.74	2.54	3.29	3.60	3.72
950	1.80	2.73	3.47	3.78	3.97
1000	2.05	2.98	3.72	3.97	4.15
1050	1.98	2.91	3.72	4.09	4.34
1100	1.92	2.85	3.72	4.15	4.53
1150	1.86	2.79	3.72	4.28	4.65
1200	1.80	2.73	3.72	4.34	4.84
1250	1.80	2.67	3.72	4.46	4.96
1300	1.74	2.60	3.72	4.53	5.15
1350	1.61	2.54	3.78	4.59	5.33
1400	1.55	2.48	3.78	4.71	5.46

Source: Habib (3)

<u>Example</u>

An urban radial arterial on the fringe of downtown currently experiences a number of double parking violations because of insufficient curb space for deliveries. Given the base data outlined below, find the excess fuel consumed from the pick up and delivery activities.

<u>Data Base</u>

4 Lane urban arterial
0.09 mile block length
A.M. peak hour
Demand 3,200 vehicles per hour green
Pick up and delivery
Activity per hour 18 each side

TSM
ENERGY ANALYSIS
WORKSHEET

URBAN GOODS MOVEMENT: CURB USE MANAGEMENT

A. BASE DATA AM PEAK - BOTH DIRECTIONS

DEMAND VOLUME		NO. LANES		DEMAND VOL. VPHG/LN	DOUBLE PKG. VEH/HR	BLOCK LENGTH (MI)
3,200	÷	4	=	800	18	.09

NO BLKG. SPEED (MPH) (FIGURE 12.1)		SPEED REDUCTION (TABLE 12.3 OR 12.4)		REVISED SPEED (MPH)
12.4	–	3.1	=	9.3

B. FUEL CONSUMPTION

		REVISED TRAVEL RATE		GALLONS PER MILE		BLOCK LENGTH (MI)		DEMAND VOL.		FUEL CONSUMPTION (GAL)
.0425 + .01	x	6.45	=	.107	x	.09	x	3,200	=	30.8
		BASE TRAVEL RATE						DEMAND VOL.		–
.0425 + .01	x	4.84	=	.091	x	.09	x	3,200	=	26.2

EXCESS FUEL/DAY		4.6
FUEL ECONOMY ADJ	x	.831
ADJUSTED EXCESS FUEL/DAY	=	3.8
TRAVEL DAYS PER YEAR	x	250
ADJUSTED EXCESS FUEL/YEAR	=	950

Results and Limitations

Application of the worksheet indicates that curb use activity along this block results in an additional 950 gallons per year of fuel consumption.

The method as outlined is designed to provide an estimate of excess fuel consumption resulting from curb use activity. This estimate presents the maximum potential impact of any curb use management which completely eliminates the influence that curb activity has on vehicle speed.

TSM
ENERGY ANALYSIS
WORKSHEET

GOODS MOVEMENT: ROUTE RESTRICTIONS

A. BASE DATA

	DEMAND VOLUME (VMT)	AVERAGE SPEED (MPH)	FCR (GPM) (TABLE 1.1)
BASE			
PROPOSED			

B. FUEL CONSUMPTION

	VMT		FCR		FUEL CONSUMPTION (GAL)
PROPOSED		X		=	
					–
BASE		X		=	

DIFFERENCE

X FUEL ECONOMY ADJ (TABLE 1.2)

= DAILY ENERGY SAVINGS

X 250 WORKDAYS PER YEAR

= ANNUAL ENERGY SAVINGS

Example

An urban residential street has been experiencing a high volume of vehicle traffic associated with trucking activity. It has been proposed that the street be restricted to auto traffic only and that a truck route around the neighborhood be designated. This route will result in an additional two miles of travel for trucks. Find the energy impact of the proposal given the base data below.

Base Data	Auto	Truck
Daily VMT on existing route (3 miles)	30,000	6,000
Average speed on existing route (MPH	25	25
Revised VMT	30,000	10,000
Revised speed	27	20

TSM ENERGY ANALYSIS WORKSHEET

GOODS MOVEMENT: ROUTE RESTRICTIONS

A. BASE DATA AUTOS

	DEMAND VOLUME (VMT)	AVERAGE SPEED (MPH)	FCR (GPM) (TABLE 1.1)
BASE	30,000	25	.045
PROPOSED	30,000	27	.044

B. FUEL CONSUMPTION

	VMT		FCR		FUEL CONSUMPTION (GAL)
PROPOSED	30,000	x	.044	=	1,320
					−
BASE	30,000	x	.045	=	1,350

-30 DIFFERENCE

x .831 FUEL ECONOMY ADJ (TABLE 1.2)

= 24.9 DAILY ENERGY SAVINGS

x 250 WORKDAYS PER YEAR

= 6,225 ANNUAL ENERGY SAVINGS

TSM
ENERGY ANALYSIS
WORKSHEET

GOODS MOVEMENT: ROUTE RESTRICTIONS

A. BASE DATA TRUCKS

	DEMAND VOLUME (VMT)	AVERAGE SPEED (MPH)	FCR (GPM) (TABLE 1.1)
BASE	6,000	25	.100
PROPOSED	10,000	20	.112

B. FUEL CONSUMPTION

	VMT		FCR		FUEL CONSUMPTION (GAL)
PROPOSED	10,000	X	.112	=	1,120
				–	
BASE	6,000	X	.100	=	600

520 DIFFERENCE

X — FUEL ECONOMY ADJ (TABLE 1.2)

= 520 DAILY ENERGY ~~SAVINGS~~ COSTS

X 250 WORKDAYS PER YEAR

= 130,000 ANNUAL ENERGY ~~SAVINGS~~ COSTS

Results and Limitations

Since auto traffic is only minimally impacted, then auto fuel consumption can be ignored. The results indicate that the route will use an additional 130,000 gallons of fuel per year.

The procedure is very general. The analyst must apply a great deal of judgement to tailor the outline to fit specific need. A more detailed analysis of speed and volume relationships can be conducted if desired.

References

1. Christiansen, Dennis F., Urban Transportation Planning For Goods and Services, prepared for FHWA by Texas Transportation Institute, College Station, Texas, 1979.
2. University of Tennessee, Planning for Urban Goods Movement, prepared for FHWA, April 1977.
3. Habib, Philip A., "Effect of On-Street Pick Up and Delivery on Level of Service of Arterial Streets", Record 772, Transportation Research Board, Washington, DC, 1980.
4. Wagner, Fredrick J., Traffic Control System Improvements: Impacts and Costs, prepared for FHWA, U.S. Department of Transportation, Washington, DC, 1980.

13. Pricing Actions

Two separate pricing actions are examined in this section: peak period congestion pricing and transit fare policies. The former includes such programs as road toll pricing and supplemental or area licensing. The latter includes such actions as reductions in transit fares, peak and off peak fare structures, and reduced fares for special groups such as the elderly and handicapped.

The pricing actions described in this section are designed to encourage reductions in vehicle miles of travel through mode shifts. The energy analysis methods presented provide short range estimates of VMT reductions through the use of demand elasticities. Default elasticity estimates are provided where required. In all cases, local estimates should be used when available. For more information concerning the use and limitations of elasticities, consult the literature (1,2,3).

Congestion and Road Pricing

Economists have argued that marginal pricing of urban peak hour travel will improve the efficiency of the urban transportation system. It has been suggested that if motorists paid the full cost of travel during peak hours then alternatives to the drive alone auto would become more attractive. A study by Levinson (4) found that motorists faced with peak hour toll surcharges considered, in order of preference, the following actions: changing routes to avoid tolls, switching time of travel, using transit, joining a carpool, or traveling less.

There has been little experience in this country with congestion pricing. Tolls have generally been levied to raise revenue and not to alter travel behavior. Implementing congestion pricing requires careful planning and analysis in addition to the full cooperation and acceptance of the urban area involved.

A short range energy analysis method is suggested below. This approach relies on the use of travel demand elasticities to provide estimates of mode shift and travel impacts. It is designed to allow a great deal of flexibility on the part of the analyst to tailor evaluation to local needs.

Instructions for Worksheet

<u>Step 1:</u> Estimate total person trips (one-way) for the analysis period. In most cases this will include only peak hour trips.
<u>Step 2:</u> Determine base market shares by mode.
<u>Step 3:</u> Multiply Step 1 x Step 2 to find total base trips by mode.
<u>Step 4:</u> Estimate average trip length (miles) by mode.
<u>Step 5:</u> Determine vehicle occupancy for each mode.

Step 6: Multiply Step 3 x Step 4 and divide by Step 5 to find base vehicle miles of travel by mode.

Step 7: Road pricing actions are generally designed to encourage drive alone auto drivers to shift to shared ride auto and transit. In this Step, the change in total trip cost, (line haul operating cost and out-of-pocket cost) for drive alone auto is estimated.

Step 8: Estimate the elasticity of demand (trips) for each mode with respect to price. Most pricing schemes affect only the drive alone total cost therefore a direct elasticity for drive alone is required and a cross elasticity for shared ride and transit demand is required. Default estimates are outlined for these values.

Step 9: Multiply Step 7 x Step 8 to find the change in market shares resulting from the pricing strategy.

Step 10: Multiply Step 2 x Step 9 and add the value in Step 2 to find the revised market shares. These estimates are normalized (i.e., add to 1.0).

Step 11: Multiply Step 1 x Step 10 x Step 4 and divide by Step 5 to find revised vehicle miles of travel by mode.

Step 12: Subtract Step 6 from Step 11 to find change in vehicles miles of travel by mode.

Step 13: The vehicle miles of travel "saved" by reduction in auto drive alone travel is multiplied by 0.6 to account for the "car left home".

Step 14: Multiply Step 12 x Step 13.

Step 15: From Table 1.3 find appropriate over the road fuel economy by mode for the analysis year. A factor of 5.0 mpg of diesel is used for transit.

Step 16: Divide Step 14 by Step 15 to find change in daily fuel consumption by mode.

Step 17: The diesel gallons for transit in Step 16 is adjusted by a factor to convert it to gasoline energy equivalent (1.104).

Step 18: Adjusted daily energy in gasoline equivalence is found from multiplying Step 16 x Step 17 for transit only.

Step 19: Add the total daily energy saving for all modes to find the change in daily gasoline savings.

Step 20: Multiply Step 19 x 250 to find yearly energy savings.

TSM
ENERGY ANALYSIS WORKSHEET

ROAD PRICING ACTIONS

A. BASE DATA

	DAILY TRIPS		BASE MKT. SHARE (%)		TRIP LENGTH		VEHICLE OCCUPANCY		BASE VMT
DA		X		X		÷	1.0	=	
SR		X		X		÷		=	
TR		X		X		÷		=	

B. CHANGE IN MARKET SHARE

	%Δ IN AUTO DRIVE ALONE COST		e_{DATC}		BASE MKT. SHARE (%)		%Δ MARKET SHARE
DA		X	-.20	X		=	
SR		X	+.40	X		=	
TR		X	+.40	X		=	

TSM
ENERGY ANALYSIS
WORKSHEET

ROAD PRICING ACTIONS (CONT'D)

C. CHANGE IN VMT

	%ΔMKT. SHARE		BASE MARKET SHARE		DAILY TRIPS		TRIP LENGTH		VEHICLE OCCUPANCY		REVISED VMT
DA	(	+	)	X		X		÷	1.0	=	
SR	(	+	)	X		X		÷		=	
TR	(	+	)	X		X		÷		=	

D. FUEL CONSUMPTION

	ΔVMT		CAR LEFT HOME FACTOR		FUEL ECONOMY BY MODE (TABLE 1.3)		DIESEL-GASOLINE CONVERSION FACTOR		ENERGY SAVINGS (GAL)
DA		X	0.6	÷				=	
SR		X	0.6	÷				=	
TR				÷	5.0	X	1.104	=	

SUBTOTAL		DAILY ENERGY SAVINGS
X	250	WORKDAYS PER YEAR
TOTAL		ANNUAL ENERGY SAVINGS

DA - DRIVE ALONE
SR - SHARED RIDE
TR - TRANSIT

e_{DATC} - ELASTICITY OF DRIVE ALONE TOTAL COST

ΔVMT = BASE VMT - REVISED VMT

Example

A peak period surcharge for all solo drivers entering the CBD of a medium sized urban area has been suggested. This fee will be in effect between the hours of 7:00 and 9:00 a.m. and will increase the total cost of drive alone autos by 10%. Given the following information, estimate the yearly gallons saved by this action.

Base Data

A.M. Peak hour person trips, total peak direction	100,000

Base Mode Shares

Auto drive alone	.70
Shared ride	.20
Transit	.10

Average Trip Length

Auto trip alone	7.0 miles
Shared ride	9.0 miles
Transit	6.5 miles

TSM
ENERGY ANALYSIS WORKSHEET

ROAD PRICING ACTIONS

A. BASE DATA

Am PEAK

	DAILY TRIPS		BASE MKT. SHARE (%)		TRIP LENGTH		VEHICLE OCCUPANCY		BASE VMT
DA	100,000	x	70	x	7.0	÷	1.0	=	490,000
SR	100,000	x	20	x	9.0	÷	2.5	=	72,000
TR	100,000	x	10	x	6.5	÷	60.0	=	1,083

B. CHANGE IN MARKET SHARE

	%Δ IN AUTO DRIVE ALONE COST		e_{DATC}		BASE MKT. SHARE (%)		%Δ MARKET SHARE
DA	+10	x	-.20	x	70	=	-1.4
SR	+10	x	+.40	x	20	=	+0.8
TR	+10	x	+.40	x	10	=	+0.4

TSM
ENERGY ANALYSIS
WORKSHEET

ROAD PRICING ACTIONS (CONT'D)

C. CHANGE IN VMT

	%ΔMKT. SHARE		NORMALIZED BASE MARKET SHARE		DAILY TRIPS		TRIP LENGTH		VEHICLE OCCUPANCY		REVISED VMT
DA	-1.4	+ 68.7	70	X	100,000	X	7.0	÷	1.0	=	480,900
SR	+0.8	+ 20.9	20	X	100,000	X	9.0	÷	2.5	=	75,240
TR	+0.4	+ 10.4	10	X	100,000	X	6.5	÷	60.0	=	1,127

D. FUEL CONSUMPTION

	ΔVMT		CAR LEFT HOME FACTOR		FUEL ECONOMY BY MODE (TABLE 1.3)		DIESEL-GASOLINE CONVERSION FACTOR		ENERGY SAVINGS (GAL)
DA	9,100	X	0.6	÷	17.7			=	308
SR	-3,240	X	~~0.6~~ NA	÷	17.7			=	-183
TR	-44			÷	5.0	X	1.104	=	-10

SUBTOTAL	115	DAILY ENERGY SAVINGS
X	250	WORKDAYS PER YEAR
TOTAL	26,750	ANNUAL ENERGY SAVINGS

DA - DRIVE ALONE
SR - SHARED RIDE
TR - TRANSIT

^{e}DATC - ELASTICITY OF DRIVE ALONE TOTAL COST

ΔVMT = BASE VMT - REVISED VMT

Results and Limitations

After completing the worksheet, it is shown that a pricing action such as the one described would result in an annual savings of 28,750 gallons of fuel on an annual basis.

The procedure suggested provides a preliminary estimate of the energy impact of congestion pricing. The results are very sensitive to the elasticity values so it is necessary to apply local estimates where possible.

Transit Pricing

A vast body of literature exists documenting the impact of transit fare policies on ridership. Eleasticities have been used in many cases to provide short range estimates of ridership changes. An energy impact analysis method is outlined below which applies elasticities to estimate the implications of changes in transit fares on ridership. This information is used to determine the savings in energy from mode shifts.

The following formula can be used to estimate gas savings from ridership changes.

$$\text{Gas Savings} = \frac{\left(\frac{\Delta R \text{ x } DIV}{OCC}\right) \text{ X } (TL)}{MPG} \text{ x } CLH$$

Where:

ΔR = Change in ridership
DIV = Diversion rate from auto to transit
TL = Trip length
MPG = Average over the road fuel economy and auto
CLH = Car left home factor

Instructions for Worksheet

Step 1: Estimate base daily market ridership. This would increase, for example, the ridership which will be impacted by a particular fare change such as peak hour riders or special groups.
Step 2: Estimate the percent change in fare for the market group.
Step 3: Determine the elasticity of the market demand with respect to price. A general system wide elasticity of -.33 is provided. For more information concerning elasticities for special groups, consult Oh and Chan (1) and Lago and Mayworm (3).
Step 4: Multiply Step 3 x Step 2 to find the percent change in daily market ridership.
Step 5: Multiply Step 1 x Step 4 to find change in ridership.
Step 6: Estimate the number of new riders (Step 5) that will be former auto trips. A default value of 0.5 is assumed.
Step 7: Multiply Step 5 x Step 6 to find the number of riders from autos.
Step 8: Estimate the average auto occupancy. Default of 1.6 given.
Step 9: Divide Step 7 by Step 8 to find the number of cars left home.
Step 10: Estimate average trip length for the market ridership.

<u>Step 11:</u> Multiply Step 9 by Step 10 to estimate car miles (VMT) saved.
<u>Step 12:</u> Average over the road fuel economy for the analysis period.
<u>Step 13:</u> Divide Step 11 by Step 12 to find gallons saved.
<u>Step 14:</u> Factor for car left home. Default of 0.6 assumed.
<u>Step 15:</u> Multiply Step 13 by Step 14 to find net daily gallons saved.
<u>Step 16:</u> Multiply Step 15 by 250 to find yearly savings.

TSM
ENERGY ANALYSIS
WORKSHEET

TRANSIT FARE POLICIES

A. BASE DATA

DAILY RIDERS		%ΔFARE		e_F		ΔDAILY RIDERS
	X		X	-.33	=	

B. FUEL CONSUMPTION

ΔDAILY RIDERS		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		AUTO MPG (TABLE 1.3)		CAR LEFT HOME
	X	0.5	÷	1.6	X	7.5	÷		X	0.6

=		DAILY ENERGY SAVINGS
X		WORK-DAYS PER YEAR
=		ANNUAL ENERGY SAVINGS

Example

A proposal has been suggested to reduce transit fares system wide from 50¢ to 35¢ in order to encourage additional ridership. The transit pricing worksheet is applied to determine daily and yearly gallons saved.

TSM
ENERGY ANALYSIS
WORKSHEET

TRANSIT FARE POLICIES

A. BASE DATA

DAILY RIDERS		%ΔFARE		e_F		ΔDAILY RIDERS
40,000	x	-30	x	-.33	=	3,960

B. FUEL CONSUMPTION

ΔDAILY RIDERS		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		AUTO MPG (TABLE 1.3)		CAR LEFT HOME
3,960	x	0.5	÷	1.6	x	7.5	÷	17.7	x	0.6

= 315 DAILY ENERGY SAVINGS

x 250 WORK-DAYS PER YEAR

= 78,750 ANNUAL ENERGY SAVINGS

Results and Limitations

After using the worksheet it is shown that the proposal will result in an annual savings of 78,750 gallons.

The estimates of ridership changes using so called "backward" elasticities, such as this example, are probably optimistic. This will result in an overstatement of energy savings. This should be kept in mind when applying the procedure.

References

1. Chan, Y. and F.L. Ou, A Tabulation of Demand Elasticities for Urban Travel Forecasting, Pennsylvania Transportation Institute, August 1977.
2. Pucher, J.R. and J. Rothenberg, Pricing in Urban Transportation: A Survey of Empirical Evidence on the Elasticity of Travel Demand, Center for Transportation Studies, 1976.
3. Mayworm, P., A.M. Lago and J.M. McEnroe, Patronage Impacts of Changes in Transit Fares and Services, prepared for UMTA, Washington, DC, 1980.
4. Levinson, H. et al, "Estimating Behavioral Response to Peak Period Congestion," Record 767, Transportation Research Board, Washington, DC, 1980.

14. Routing, Scheduling and Dispatching Changes

Introduction

There are four basic ways in which routing, scheduling and dispatching changes can affect ridership. Routing changes can change the out-of-vehicle time (especially the access or "walk" time), the vehicle miles of a given route and possibly the bus speed or in-vehicle time. Scheduling changes can affect headways and therefore waiting time (another component of out-of-vehicle time); scheduling changes can also change total route VMT. Dispatching changes can facilitate transfers and so reduce waiting time. This section suggests ways to measure the impact of changes in route VMT, in-vehicle time or bus speed, waiting time, and access time on transit patronage for a given route.

General Formula for Computing Gasoline Savings

Transit-related TSM actions save gasoline by enticing potential riders out of the automobile and into public transit. In order to compute gasoline savings, one must know or be able to estimate the change in ridership, the automobile diversion rate, the trip length of the diverted rider, average auto occupancy, average fuel efficiency of the automobile fleet, and the use of the "car left home" by the new transit user. Gasoline savings are calculated using the following formula:

$$GS = \frac{\frac{\Delta R \ . \ DIV}{OCC} \ . \ TL}{MPGa} \qquad CLH$$

where GS = gasoline savings in gallons
ΔR = change in ridership resulting from TSM action
DIV = automobile diversion rate (default = 0.5)
TL = trip length for diverted trips (default = 7.5)
OCC = auto occupancy (default = 1.6)
$MPGa$ = fuel efficiency of the automobile fleet (default = 17.7)
CLH = factor for the car left home (default = 0.6)

This is the general formula for computing gasoline savings. It is used for all transit-related TSM actions involving ridership changes.

Elasticities have been developed relating ridership changes to changes in various service measures; where appropriate, these are used to compute ridership changes. For other actions, best estimates of percentage change in ridership are reached from a survey of the transportation literature.

Default factors are provided for other variables in the formula. The percentage of induced trips, as opposed to diverted trips, resulting from transit improvements have been estimated to be as high as 50% (1,2). A conservative estimate of the percentage of new transit trips diverted from the automobile (assuming that 50% of new trips are induced) is 50%. For this analysis, an automobile diversion rate of 0.5 is the default value. A standard value of 1.6 persons per automobile is used for the occupancy rate. There is a wide range of estimates for trip length (3,4,5,6,7,8,); since diverted trips can be presumed to be longer (many of the shortest new trips are likely to be induced from walking), a liberal value of 7.5 miles is assigned as the trip length default value. Fleet efficiency projections can be obtained from EPA (9); the 17.7 mph default value is the conservative projection for 1981. Finally, a study on the use of the "car left home" indicates that such use accounts for 40% of gasoline savings resulting from the mode shift to transit (10); the default value is therefore 0.6.

In cases where bus VMT changes, the general formula is extended to include an additional calculation:

$$GS = \frac{-\Delta VMT}{MPGt} \cdot 1.104$$

where ΔVMT is the change in bus VMT
MPGt is the average bus mileage (in miles per diesel gallon; default is 4.0)
1.104 is a conversion factor from diesel fuel to gasoline equivalent.

A federal study (11) gives an average MPG figure for a diesel bus used for transit of 4.6. In this report, a figure of 4.0 miles per diesel gallon is used for local buses and 5.0 for express buses.

For each transit-related TSM action, ridership and VMT changes must be estimated. Once these are obtained, the values can be inserted into the general formula to determine gasoline savings.

Methodology

A range of estimates for the elasticities of transit ridership with respect to bus VMT, in-vehicle time, waiting time and access time is presented in the transportation literature. The range of elasticities with respect to each variable is presented here, and default values are selected.

Two studies present the elasticity of ridership with respect to bus VMT. One (12) reports an elasticity of +0.69 ±0.31, while the other study (1) finds an average elasticity of +0.91, with a range from 0.73 to 1.16. A default value of +0.80, the midpoint between the two mean elasticities, is selected for this analysis.

Several studies estimate the elasticity of ridership with respect to in-vehicle time (2,13,14). The lower bound ranges from -0.16 to -0.30, the upper bound from -0.40 to -0.69. The average of the mean elasticities from the three studies is -0.39; a conservative estimate of -0.35 is selected as the default value.

Several studies estimate the elasticity of ridership with respect to in-vehicle time (2,,13,14). The lower bound ranges from -0.16 to -0.30, the upper bound from -0.40 to -0.69. The average of the mean elasticities from the three studies is -0.39; a conservative eatimate of -0.35 is selected as the default value.

Waiting time is generally estimated as one-half of the headway. The elasticities of ridership with respect to waiting time and to headway are therefore measuring the same concept. A wide range of values is reported in the literature (2, 12, 13, 15,16), from a low estimate of -0.10 to a high estimate of -3.8. If the two extreme values are discarded, the average of the mean elasticities is -0.76. A default value of -0.75 is used here; this is slightly more than twice as great as the in-vehicle time elasticity. This agrees with findings of relative importance of in-vehicle time and wait time. (17,18). The waiting time elasticity applies to transfer waiting time as well.

One study estimates the elasticity of ridership with respect to walk time (12). A peak value of -0.26 and an off-peak value of -0.14 is reported. The default value for this analysis is -0.20.

The methodology permits analysis at any level appropriate to a given problem. The most appropriate level of analysis for gasoline savings resulting from routing, scheduling and dispatching changes is the transit route. The analysis proceeds as follows:

Step 1: Determine whether the change affects bus VMT (Step 2A), bus speed or in-vehicle time (Step 2B), headway or waiting time (Step 2C) or access or walk time (Step 2D). Proceed to the appropriate step. If more than one variable is affected, go to all relevant steps.
Step 2A: Estimate the ridership change resulting from a change in bus VMT.

Data needed: bus VMT and ridership for route under analysis; VMT added or deleted.

The percentage change in ridership (r) is:

$$r = E_{VMT} \cdot v$$

where E_{VMT} is the elasticity of ridership with respect to bus VMT (default = 0.8)

v is the percentage change in VMT

and $R = \frac{r}{100} . Ro$

where Ro is the original ridership on the route under consideration.

Step 2B: Estimate the ridership change resulting from a change in in-vehicle time.

Data Needed: run time and ridership for route under analysis; new run time. Run time can be figured from average speed and route VMT. An end-of-route extension is not considered to affect in-vehicle time for original riders. The only way in which such an extension could affect their in-vehicle time is if it brought them closer to their destination and thereby decreased access time; this is taken into account in Step 2D.

The percentage change in ridership (r) is:

$$r = E_{it} . t$$

where E_{it} is the elasticity of ridership with respect to in-vehicle time (default = -0.35)

t is the percentage change in run time,

and $R = \frac{r}{100} . Ro$

where Ro is the original ridership on the route under consideration.

Step 2C: Estimate the ridership change resulting from a change in headway.

Data needed: headway and ridership for route under analysis; change in headway.

The percentage change in ridership (r) is:

$$r = E_h . h$$

where E_h is the elasticity of ridership with respect to wait-time or headway (default = -0.75)

h is the percentage change in headway,

and $R = \frac{r}{100} . Ro$

where Ro is the original ridership on the route under consideration.

Step 2D: Estimate the ridership change resulting from a change in access time.

. Data needed: Average walk time to transit and ridership for route under analysis; change in average walk time.

The percentage change in ridership (r) is:

$$r = E_w \cdot w$$

where E_w is the elasticity of ridership with respect to walk time (default = -0.20).

w is the percentage change in average walk time.

and $R = \frac{r}{100} \cdot Ro$

where Ro is the original ridership on the route under consideration.

Step 3: Calculate the gasoline savings resulting from ridership increases using the general formula derived earlier:

$$GS = \frac{\frac{\Delta R \cdot DIV}{OCC} \cdot TL}{MPGa} \cdot CLH$$

with default values:

DIV = 0.5
TL = 7.5
OCC = 1.6
MPGa = 17.7
CLH = 0.6

Step 4: If there is a change in bus VMT, calculate the resulting gasoline savings:

$$GS = \frac{-\Delta VMT}{MPGt} \cdot 1.104$$

with a default value of 4.0 for MPGt.

Step 5: Add the gasoline savings from Step 3 and 4. This is the overall gasoline savings resulting from the routing, scheduling or dispatching action.

A worksheet is provided to aid in the calculations.

TSM
ENERGY ANALYSIS WORKSHEET

ROUTING, SCHEDULING AND DISPATCHING IMPROVEMENTS

A. CHANGE IN VEHICLES MILES

ΔBUS VMT		BUS VMT		e_{VMT}		RIDERSHIP		ΔR
	÷		x	0.3	x		=	

B. CHANGE IN IN-VEHICLE TRAVEL TIME

ΔRUN TIME		RUN TIME		e_{TT}		RIDERSHIP		ΔR
	÷		x	-0.35	x		=	

C. CHANGE IN HEADWAY/WAIT TIME

ΔHEADWAY		HEADWAY		e_{WAIT}		RIDERSHIP		ΔR
	÷		x	-0.75	x		=	

D. CHANGE IN WALK TIME

ΔWALK TIME		WALK TIME		e_{WALK}		RIDERSHIP		ΔR
	÷		x	-0.2	x		=	

ΣΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		FACTOR FOR CAR LEFT HOME		GAS SAVINGS
	x	0.5	÷	1.6	x	7.5	÷		x	0.6	=	

ΔBUS VMT		BUS MPG		DIESEL-GASOLINE CONVERSION FACTOR		GAS COSTS
	÷	4.0	x	1.104	=	

GAS SAVINGS		GAS COSTS		DAILY NET ENERGY SAVINGS		WORKDAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
	-		=		x	250	=	

Example

Given the various ways in which routing, scheduling and dispatching changes can affect ridership, an example incorporating many such changes is appropriate for demonstrating use of the techniques presented in this section. While the example itself is hypothetical, data from weekday operation of an actual bus route in Nassau County (NYC metropolitan area) is used as a base for calculation (19). Daily ridership is 2,400, headway is 30 minutes, the one-way route length is 15.0 miles and daily bus VMT on this route is 1,200.

The example involves a re-routing to serve a new employment center and a dispatching change to facilitate transfer from a cross-route. The rerouting will decrease average walk time by 10%, increase average in-vehicle time by 5% and add 0.5 mile to one-way route length. The dispatching change will decrease average wait time from 16 to 15 minutes and increase in-vehicle time by 5%. Both changes can be evaluated together.

The changes result in a savings of 0.16 equivalent gallons of gasoline for an average weekday. Assuming that the changes primarily affect work trips, the annual savings are 40 equivalent gallons of gasoline. An example worksheet details the calculations determining energy savings due to these changes.

TSM
ENERGY ANALYSIS
WORKSHEET

ROUTING, SCHEDULING AND DISPATCHING IMPROVEMENTS

A. CHANGE IN VEHICLES MILES

ΔBUS VMT		BUS VMT		e_{VMT}		RIDERSHIP		ΔR
40	÷	1,200	x	0.3	x	2,400	=	64

B. CHANGE IN IN-VEHICLE TRAVEL TIME

ΔRUN TIME		RUN TIME		e_{TT}		RIDERSHIP		ΔR
-10%	÷		x	-0.35	x	2,400	=	-84

C. CHANGE IN HEADWAY/WAIT TIME

ΔHEADWAY		HEADWAY		e_{WAIT}		RIDERSHIP		ΔR
-2	÷	32	x	-0.75	x	2,400	=	113

D. CHANGE IN WALK TIME

ΔWALK TIME		WALK TIME		e_{WALK}		RIDERSHIP		ΔR
-10%	÷		x	-0.2	x	2,400	=	48

ΣΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		FACTOR FOR CAR LEFT HOME		GAS SAVINGS
141	x	0.5	÷	1.6	x	7.5	÷	17.7	x	0.6	=	11.20

ΔBUS VMT		BUS MPG		DIESEL-GASOLINE CONVERSION FACTOR		GAS COSTS
40	÷	4.0	x	1.104	=	11.04

GAS SAVINGS		GAS COSTS		DAILY NET ENERGY SAVINGS		WORKDAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
11.20	-	11.04	=	0.16	x	250	=	40

Limitations

This section has presented a methodology for evaluating the effects of routing, scheduling and dispatching changes. Elasticities relating ridership to bus VMT, in-vehicle time, wait time and walk time have been used to determine ridership changes. A general formula for computing gasoline savings has been derived; this formula is used in following sections to evaluate energy effects once ridership changes are known. Examples of the use of these techniques have also been presented.

It is an oversimplification to divide up actions in this category by service variable affected, use various elasticities to determine ridership changes and add these changes to obtain net ridership change. It is intuitively obvious that there are some overlapping effects, but to address these adequately was found to be beyond the scope of this study. Results obtained from these techniques can be viewed with confidence as to their accuracy, but the analyst should be aware of overlapping effects and subtle interrelationships.

There are certain changes which do not lend themselves to simple analysis by these techniques. For example, the success of a route extension in attracting new riders depends heavily on type and density of land use in the immediate area of that extension. Treating a route extension by measuring increased bus VMT does not take land use into account and so may produce misleading results. In such a case, a different, more comprehensive approach may be desirable. While the techniques could take into account such variance in ability to attract riders by using a number from the high range of elasticities in extensions to densely-settled areas or to major employment centers, there is little evidence upon which to base the choice of a different number.

This highlights an obvious point. The success of application of these techniques depends upon the analyst's ability to adapt the techniques to local conditions when necessary.

References

1. F.A. Wagner and K. Gilbert, Transportation System Management: An Assessment of Impacts, Washington, DC, prepared for UMTA by Alan M. Voorhees, Inc., November 1978.
2. M.J. Rothenberg, Public Transportation: An Element of the Urban Transportation System, Washington, FHWA, February 1980.
3. B.T. Goley, G. Brown and E. Samson, USDOT, FHWA, Nationwide Personal Transportation Study - Household Travel in the U.S., Report No. 7 Washington, USDOT, December 1972.
4. Chicago Area Transportation Study, 1970 Travel Characteristics - Trip Length, Chicago, Chicago Area Transportation Study, February 1975.
5. Janis M. Gross et al, "Energy Impacts of Transportation Systems Management Actions in New York State, 1978-1980," Preliminary Research Report No. 151, Albany, NYSDOT, Planning Research Unit, May 1979.
6. Tri-State Regional Planning commission, Journey to Work Trip Length, Interim Technical Report 1302, New York, Tri-State Regional Planning Commission, February 1977.
7. Gerald S. Cohen and Michael A. Kocis, "Components of Change in Urban Travel," Preliminary Research Report No. 159, Albany, NYSDOT, Planning Research Unit, July 1979.
8. Agnes Rapoli, New York State: Profile of the 80's, draft report, unpublished, (circa May 1981).
9. U.S. Department of Transportation, Automotive Fuel Economy Program: Fifth Annual Report to Congress, Washington, DC, USDOT, January 1981.
10. J.M. Gross, "The Car Left Home", Preliminary Research Report No. 168, Albany, New York State Department of Transportation, Planning Research Unit, August 1979.
11. Truck and Bus Panel, USDOT and USEPA, Study of Potential for Motor Vehicle Fuel Economy Improvements, Report No. 7 of Seven Panel Reports, Washington, DC, USDOT and USEPA, January 1975.
12. P. Mayworm, A.M. Lago and J.M. McEnroe, Patronage Impacts of Changes in Transit Fares and Services, Washington DC, prepared for UMTA by Ecosometrics, Inc., September 1980.
13. T.J. Atherton and J.H. Suhrbier, Urban Transportation Energy Conservation: Case City Applications of Analysis Methodologies, Vol. III, Washington, DC, prepared for DOE by Cambridge Systematics, Inc. September 1978.
14. T.J. Tardiff, J.L. Benham and S. Greene, "Methods for Analyzing Fuel Supply Limitations on Passenger Travel," NCHRP Report No. 229, Washington, DC, prepared for TRB by Charles River Associates, Inc., December 1980.
15. M.A. Abe, "Pricing and Welfare in Public Transportation," Traffic Quarterly, Vol. 27, No. 3, July 1973.
16. C.H. Buttke, "Estimating Ridership on Small Systems," presented as case study in Rothenberg, op.cit.

17. D.K. Holland, *A Review of Reports Relating to the Effect of Fare and Service Changes in Metropolitan Public Transportation Systems,* prepared for FHWA by Center for Urban Programs, St. Louis Univercity, St. Louis, MO, June 1974.
18. M. Fried, J. Havens and M. Thall, *Travel Behavior - A Synthesized Theory,* Final Report, NCHRP Project 8-14, prepared by Laboratory of Psychosocial Studies, Boston College, Chestnut Hill, Massachusetts, March 1977.
19. L. Malsam and C. Cohen, *Emergency Energy Contingency Plan for Nassau County*, Mineola, New York, Nassau County Planning Commission, December 1979, (Route N-19 supplies base data).

15. Express Bus and Park-and-Ride Actions

Because these two TSM actions are so complementary, it is difficult to separate them for analytical purposes. Many of the studies in this area analyze the effects of projects involving both actions (1, 2, 3, 4). In this section, we will examine the combined effects of express bus service and park and ride facilities and also suggest a method to apportion the effects between the two actions.

Considerations

As in the case with most of the transit-related TSM actions, the most difficult aspect of the analysis is the determination of a method by which ridership changes can be estimated. There are many factors that influence the success of an express bus route or a park-and-ride lot, and it is not the intention of this section to measure the effects of each factor. Instead, a range of expected ridership increases is provided.

Several studies have estimated ridership for express bus service. These estimates range from a low of 10 riders per express bus trip (2) to a high of 53 (1). A survey of 20 express bus/park and ride case studies reports an average of 35 riders per express bus trip (1). When information of number of bus trips and ridership by borough is put together for all express routes in New York City, an average of 36 riders per express bus trip is obtained (5). The similar results from both studies indicate that the estimate of 35 riders per trip may be used with reasonable confidence as the average patronage for express bus service with park and ride facilities. The high and low figures cited can provide a range of potential ridership and energy savings under different conditions.

There is little guidance for apportioning the new ridership resulting from park and ride facilities and express bus service between the two actions. Common sense would indicate that express bus service is the dominant force of the two in attracting new riders. The only evidence found is from Seattle and Minneapolis, where there is some provision of park-and-ride facilities along with a substantial degree of local collection by the express buses. Experience in both places indicates that approximately 14% of inbound passengers board at park-and-ride lots (1). Use of this figure to apportion ridership increases between express bus service and park-and-ride facilities results in averages of 30 riders per bus trip attracted by express bus service and 5 riders per bus trip attracted by park-and-ride facilities. Note that while New York City's average of 36 riders per express bus trip was achieved without provision of significant park-and-ride facilities, density of residential development and habits of transit usage in New York City justify use of a lower <u>average</u> figure for ridership increases attributable solely to express bus service.

The general formula for energy savings developed in Section 14 can be applied once ridership increases are known, but certain default values need to be changed. Evidence from many case studies indicates that the diversion rate from auto to transit for express bus/park and ride service averages 0.62 (1, 2, 3). There is some indication that diversion rates are lower for express bus service without park and ride lots (4), but this is not conclusive and a diversion rate from automobile of .62 is suggested as the default value for all calculations.

Trip length is longer for express bus trips; an average length of 10.0 miles is plausible, although given the length and collection characteristics of a proposed express bus route, average trip length should be simple to compute. It is assumed that express bus/park-and-ride service intercepts automobile trips at the boarding point and "saves" the auto VMT corresponding to bus trip length. Experience with a park-and-ride facility in Seattle indicates that roughly 15% of passengers boarding at the lot backtracked to reach the lot (1). This is a relatively insignificant energy use and so backtracking is not considered in this analysis. If the local analyst feels this to be important, average length of trip diverted from auto may be adjusted by subtracting the average backtracking trip length for the 15% of passengers who backtrack. If a 1.0 mile trip length is assumed for backtracking, and the default value for trip length is used, then:

$$\begin{aligned}\text{Adjusted Average Trip Length} &= 10.0 -(.15)\ (1.0)\\ &= 9.85 \text{ miles.}\end{aligned}$$

In general, an adjustment factor is subtracted from the average trip length to take the backtracking effect into account. This adjustment factor is of this form:

$$p.t_b$$

where p is the proportion of passenger boarding at the lot who backtrack, and tb is the average length of the backtracking trip.

There is strong evidence that automobile occupancy is lower for those using express bus/park and ride service. An occupancy rate of 1.2 is used as the default value for these actions. Since a car left in a park-and-ride lot is not used during the day, the factor for car left home must be adjusted. Recall that 14% of inbound passengers board at park-and-ride lots. The defalut value of 0.6 presented in Section 14 is based on the finding that 40% of the gasoline saved by not using the car for the trip to work is used for other trips during the day. If 14% of riders use a park and ride lot, then the adjusted proportion of energy which is saved by a mode shift but used by the car left home is:

Proportion of energy savings used by car left home = .40 (1 - 0.14)
= .34

and the adjusted factor for the car left home is then:

CLH = 1 - .34 = .66

This is the default value used for analyzing express bus service which includes park-and-ride lots. For express bus service only, the factor is not adjusted from its original default value of .6; for park-and-ride actions alone, the factor may be approximated at 1.0.

Finally, a fuel efficiency of 5.0 miles per diesel gallon is assumed for express bus. Other default values from Section 14 remain unchanged.

The apportioning of effects between express bus and park-and-ride services provides an estimation of ridership increases resulting from park-and-ride lots not associated with express bus service, but a further distinction must be made. There are two types of park-and-ride lots (6). This section has so far dealt only with remote park-and-ride lots, those beyond a distance of 3 miles from the CBD and involving the use of public transportation for the major portion of the trip. Peripheral park-and-ride lots are generally within 3 miles of the CBD and involve use of the automobile for the major portion of the trip, with public transportation used for the final trip distribution within the CBD. Ridership estimates for peripheral lots are determined in a different manner. Surveys of peripheral lots indicate that lots with up to 600 spaces are generally used at or near full capacity, while use of larger lots is as low as 50% of capacity (3, 6). Since peripheral lots are a form of CBD parking, with reliable, generally frequent transit service compensating for the lots' location at the fringe of the CBD, and since the automobile is used for the major portion of the trip, thus necessitating no major changes in habit, it is no surprise that peripheral lots are heavily patronized. For lots with fewer than 600 spaces, 90% capacity is assumed. For larger lots, less than 90% capacity is likely, but the decision is left up to local analysts. Ridership changes can then be computed:

$$\Delta R = \frac{c}{100} \cdot S \cdot OCC$$

where c is percentage of capacity used (90% default value for lots with fewer than 600 spaces).

S is number of spaces in the lot,

OCC is average auto occupancy (default value = 1.3).

A higher auto occupancy rate as well as a higher diversion rate are noted in one study of peripheral lots (3). A default value of 0.75 is used for diversion rate from automobile for peripheral park-and-ride facilities (3). However, since all users of peripheral lots arrive by automobile, there is a reverse diversion that must be taken into account. Given a diversion rate of 0.75 from automobile to peripheral park-and-ride facilities, it follows that 25% of those using such facilities (and therefore arriving by automobile) formerly used transit to reach the CBD. This represents lost energy, and can be calculated with a slight adjustment of the general formula:

$$GL = \frac{\frac{\Delta R \cdot (1 - DIV)}{OCC} \cdot (TL - TL_{CBD})}{MPG_a} \cdot CLH$$

where GL is energy losses from auto-transit diversion
DIV is diversion rate from automobile to peripheral facilities
TL_{CBD} is distance from the lot to the CBD
and all other variables are as defined in Section 14.
Default values are listed later in this section.

A final consideration is a methodology to analyze conversion of an existing bus route from local to express service. In such a case, change in in-vehicle time is the key variable, and the elasticity of ridership with respect to in-vehicle time can be used to estimate ridership change:

$$r = E_{it} \cdot t$$

where r is percentage change in ridership
E_{it} is the elasticity of ridership with respect to in-vehicle time (default value = -0.35)
t is percentage change in average in-vehicle time (percentage change in run time can be used as an approximation).

This is the simplest method to estimate ridership changes resulting from conversion of local bus routes to express service.

With these considerations as background, we can now proceed to the evaluation methodology.

Methodology

Step 1. Determine whether this TSM action involves express bus service coupled with park-and-ride facilities (Step 2A), express bus service with no park-and-ride lots (Step 2B), remote park-and-ride facilities (more than 3 miles from the CBD) with no express bus service (Step 2C), peripheral park-and-ride facilities (less than 3 miles from the CBD - Step 2D) or conversion of local bus routes to express service (step E), and go to the appropriate step.

Step 2A. Data needed: daily number of one-way express bus trips (n) For express bus service coupled with park-and-ride facilities, ridership is estimated as follows:

$$\Delta R = m \cdot n$$

where m is the average number of passengers per express bus trip (default = 35).

Step 2B. For express bus service with no park-and-ride facilities, ridership is estimated as follows:

$$\Delta R = m \cdot n$$

where m and n are as defined in Step 2A, data needed is the same as in Step 2A and the default value for m is 30.

Step 2C. For remote park-and-ride facilities with no associated express bus service, ridership change on the route associated with such facilities is:

$$\Delta R = m \cdot n$$

where m and n are as defined in Step 2A, data needed is the same as in Step 2A and the default value for m is 5. If two park-and-ride lots are associated with a single route, only one such calculation is made. This step is appropriate also for estimating ridership changes resulting from provision of park-and-ride facilities serving express bus service.

Step 2D. Data needed: number of spaces in peripheral lot (S).

For peripheral park-and-ride faciliites, ridership is estimated as follows:

$$\Delta R = \frac{c}{100} \cdot S \cdot OCC$$

where c is percentage of capacity used (default = 90 for lots with fewer than 600 spaces)
OCC is automobile occupancy (default = 1.3)

Step 2E. Data needed: percentage change in either in-vehicle travel time or run time. For conversion of local to express bus service, the percentage change in ridership is:

$$r = E_{it}$$

where E_{it} is the elasticity of ridership with respect to in-vehicle travel time (default = 0.35)

t is the percentage change in in-vehicle travel time (percentage change in run time may be used as an approximation).

$$\Delta R = r \cdot R_o$$

where R_o is ridership on the existing local bus route.

Step 3. Compute the energy savings associated with the ridership changes using the general formula:

$$GS = \frac{\frac{\Delta R \cdot DIV}{OCC} \cdot TL}{MPG_a} \cdot CLH$$

Default values differ according to the nature of the express bus/park-and-ride action. Default values can be presented according to the method of computing ridership chnages, as shown:

Default Value for:	Step used to compute ridership 2A	2B	2C	2D	2E
DIV	.62	.62	.62	.75	.62
OCC	1.2	1.2	1.2	1.3	.12
TL	10.0	10.0	TL	TL	10.0
MPG_a	17.7	17.7	17.7	17.7	17.7
CLH	0.66	0.6	0.66	1.0	0.6

Step 4. Data needed: route length, number of one-way express bus trips. Compute the energy savings (or losses) from increased transit VMT, if any. Assuming 50% deadheading,

$$VMT = 2Zn$$

where Z is the route length in miles (default = 10.0)
n is the number of one way express bus trips.

The energy savings are:

$$GS = \frac{-VMT}{MPG_t} \cdot 1.104$$

This formula was derived in the previous section. For express bus service, 5.0 is the default value for MPG_t.

Step 5. Data needed: distance from peripheral lot to CBD.
For actions involving peripheral lots, calculate the energy lost through transit-auto diversion.

The formula is:

$$GL = \frac{\frac{\Delta R \cdot (1-DIV)}{OCC} \cdot (TL-TL_{CBD})}{MPG_a} \cdot CLH$$

where DIV is diversion rate from auto to peripheral facilities (default = .75)
OCC is average auto occupancy (default = 1.3)
TL is average trip length (default = 7.5)
TL_{CBD} is distance from the lot to CBD
MPG_a is average auto fuel efficiency (default = 17.7)
CLH is factor for the car left home (default = 1.0).

Step 6. Add Steps 3 and 4 and subtract Step 5 to obtain net energy savings.

TSM
ENERGY ANALYSIS
WORKSHEET

EXPRESS BUS/PARK AND RIDE

A. EXPRESS BUS/REMOTE PARK AND RIDE

1 WAY EXPRESS TRIPS		RIDERS PER TRIP		ΔR
	x	35	=	

B. PERIPHERAL PARK AND RIDE LOTS ONLY

# SPACES		PROPORTION USED		ΔR
	x	0.9	=	

C. LOCAL TO EXPRESS ROUTE CONVERSION

CHANGE IN RUN TIME		ORIGINAL (LOCAL) RUN TIME		e_{TT}		ORIGINAL (LOCAL) RIDERSHIP		Δ R
	÷		x	-0.35	x		=	

FOR EXPRESS BUS AND/OR REMOTE PARK AND RIDE

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		CAR LEFT HOME FACTOR		GAS SAVINGS
	x	0.62	÷	1.2	x	10.0 OR LOT-CBD DIST.	÷		x	NON-PARK-AND-RIDE 0.6	=	
										PARK-AND-RIDE 0.66	=	

ΔBUS VMT		BUS MPG		DIESEL-GASOLINE CONVERSION FACTOR		GAS COSTS
	÷	5.0	x	1.104	=	

FOR PERIPHERAL PARK AND RIDE

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		LOT TO CBD DISTANCE		(TABLE 1.3) AUTO MPG		CAR LEFT HOME FACTOR		GAS SAVINGS
	x	0.75	÷	1.3	x		÷		x	1.0	=	

ΔBUS VMT		BUS MPG		DIESEL-GASOLINE CONVERSION FACTOR		GAS COSTS FROM OPERATION
	÷	5.0	x	1.104	=	

ΔR		REVERSE DIVERSION RATE		AUTO OCCUPANCY			AVG. DIVERTED TRIP LENGTH		LOT TO CBD DISTANCE			AUTO MPG		GAS COSTS FROM FORMER LOCAL TRANSIT USERS
	x	0.25	÷	1.3	x	(	7.5	-		)	÷		=	

ΣGAS SAVINGS		ΣGAS COSTS		DAILY NET ENERGY SAVINGS		WORKDAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
	-		=		x	250	=	

Example

An express bus route is being established, with some park-and-ride facilities, in Syracuse, New York. The route length is 9.0 miles and there are 6 daily bus trips. The net energy effect can be computed by use of the worksheet.

As can be seen from the example worksheet, there is a daily ridership increase of 210 resulting in a daily energy savings of 12.6 equivalent gallons of gasoline and an annual savings of 3,150 equivalent gallons of gasoline due to the new express bus route with some park-and-ride facilities.

Limitations

There is a large range of average ridership per expres bus. Use of the average figure assumes that the express bus route is established along reasonably heavily-traveled corridors and that the locations for park-and-ride lots are selected carefully. Quality of express bus service, while generally higher than local service, can vary considerably. Since quality of service has been suggested as a key factor in determining ridership levels (7), variations in quality of service contribute to the large range of average ridership and must be taken into account.

Apportionment of ridership increases between express bus service and park-and-ride facilities is based on results from only two cities. The estimation of ridership increases from park-and-ride facilities is not dependent on the number of facilities serving a specific route. These two conditions indicate that the results from the technique for remote park-and-ride lots should be considered tentative. The approach taken here does provide consistency in the method of analysis of express bus service and park-and-ride facilites, but a careful study of their relative importance is needed before the results for either action taken alone can be considered definitive. Conversations with officials from Albany, New York's Capital District Transportation Authority indicate that some of the salient factors affecting usage of park-and-ride lots are level of service, quality of service, length of walk from parked car to bus stop and location of the lot; the precise effects of these factors on usage of park-and-ride lots deserves further investigation.

TSM
ENERGY ANALYSIS
WORKSHEET

EXPRESS BUS/PARK AND RIDE

A. EXPRESS BUS/REMOTE PARK AND RIDE

1 WAY EXPRESS TRIPS		RIDERS PER TRIP		ΔR
6	x	35	=	210

B. PERIPHERAL PARK AND RIDE LOTS ONLY

# SPACES		PROPORTION USED		ΔR
NA	x	0.9	=	NA

C. LOCAL TO EXPRESS ROUTE CONVERSION

CHANGE IN RUN TIME		ORIGINAL (LOCAL) RUN TIME		e_{TT}		ORIGINAL (LOCAL) RIDERSHIP		Δ R
NA	÷	MA	x	-0.35	x	NA	=	NA

FOR EXPRESS BUS AND/OR REMOTE PARK AND RIDE

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		CAR LEFT HOME FACTOR		GAS SAVINGS
210	x	0.62	÷	1.2	x	~~19.0~~ OR 9.0 LOT-CBD DIST.	÷	17.7	x	NON-PARK-AND-RIDE ~~0.6~~	=	NA
										PARK-AND-RIDE 0.66	=	36.4

ΔBUS VMT		BUS MPG		DIESEL-GASOLINE CONVERSION FACTOR		GAS COSTS
108	÷	5.0	x	1.104	=	23.8

FOR PERIPHERAL PARK AND RIDE

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		LOT TO CBD DISTANCE		(TABLE 1.3) AUTO MPG		CAR LEFT HOME FACTOR		GAS SAVINGS
NA	x	0.75	÷	1.3	x	NA	÷	NA	x	1.0	=	NA

ΔBUS VMT		BUS MPG		DIESEL-GASOLINE CONVERSION FACTOR		GAS COSTS FROM OPERATION
NA	÷	5.0	x	1.104	=	NA

ΔR		REVERSE DIVERSION RATE		AUTO OCCUPANCY		AVG. DIVERTED TRIP LENGTH		LOT TO CBD DISTANCE		AUTO MPG		GAS COSTS FROM FORMER LOCAL TRANSIT USERS
NA	x	0.25	÷	1.3	x [	7.5	-	NA	] ÷	NA	=	NA

ΣGAS SAVINGS		ΣGAS COSTS		DAILY NET ENERGY SAVINGS		WORKDAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
36.4	-	23.8	=	12.6	x	250	=	3,150

References

1. F.A. Wagner and K. Gilbert, Transportation System Management: An Assessment of Impacts, Washington, D.C., prepared for UMTA by Alan M. Voorhees, Inc., November 1978.
2. D.L. Christiansen, D. Bullard, P.L. Benfer and P. Guseman, Factors Influencing the Utilization of Park-and-Ride--Dallas/Garland Survey Results, Austin, Texas, prepared for Texas State Department of Highways and Public Transportation and for FHWA by Texas Transportation Institute, July 1980.
3. R.H. Ellis, J.C. Burnett and P.R. Rassam, Fringe Parking and Intermodal Passenger Transportation: Operational Experience in Five Cities, Washington, D.C., prepared for FHWA by Peat, Marwick, Mitchell and Co., November 1971.
4. Alan M. Voorhees and Associates, Inc., Blue Streak Bus Rapid Transit Demonstration Project - Final Report, Seattle, Alan M. Voorhees and Associates., Inc., June 1973.
5. F. Chesler, J. Levy and S. Platt, Better Integration of Transportation Modes Project, Background Interim Technical Report (Draft), Express Bus, New York, New York, New York City Transportation Administration, March 1976.
6. J.M. Gross et al., "Energy Impacts of Transportation Systems Management Actions in New York State, 1978-1980," Preliminary Research Report No. 151, Albany, New York, New York State Department of Transportation, Planning Research Unit, May 1979.
7. D.T. Hartgen, "Forecasting Remote Park-and Ride Transit Usage," Preliminary Research Report No. 39, Albany, New York State Department of Transportation, Basic Research Unit, December 1972.

16. Shuttle Transit Services

There are two basic types of shuttle transit: service linking two activity centers and a more general circulator within the CBD. A variation on this second type is establishment of a free-fare zone utilizing existing transit service in a downtown area.

Shuttle transit services can attract people to downtown, ease movement within the CBD, and increase accessibility between activity areas. Where free service has been provided in the CBD, substantial ridership gains have been reported.

Considerations

Methods of estimating ridership increases differ for different kinds of shuttle service. For establishment of a free-fare zone, one would expect, from the standard elasticity of ridership with respect to fare, an increase of 33% in ridership resulting from a 100% decrease in fare. Experience with several free-fare zones, however, indicate ridership increases of a much larger magnitude. Examination of ridership increases as a percentage of ridership on CBD indicates a range of ridership increases from 58% in Denver through 82% to 171% in Dallas, 191% in Albany, 199% in Seattle and 1525% in Rochester (1,2,3). Limits on the time of day when the free fare was in effect did not seem to affect the magnitude of change in ridership. The numbers at the lower end of the range reflect a short period of time between the before and after evaluation points. A reasonable estimate of the magnitude of ridership increases on CBD routes resulting from a free-fare zone in the CBD is 200%.

Information on two shuttle services in Syracuse, New York (4) and a shuttle bus associated with park-and-ride facilities in downtown Atlanta (5) indicates a generally low degree of patronage. One shuttle in Syracuse, the "Farmer's Market Shuttle", connects various offices downtown with a farmer's market during lunch hour on Tuesday; the other, operating on Saturday, connects the Syracuse University campus with downtown (6). These services are in addition to a free-fare zone in the CBD. The Atlanta "Town Flyer" service runs through downtown between two park-and-ride facilities, and the fare includes parking costs. Average patronage on these three shuttle services connecting activity modes is 5 riders per shuttle trip (4,5). This is also a likely estimate for a circulator system involving payment of fare, since such a system's effect on ridership is assumed to be relatively minor.

Studies indicate a low diversion rate, ranging from 12 to 28 percent, from auto to transit (1,7). It is assumed here that provision of shuttle transit services does not divert automobile trips into the CBD, but that trips within the CBD are diverted. This assumption affects values in the calculations for trip length and factor for the car left home. Unpublished data from the Freewheeler demonstration in Albany, New York, indicates an average trip length of approximately 0.75 mile. It is assumed that an automobile sojourn in the CBD would not be so direct, so the average length of the diverted trip is assigned a default value of 1.0 mile. If automobile trips into the CBD are not diverted, then there is no car left home and the factor can be fixed at 1.0. The default value for the diversion rate is set at 0.2.

A different assumption concerning diversion of trips into the CBD may be made if the analyst so chooses. As an example, say that of the 20% of trips diverted from the automobile, 80% involve within-CBD diversion only and 20% involve diversion of trips into the CBD as well as within-CBD trips. In other words, provision of shuttle service would under this assumption induce 20% of those using the shuttle to use public transportation for the journey into the CBD. Using the previous default value for trip length of 7.5 for trips into the CBD, average trip length then becomes:

$$\begin{aligned} TL &= 1.0 + (.2 \cdot 7.5) \\ &= 2.5 \text{ miles} \end{aligned}$$

Since the car is now left home 20% of the time, the factor for the car left home becomes:

$$\begin{aligned} CLH &= 1 - \text{proportion of saved energy used by the car left home} \\ &= 1 - (0.4 \cdot 0.2) \\ &= 0.92. \end{aligned}$$

Choice of assumption is left to the analyst. The former assumption is used in this analysis.

Section 14 contains the derivation of the general formula used to compute gasoline savings. This general formula is at the heart of the methodology used to analyze shuttle transit services.

Methodology

Step 1: Determine whether the change involves a free-fare zone (Step 2A) or some other type of shuttle transit service (Step 2B).

Step 2A: Determine the ridership change resulting from the establishment of a free-fare zone.

Data needs: ridership on routes in the free-fare zone (Ro).

The ridership change can be computed as:

$$\Delta R = \frac{c}{100} \cdot Ro$$

Where c is the percentage increase in ridership resulting from a free-fare zone in the CBD (default = 200).

Step 2B: Determine the ridership change resulting from other types of shuttle transit service.

Data needs: number of shuttle trips.

The ridership change can be computed as:

$$\Delta R = m \cdot n$$

where m is the number of passengers per shuttle bus trip (default = 5.0) and n is the number of shuttle bus trips.

Step 3: Compute energy savings resulting from ridership increases by use of the general formula:

$$GS = \frac{\frac{\Delta R \cdot DIV}{OCC} \cdot TL}{MPGa} \cdot CLH$$

with default values of

0.2 for DIV
1.6 for OCC
1.0 for TL
17.7 for MPGa
1.0 for CLH

Step 4: If bus VMT is increased, compute its effect on energy savings.

Data Needs: Change in bus VMT.

The formula is:

$$GS = \frac{-\Delta VMT}{MPGt} \cdot 1.104$$

where MPGt has a default value of 4.0.

Step 5: Add together the results of Steps 3 and 4 to obtain net energy savings.

This methodology is presented on the following worksheet.

TSM
ENERGY ANALYSIS WORKSHEET

SHUTTLE TRANSIT SERVICES

A. FARE-FREE ZONE

RIDERSHIP ON ROUTES WITHIN ZONE		RATE OF R INCREASE		ΔR
	x	2.0		

B. SHUTTLE ROUTE

# SHUTTLE TRIPS		RIDERS PER SHUTTLE TRIP		ΔR
	x	5.0	=	
		ROUTE LENGTH		ΔBUS VMT
	x		=	

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH (FARE-FREE) ROUTE LENGTH		(TABLE 1.3) AUTO MPG		CAR LEFT HOME FACTOR		GAS SAVINGS
	x	0.2	÷	1.6	x	1.0 	÷		x	1.0	=	

ΔBUS VMT		BUS MPG		DIESEL-GASOLINE CONVERSION FACTOR		GAS COSTS
	÷	4.0	x	1.104	=	

GAS SAVINGS		GAS COSTS		DAILY NET ENERGY SAVINGS		WORKDAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
	-		=		x	250	=	

Example

Examples of a free-fare zone and of a shuttle route are presented here.

In Albany, NY, the Freewheeler demonstration involves a free-fare zone in the CBD each weekday from 10 AM to 3 PM. Daily ridership within the zone averaged 1100 before institution of the Freewheeler. Existing bus routes have not been altered; there has been no increase in bus VMT.

As can be seen on the worksheet the energy savings is 15.5 gallons of gasoline per day or (multiplying by 250) 3875 gallons per year. In actuality, the Freewheeler resulted in a daily ridership increase of 2100, a daily energy savings of 15.4 gallons and an annual energy savings of 3850 gallons of gasoline. This is within 1% of the savings computed here.

The second example deals with a shuttle bus in Syracuse, NY. The bus operates on Saturday between the Syracuse University campus and CBD. The one-way route length is 3.0 miles and the shuttle makes 24 trips each Saturday. It is assumed that a car left home on campus is not used by anyone else.

Because shuttle transit does not attract many passengers and because of the increased bus VMT, there is a net energy loss of 905 gallons yearly. In actuality, the route attracted 125 riders instead of the 120 estimated here and net energy loss was 889 equivalent gallons of gasoline, within 1.5% of the estimate here.

TSM
ENERGY ANALYSIS WORKSHEET

SHUTTLE TRANSIT SERVICES

CBD - ALBANY

A. FARE-FREE ZONE

RIDERSHIP ON ROUTES WITHIN ZONE		RATE OF R INCREASE	ΔR
1,100	x	2.0	2,200

B. SHUTTLE ROUTE

# SHUTTLE TRIPS		RIDERS PER SHUTTLE TRIP		ΔR
—	x	5.0	=	—

# SHUTTLE TRIPS		ROUTE LENGTH		ΔBUS VMT
—	x	—	=	—

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH (FARE-FREE) / ROUTE LENGTH		(TABLE 1.3) AUTO MPG		CAR LEFT HOME FACTOR		GAS SAVINGS
2,200	x	0.2	÷	1.6	x	1.0 NA	÷	17.7	x	1.0	=	15.5

ΔBUS VMT		BUS MPG		DIESEL-GASOLINE CONVERSION FACTOR		GAS COSTS
0	÷	4.0	x	1.104	=	0

GAS SAVINGS		GAS COSTS		DAILY NET ENERGY SAVINGS		WORKDAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
15.5	-	0	=	15.5	x	250	=	3,875

TSM
ENERGY ANALYSIS
WORKSHEET

SHUTTLE TRANSIT SERVICES

SHUTTLE - SYRACUSE

A. FARE-FREE ZONE

RIDERSHIP ON ROUTES WITHIN ZONE		RATE OF R INCREASE	ΔR
—	x	2.0	—

B. SHUTTLE ROUTE

# SHUTTLE TRIPS		RIDERS PER SHUTTLE TRIP		ΔR
24	x	5.0	=	120
		ROUTE LENGTH		**ΔBUS VMT**
	x	3.0	=	72

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH (FARE-FREE)		(TABLE 1.3) AUTO MPG		CAR LEFT HOME FACTOR		GAS SAVINGS
120	x	0.2	÷	1.6	x	~~1.0~~	÷	17.7	x	1.0	=	2.5
						ROUTE LENGTH						
						3.0						

ΔBUS VMT		BUS MPG		DIESEL-GASOLINE CONVERSION FACTOR		GAS COSTS
72	÷	4.0	x	1.104	=	19.9

GAS SAVINGS		GAS COSTS		DAILY NET ENERGY SAVINGS		WORKDAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
2.5	-	19.9	=	-17.4	x	~~50~~ 52	=	-904.8

Limitations

While it is logical that a shuttle service between only two activity points does not attract a great deal of patronage, the assumption that the same holds true for a CBD circulator with required fare can be questioned. In the absence of evidence to the contrary, we have made that assumption. Since a free-fare zone has the same effect on mobility within the CBD, requires no new bus routes, is often subsidized by downtown merchants, and generates excellent publicity for the transit operator and the downtown community, it has emerged as the preferred action among shuttle transit services.

References

1. K.M. Goodman and M.A. Green, Low-Fare and Fare-Free Transit: Some Recent Applications by U.S. Transit Systems, Washington, DC, prepared for UMTA by the Urban Institute, February 1977.
2. Unpublished data supplied by Mr. Jack Reilly, Captial District Transportation Authority, Albany, NY, Publication of the study is due in May 1981.
3. J.H. Suhrbier, et al, Implementation and Administration of Air Quality Transportation Controls: An Analysis of the Denver, Colorado Area, Washington, DC, prepared for USDOT in cooperation with USEPA by Cambridge Systematics, April 1978.
4. J.M. Gross, et al, "Energy Impacts of Transportation Systems Management Actions in New York State, 1978-80," Preliminary Reasearch Report No. 151, Albany, NY, New York State Department of Transportation, Planning Research Unit, May 1979.
5. R.H. Ellis, J.C. Bennett and P.R. Rassam, Fringe Parking and Intermodal Passenger Transportation: Operational Experience in Five Cities, Washington, DC, prepared for FHWA by peat, Marwick, Mitchell and Cp., November 1971.
6. Syracuse Metropolitan Transportation Study, Transportation Systems Management for the Syracuse Urbanized Area, 1978, Syracuse, NY, Syracuse Metropolitan Transportation Study, June 1978.
7. Environmental Protection Agency, Office of Transportation and Land Use Policy, Air Quality Impacts of Transit Improvement, Preferential Lane, and Carpool/Vanpool Programs, Washington, DC, Environmental Protection Agency, March 1978.

17. Demand-Responsive/Paratransit Services

The fixed-route, fixed-schedule operation associated with conventional mass transit cannot compete with the automobile in terms of convenience. Realizing this, transit operators have explored more flexible services in an attempt to attract more users to transit. Ideally, demand-responsive and paratransit services combine the convenience of the automobile with the efficiency of mass transit. Demand-responsive services can also serve the handicapped and the elderly more effectively than conventional transit.

For the pruposes of this analysis, demand-responsive and paratransit services include dial-a-ride, shared-taxi, fixed-route services which operate without a set schedule, and route-deviation services. All have in common a degree of flexibility in serving travel needs.

Considerations

There are many possible ways to estimate ridership for a demand-responsive system. The simplest in terms of data needs is to use an average passengers per vehicle-mile figure, since VMT must be known to compute energy used in operation. In introducing a demand-responsive system, however, a transit operator may have only a vague notion of expected VMT and may feel more confident in another method to estimate ridership. If so, average figures for passengers per vehicle hour or passengers per seat may be used to estimate ridership, and the average passengers per vehicle-mile may be used to derive estimated VMT.

Examination of the results of several studies on demand-responsive services indicate that services oriented toward a university campus generally show much higher rates of patronage. This is most obvious in Ann Arbor, Michigan, where a fixed-route paratransit operation serving the campus of the University of Michigan had a passenger-per-vehicle-mile figure which was nearly five times greater than the figure for a dial-a-ride service focused on residential portions of the city (1). Because the characteristics of a college community differ markedly from those of the population at large, utilization of paratransit services on or near a college campus is not representative of general utilization. Demand-responsive services aimed at a college community are, therefore, not included in the calculations of the average figures mentioned in the preceding paragraph.

Data on riders per vehicle-mile of demand-responsive has been collected from 18 systems around the U.S. (2). Of these 18 systems, 12 are characterized as "demand-responsive" (presumably dial-a-ride services) and 6 involve fixed-route or route-deviation service. The average figure for riders per vehicle-mile (sum of passengers ÷ sum of vehicle-miles) on the demand-responsive systems is 0.42, while for the other systems the average figure is 0.49. These figures are used as the default values in this analysis. Shared-taxi systems are considered more similar to dial-a-ride than to fixed-route or route-deviation services.

Figures on riders per vehicle-hour of demand-responsive service have been collected from 26 systems (1,3,4,5,). Of these, 14 involve dial-a-ride service, 8 are fixed-route or route-deviation systems and 4 are shared-taxi services. The average figure for riders per vehicle-hour (sum of passengers ÷ sum of vehicle-hours) ranges from 4.7 for shared taxi to 9.9 for dial-a-ride to 16.9 for fixed-route/route deviation. These average figures are the default values for riders per vehicle-hour for the respective types of demand-responsive services. These values are also within the expected range given in a survey of demand-responsive systems (6), although values for passengers per vehicle-hour seem higher on Canadian systems (7).

Number of riders per seat is the next measure with which demand-responsive ridership may be estimated. Information is available from 29 systems (2,3,5) of which 19 involve dial-a-ride services, 6 are fixed-route or route-deviation systems and 4 are shared taxi services. The average figure for riders per seat (sum of passengers ÷ sum of available seats) varies from 6.7 for shared-taxi to 5.7 for dial-a-ride to 3.3 for fixed-route/route deviation. These average figures are the default values of passengers per seat for the respective types of demand-responsive services.

There is evidence that services provided specifically for the handicapped have lower patronage per unit of service. An average rate for demand-responsive service ranges from 6 to 16 riders per vehicle-hour, but is as low as 1 to 2 riders per vehicle-hour for services to the handicapped (8). For demand-responsive services targeted specifically for the handicapped, average patronage per unit of service should be estimated at 1/5 of the average measures derived above.

Choice of method for estimating ridership increases is left up to the local analyst and will depend on the data available. Since the calculations are not time-consuming, it might be desirable to obtain a range of estimates using more than one method.

The general formula for computing energy savings resulting from transit-related TSM actions has been derived in Section 14. Adjustments in certain default values are appropriate for analyzing demand-responsive services. Trip lengths associated with demand-responsive services are lower than the original default value of 7.5 miles. One study indicates trip lengths ranging from 1.8 to 2.5 miles on demand-responsive vehicles (9). While paratransit services in rural areas involve longer trips (10), a general default value of 2.5 miles is used for trip length in this analysis.

Average fuel efficiency is greater for demand-responsive transit vehicles, since a van, minibus or full-sized car is often used instead of a bus. A fuel efficiency of 7.2 miles per gallon is reported in Ann Arbor (11), while an efficiency of 6.5 miles per gallon is given for a 19-seat minibus (12). For this analysis, a default value of 7.0 miles per gallon is used, but the local analyst should adjust this depending on type of vehicle used.

Estimates of diversion rates vary widely. Since one of the stated purposes of demand-response transit is to increase mobility, it is obvious that such services will result in a large number of induced trips. Studies in 9 cities indicate a diversion rate ranging from 10% to 60%, with no cause for the variation being immediately apparent (4,5,7,13,14,15). The average of the 9 diversion rates is 28%; for this analysis, a slightly more conservative estimate of 25% is used as the default value.

Other original default values presented in the derivation of the general formula (Section 14) remain unchanged.

Methodology

Step 1: Determine whether the demand-responsive/paratransit service is primarily dial-a-ride, shared-taxi or fixed-route/route deviation.

Step 2: Determine which of the following is an appropriate method of estimating demand-responsive ridership, given the data available: riders per vehicle-mile (Step 3A), riders per vehicle-hour (Step 3B), or riders per seat (Step 3C).

Step 3A: Data needs: daily VMT for demand-responsive services. Demand-responsive ridership can be computed as:

$$\Delta R = a \cdot VMT$$

where VMT is daily VMT for the demand-responsive service and a is average ridership per VMT (default = 0.42 for dial-a-ride/shared-taxi = 0.49 for fixed-route/route-deviation).

Step 3B: Data needs: daily vehicle-hours of service (vh). Ridership can be estimated as:

$$\Delta R = b \cdot vh$$

where b is average ridership per vehicle-hour
(default = 4.7 for shared-taxi
= 9.9 for dial-a-ride
=16.9 for fixed-route/route-deviation).

Step 3C: Data needs: seat per vehicle (s), number of vehicles in service daily (v).

System seat capacity (S) is:

$$S = s \cdot v$$

and daily ridership is estimated as:

$$\Delta R = c \cdot S$$

where c is average daily ridership per seat
(default = 6.7 for shared-taxi
= 5.7 for dial-a-ride
= 3.3 for fixed-route/route deviation).

Step 4: If more than one of the methods in Step 3 are used to compute ridership, take the average of the ridership estimates.

Step 5: If the demand-responsive services are targeted specifically for the handicapped, adjust the ridership estimate by a factor of 0.2:

$$\Delta R_h = 0.2 \cdot \Delta R$$

Step 6: Using the general formula, calculate the energy savings resulting from ridership increases:

$$GS = \frac{\frac{\Delta R \cdot DIV}{OCC} \cdot TL}{MPGa} \cdot CLH$$

with default values:

DIV = 0.25
OCC = 1.6
TL = 2.5
MPGa =17.7
CLH = 0.6

Step 7: Calculate the energy effect of increased VMT resulting from demand-responsive services.

Data needs: increased daily VMT due to demand-responsive services.

$$GS = \frac{-\Delta VMT}{MPGt}$$

where MPGt is average fuel efficiency for the transit vehicle
(default = 7.0).

If a vehicle using diesel fuel provides the service, then a value of 1.104 is needed in the equation as a conversion factor from gallons of diesel fuel to equivalent gallons of gasoline.

Step 8: Add the results of Steps 6 and 7 to obtain the net daily energy savings. To convert this to an annual figure, multiply by 330, since demand-responsive transit is likely to receive heavy use on weekends as well as on workdays.

Note that while the methodology assumes use of daily ridership and VMT figures, it can be used equally well with weekday, monthly or annual data. A worksheet is provided on the following pages.

TSM
ENERGY ANALYSIS
WORKSHEET

DEMAND RESPONSIVE SERVICES

A. VMT METHOD:

VMT		RIDERS PER VMT			SERVICES ORIENTED TOWARD HANDICAPPED		ΔR_1
	X		0.42 FOR SHARED TAXI 0.42 FOR DIAL-A-RIDE 0.49 FOR FIXED ROUTE	X	0.2	=	
					OTHERWISE		
					1.0		

B. VEHICLE HOURS (VH) METHODS:

VH		RIDERS PER VH			FACTOR FOR HANDICAPPED (SEE ABOVE)		ΔR_2
			4.7 FOR SHARED TAXI 9.9 FOR DIAL-A-RIDE 16.9 FOR FIXED ROUTE	X		=	

C. SEAT CAPACITY METHOD:

# SEATS IN FLEET		RIDERS PER SEAT			FACTOR FOR HANDICAPPED (SEE ABOVE)		ΔR_3
	X		6.7 FOR SHARED TAXI 5.7 FOR DIAL-A-RIDE 3.3 FOR FIXED ROUTE	X		=	

[ΔR_1		ΔR_2		ΔR_3]		# METHODS USED		ΔR
	+		+		÷		=	

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		FACTOR FOR CAR LEFT HOME		GAS SAVINGS
	X	0.25	÷	1.6	X	2.5	÷		X	0.6	=	

ΔBUS/VAN VMT		DEMAND RESPONSIVE MPG		GAS COSTS
	÷	7.0	=	

GAS SAVINGS		GAS COSTS		DAILY NET ENERGY SAVINGS		TRAVEL DAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
	-		=		X	330	=	

Example

Data on 18 demand-responsive system is available in Kidder's study (2). Two systems are selected as examples: The Broward County, Florida fixed-route system and the PERT dial-a-ride system in Rochester, NY. The Broward County system has a seating capacity of 60 passengers and runs 251,474 vehicle-miles per year or (dividing by 330) 762 vehicle-miles daily. PERT has a seating capacity of 130 and runs 459,259 vehicle-miles per year or 1,392 vehicle-miles daily. While both systems provide services for the handicapped, neither has as its primary purpose serving the handicapped. The results show that the Broward county system lost an estimated 34,700 gallons yearly, and the Rochester system lost 62,700 gallons. These results are expected since demand-responsive systems generally have low patronage with high levels of VMT. Separate worksheets are used to analyze each system.

In actuality, Broward County's daily ridership was 226 passengers; producing a daily energy savings due to ridership increases of 3.0 gallons, and net energy losses of 105.9 gallons daily and 34,947 gallons annually. The energy estimate obtained by the methods here is within 1% of the actual energy effect.

For the Rochester example, net daily energy losses are 199 gallons. Annually, this is an energy loss of 62,733 gallons of gasoline.

In Rochester, PERT's actual daily ridership was 835 riders producing a daily energy savings due to ridership increases of 11.1 gallons, and net energy losses of 187.8 gallons daily and 61,974 gallons annually. The energy estimate obtained by the methods here is within 2% of the actual energy effect.

TSM
ENERGY ANALYSIS
WORKSHEET

DEMAND RESPONSIVE SERVICES

A. VMT METHOD: BROWARD COUNTY, FL.

VMT		RIDERS PER VMT			SERVICES ORIENTED TOWARD HANDICAPPED		ΔR_1
762	x	0.49	0.42 FOR SHARED TAXI 0.42 FOR DIAL-A-RIDE 0.49 FOR FIXED ROUTE	x	0.2 OTHERWISE 1.0	=	373

B. VEHICLE HOURS (VH) METHODS:

VH		RIDERS PER VH			FACTOR FOR HANDICAPPED (SEE ABOVE)		ΔR_2
—		—	4.7 FOR SHARED TAXI 9.9 FOR DIAL-A-RIDE 16.9 FOR FIXED ROUTE	x	—	=	—

C. SEAT CAPACITY METHOD:

# SEATS IN FLEET		RIDERS PER SEAT			FACTOR FOR HANDICAPPED (SEE ABOVE)		ΔR_3
60	x	3.3	6.7 FOR SHARED TAXI 5.7 FOR DIAL-A-RIDE 3.3 FOR FIXED ROUTE	x	1.0	=	198

	ΔR_1		ΔR_2		ΔR_3			# METHODS USED		ΔR
(	373	+	—	+	198	)	÷	2	=	286

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		FACTOR FOR CAR LEFT HOME		GAS SAVINGS
286	x	0.25	÷	1.6	x	2.5	÷	17.7	x	0.6	=	3.8

ΔBUS/VAN VMT		DEMAND RESPONSIVE MPG		GAS COSTS
762	÷	7.0	=	108.9

GAS SAVINGS		GAS COSTS		DAILY NET ENERGY SAVINGS		TRAVEL DAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
3.8	-	108.9	=	-105.1	x	330	=	-34,683

TSM
ENERGY ANALYSIS
WORKSHEET

DEMAND RESPONSIVE SERVICES

PERT - ROCHESTER, NY

A. VMT METHOD:

VMT		RIDERS PER VMT			SERVICES ORIENTED TOWARD HANDICAPPED		ΔR_1
1,392	x	0.42	0.42 FOR SHARED TAXI 0.42 FOR DIAL-A-RIDE 0.49 FOR FIXED ROUTE	x	0.2	=	585
					OTHERWISE		
					1.0		

B. VEHICLE HOURS (VH) METHODS:

VH		RIDERS PER VH			FACTOR FOR HANDICAPPED (SEE ABOVE)		ΔR_2
—		—	4.7 FOR SHARED TAXI 9.9 FOR DIAL-A-RIDE 16.9 FOR FIXED ROUTE	x	—	=	—

C. SEAT CAPACITY METHOD:

# SEATS IN FLEET		RIDERS PER SEAT			FACTOR FOR HANDICAPPED (SEE ABOVE)		ΔR_3
130	x	5.7	6.7 FOR SHARED TAXI 5.7 FOR DIAL-A-RIDE 3.3 FOR FIXED ROUTE	x	1.0	=	741

ΔR_1		ΔR_2		ΔR_3		# METHODS USED		ΔR
[585	+	—	+	741]	÷	2	=	663

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		FACTOR FOR CAR LEFT HOME		GAS SAVINGS
663	x	0.25	÷	1.6	x	2.5	÷	17.7	x	0.6	=	8.8

ΔBUS/VAN VMT		DEMAND RESPONSIVE MPG		GAS COSTS
1,392	÷	7.0	=	198.9

GAS SAVINGS		GAS COSTS		DAILY NET ENERGY SAVINGS		TRAVEL DAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
8.8	-	198.9	=	-190.1	x	330	=	-62,733

Limitations

Results of the examples are representative of the energy losses involved in demand-responsive ridership; the energy used by the increase in transit VMT and the fact that a high proportion of the trips are induced more than offset energy saved from modal shifts. It must be remembered, however, that energy is not the sole criterion by which to judge the effectiveness or desirability of TSM actions. Demand-responsive services provide mobility for a segment of population which presently is limited in that regard. Policy-makers should be aware of the trade-offs involved in any action, for intelligent decisions are most easily made when full information is available. In the case of demand-responsive service, increasing mobility is associated with an energy cost. This section has provided a methodology with which the energy cost can be estimated.

References

1. J. Misner and R. Waksman, "Service and Cost Characteristics of Small Community Transit: A Tentative Overview of Operational Results," in Paratransit, Washington, DC, Transportation Research Board Special Report 164, 1976.
2. A.E. Kidder et al, "Costs of Alternative Transportation Systems for the Elderly and the Handicapped in Small Urban Areas," Transportation Research Record 660, Washington, DC, Transportation Research Board, 1977.
3. B.I. Keyani and E.S. Putnam, Transportation System Management: State of the Art, Washington, DC, prepared for UMTA by INTERPLAN Corp., Santa Barbara, California, September, 1976.
4. W.F. Hoey, "Dial-a-Ride in the Context of Demand-Responsive Transportation: A Critical Appraisal," Transportation Research Record 608, Washington, DC, Transportation Research Board, 1976.
5. A. Hollinden and R. Blair, "Comparisons of Productivity of Four Modes of Service in Orange County," Urban Transport Service Innovations, Washington, DC, Transportation Research Board Special Report 184, 1979.
6. K. Bhatt, "Costs and Productivities of Innovative Urban Transportation Services," Urban Transport Service Innovations,, TRB Special Report 184, 1979.
7. S. Ling Suen and A. Lehuen, "Review of Paratransit Activities in Canada," Urban Transport Service Innovations, TRB Special Report 184, 1979.
8. Alan M. Voorhees and Associates, Inc., Handbook for Transportation System Management Planning, Volume 2: Handbook for the Evaluation of Individual Transit-Related TSM Actions, Bedford, Texas, prepared for North Central Texas Council of Governments by Alan M. Voorhees and Associates, Inc. August 1977.
9. W.R. Hershey, "Impact of Dial-a-Ride on Transportation-Related Energy Consumption in Small Cities," Transportation Research Record 650, Washington, DC, Transportation Research Board, 1977.
10. Y.J. Stephanedes, Techniques for Analyzing the Performance of Rural Transit System: Performance Indicators and Policy Evaluation in Rural Transit, Volume 2, Washington, DC, prepared for USDOT by Thayer School of Engineering, Dartmouth College, Hanover, NH, October 1980.
11. K.W. Guenther, "Demand-Responsive Transportation in Ann Arbor: Planning and Administration," Transportation Research Record 608, 1976.
12. DeLeuw Cather and Co., Characteristics of Urban Transportation Systems: A Handbook for Transportation Planners, prepared for USDOT, July 1977.
13. E. Kadish, "Evaluation of DRT Systems in Richmond and Santa Barbara," Transportation Research Record 608, 1976.
14. W.R. McDougall, Moderator, Panel Discussion, "Growing Demand-Responsive Systems in the United States and Canada," Demand Responsive Transportation, Washington, DC, Transportation Research Board Special Report 147, 1974.

15. D.S. Greenbaum et al, "Implementation and Preliminary Impacts of Shared-Ride Taxi Service at Boston Logan International Airport," Urban Transport Service Innovations, TRB Special Report 184, 1979.

18. Fare Collection

Improved methods of fare collection can attract new riders to a transit system through increased convenience or through lower per-ride cost. While there is evidence that riders value the convenience of not having to carry exact change (1,2,3), there is also evidence to the contrary (4). It is clear, however, that improved fare collection techniques can reduce boarding time (5) and so reduce in-vehicle travel time. This reduction in in-vehicle travel time is used as the measure for convenience. Many prepayment techniques offer a discount of per-ride cost; this is simple to measure. The effects on transit ridership can be computed using elasticities with respect to in-vehicle time and to cost.

Considerations

Alan M. Voorhees and Associates have provided boarding times per boarding passengers given various fare collection methods (5). Using these figures, a percentage change in boarding time given a switch from one method of fare collection to another can be computed. Results are summarized in Table 18.1. The same source indicates that passenger loading/unloading time comprises 7-25% of in-vehicle travel time (5) for an average of 16%. If the ratio of loading to unloading time is assumed to be 3:1, 12% of total in-vehicle travel time is consumed by passenger loading. If the system does not completely change collection techniques, the local analyst must know the proportion of boarding passengers using each of the various fare collection methods. An on-board survey prior to a change would provide this information. If this information is not available, assume that 1/(n+1) of the riders use each of n techniques and that 2/(n+1) of the riders use cash. This takes into account the likelihood of irregular transit users relying on cash as their form of payment.

Evidence on the elasticity of ridership with respect to in-vehicle travel time has been gathered and presented in Section 14 (6,7,8,). A default value of -0.35, the average of the elasticities reported in the studies cited, is used in this analysis. Percentage change in ridership (r1) can be computed as:

$$r_1 - E_{it} \cdot (b \cdot p) \cdot a$$

where:

E_{it} is the elasticity of ridership with respect to in-vehicle travel time (default = -0.35).

b is the percentage change in boarding time, from Table 18.1

p is the proportion of in-vehicle travel time consumed by passenger loading (default = 0.12).

a is the proportion of passengers using the fare collection method under analysis (default $= \frac{1}{n+1}$ where n is number of collection methods used on the system and $\frac{2}{n+1}$ for the cash method).

Elasticities can also be used to estimate ridership increases due to cost savings. In cases of limited-use prepayment (e.g. a 20-trip ticket or a package of 10 tokens), the cost per ride is known. In cases of limited-time prepayment (monthly pass), the transit operator has in mind an estimate of average use in pricing the pass, and this estimate can be used to calculate cost per ride. Average cost per ride can also be calculated in the event of a change in transfer price.

The Curtin rule gives the elasticity of ridership with respect to fare as -0.33 (9). While there is some disagreement as to whether this figure is valid for fare decreases as well as increases (10, 11), it is considered reliable for the likely range of cost-per-rider decreases and so is used as the default value in this analysis. Percentage change in ridership (r2) due to changes in cost per ride may be computed as follows:

$$r_2 = E_f \cdot c \cdot a$$

where

E_f is the elasticity of ridership with respect to fare (default = -0.33)

c is percentage change in cost per ride

a is the proportion of passengers using the fare collection method under analysis (default - $\frac{1}{n+1}$ where n is number of collection methods used on the system and $\frac{2}{n+1}$ for the cash method).

The overall percentage change in ridership is the sum of the percentage changes resulting from changes in in-vehicle time and in cost per ride.

The general formula for calculating energy savings has been developed in Section 14. Original default values remain unchanged. There is evidence that bulk discounts on fares do not attract riders from automobile (12), but results from surveys in 3 cities seem to indicate a diversion rate over 50% (3). Therefore, the original default value of a 0.5 diversion rate is used here.

Methodology

Step 1: Determine whether the change in fare collection method will change average boarding time. Use Table 18.1. If there is a change, go to Step 2; if not, go to Step 3.

Step 2: Compute percentage change in ridership (r1) due to the change in average boarding time. The formula is:

$$r_1 = E_{it} \cdot (b \cdot p) \cdot a$$

where

E_{it} is the elasticity of ridership with respect to in-vehicle travel time (default = -0.35)

b is percentage change in boarding time (from Table 18.1)

p is the proportion of in-vehicle travel time consumed by passenger loading (default = 0.12)

a is proportion of riders using the new fare collection techniques (default = $\frac{1}{n+1}$ where n is the number of collection methods in use and $\frac{2}{n+1}$ for the cash method).

Step 3: Determine whether the change in fare collection method will change cost per ride. If so, go to Step 4; if not, go to Step 5.

Step 4: Data needs: cost per ride before and after change in collection method.

Compute percentage change in ridership (r_2) due to the change in cost per ride. The formula is:

$$r_2 = E_f \cdot (c_2 - c_1/c_1) \cdot 100 \cdot a$$

where

E_f is the elasticity of ridership with respect to fare (default = -0.33)

c_1 is cost per ride before the change in collection method

c_2 is cost per ride after the charge in collection method

a is proportion of riders using the new collection method (default = $\frac{1}{n+1}$ where n is number of collection methods in use
= $\frac{2}{n+1}$ for the cash method).

Step 5: Compute overall percentage change in ridership resulting from change in fare collection method:

$$r = r_1 + r_2$$

Step 6: Data needs: ridership on route or system before change in collection methods (Ro). Compute change in ridership:

$$\Delta R = \frac{r}{100} \cdot R_o$$

Step 7: Using the general formula developed in Section 14, compute energy savings:

$$GS = \frac{\frac{\Delta R \,.\, DIV}{OCC} \,.\, TL}{MPGa} \,.\, CLH$$

with variables and default values:

DIV = auto-transit diversion rate; default = 0.5
OCC = auto occupancy; default = 1.6
TL = Length of diverted trip; default = 7.5
CLH = Factor for car left home; default = 0.6
MPGa = auto fuel efficiency; default = 17.7

Note that since changes in fare collection techniques do not require increased transit VMT, this figure is the net energy savings. To convert from daily to annual savings, multiply by 250. A worksheet is provided.

TSM
ENERGY ANALYSIS
WORKSHEET

FARE COLLECTION TECHNIQUES

A. TRAVEL TIME EFFECT

% Δ AVG. BOARDING TIME (TABLE 18.1)		PROPORTION OF IN-VEHICLE TRAVEL TIME CONSUMED BY BOARDING		% Δ IN-VEHICLE TRAVEL TIME		e_{TT}		PROPORTION OF RIDERS USING NEW TECHNIQUES (n TECHNIQUES)		$\% \Delta R_1$
	x	0.12	=		x	-0.35	x	$\frac{1}{n+1}$	=	

B. COST EFFECT

% Δ COST PER RIDE		e_{FARE}		PROPORTION OF RIDERS USING NEW TECHNIQUE (n TECHNIQUES)		$\% \Delta R_2$
	x	-0.33	x	$\frac{1}{n+1}$	=	

	$\% \Delta R_1$		$\% \Delta R_2$			PERCENTAGE CONVERSION		RIDERSHIP		ΔR
(		+		)	÷	100	x		=	

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		FACTOR FOR CAR LEFT HOME		DAILY NET ENERGY SAVINGS
	x	0.5	÷	1.6	x	7.5	÷		x	0.6	=	

	WORKDAYS PER YEAR
x	250

	ANNUAL NET ENERGY SAVINGS
=	

Table 18.1

Percentage Change in Boarding Time Resulting From a Change in Fare Collection Technique

New Method	Cash with Zones	Cash	Token/ Single Coin	Passes	On-board	Prepayment
Cash with Zones	--	+40	+40	+75	+75	+75
Cash	-29	--	0	+25	+25	+25
Token/Single Coin	-29	0	--	+25	+25	+25
Passes	-43	-20	-20	--	0	0
On-board	-43	-20	-20	0	--	0
Prepayment	-43	-20	-20	0	0	--

Source: Alan M. Voorhees and Associates (5), Analytical Method 5.

Example

This example is partly hypothetical and partly based on data drawn from a report on a monthly pass system in Sacramento, CA (2). While this data was collected prior to another project involving employer pass sales, it can provide an idea of the impact of the original pass program. For a daily commuter, a monthly pass represents an 18% reduction in cost per ride. About 20% of all riders use the monthly pass. It is assumed that cash was the only prior method of payment available, and that daily ridership on the system is 40,000.

The example worksheet shows a 0.17% ridership increase due to improvements in boarding time and a 1.19% ridership increase resulting from cost reductions. This 1.36 ridership increase translates into an additional 554 daily riders and a daily energy savings of 43.2 gallons. The annual energy savings is 10,805 gallons of gasoline.

TSM
ENERGY ANALYSIS
WORKSHEET

FARE COLLECTION TECHNIQUES

A. TRAVEL TIME EFFECT

% Δ AVG. BOARDING TIME (TABLE 18.1)		PROPORTION OF IN-VEHICLE TRAVEL TIME CONSUMED BY BOARDING		% Δ IN-VEHICLE TRAVEL TIME		e_{TT}		PROPORTION OF RIDERS USING NEW TECHNIQUES (n TECHNIQUES)		$\% \Delta R_1$
-20	x	0.12	=	-2.4	x	-0.35	x	$\cancel{\frac{1}{n+1}}$ .2	=	0.17

B. COST EFFECT

% Δ COST PER RIDE		e_{FARE}		PROPORTION OF RIDERS USING NEW TECHNIQUE (n TECHNIQUES)		$\% \Delta R_2$
-18	x	-0.33	x	$\cancel{\frac{1}{n+1}}$ .2	=	1.19

	$\% \Delta R_1$		$\% \Delta R_2$			PERCENTAGE CONVERSION		RIDERSHIP		ΔR
[	0.17	+	1.19	]	+	100	x	40,000	=	544

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		FACTOR FOR CAR LEFT HOME		DAILY NET ENERGY SAVINGS
544	x	0.5	÷	1.6	x	7.5	÷	17.7	x	0.6	=	43.2

	WORKDAYS PER YEAR
x	250

	ANNUAL NET ENERGY SAVINGS
=	10,805

Limitations

Note that a value of 0.2 is used in the above example for the proportion of riders using a monthly pass. If the default value of $\frac{1}{n + 1}$ or 0.33 is used, the resulting change in ridership becomes 2.24% or 896 and the energy savings becomes 74 gallons daily or 18,500 gallons annually, more than 60% greater than in the example. Proportion of riders using a monthly pass or other special collection technique varies widely (up to 97% in Tulsa (3)). Since this is a key variable in calculating ridership and energy effects, a pre-change survey to indicate potential use might give the local analyst a better feel for an appropriate value.

Care should be taken in comparing the results of this example to results of previous examples. By the nature of this TSM action, the example in this section estimates the change in systemwide ridership; actions in previous sections have been more suited to analysis at the route level.

References

1. R.H. Pratt, N.J. Pederson and J.J. Mather, Traveler Response to Transportation System Changes, Washington, DC, prepared for FHWA by R.H. Pratt Associates, Kensington, MD, February 1977.
2. Public Technology, Inc., Transit Pricing Techniques to Improve Productivity: Proceedings of the March 1979 Forum on Recent Advances and New Directions, Washington, DC, prepared for UMTA by Public Technology, Inc., June 1979.
3. W.R. Hershey et al, Transit Fare Prepayment, Washington, DC, prepared for UMTA by the Huron River Group, Inc., Ann Arbor, Michigan, August 1976. See particularly the experience in Portland and Tulsa.
4. A.E. Shaughnessy (ed), Urban Transportation Economics, Washington, DC, Transportation Research Board Special Report 181, 1978. See particularly the BART experience, reported in "Product Planning and Development" (no author given).
5. Alan M. Voorhees and Associates, Handbook for Transportation System Management Planning, Volume 2: Handbook for the Evaluation of individual Transit-Related TSM Actions, Bedford, Texas, prepared for North Central Texas Council of Governments by Alan M. Voorhees and Associates, August 1977. See particularly Analytical Method 5.
6. M.J. Rothenberg, Public Transportation: An Element of the Urban Transportation System, Washington, DC, FHWA, February 1980.
7. T.J. Atherton and J.H. Suhrbier, Urban Transportation Energy Conservation: Case City Applications of Analysis Methodologies, Volume III, Washington, DC, prepared for DOE by Cambridge Systematics, Inc., September 1978.
8. T.J. Tardiff, J.L. Benham and S. Green, "Methods for Analyzing Fuel Supply Limitations on Passenger Travel," NCHRP Report No. 229, Washington, DC, prepared for Transportation Research Board by Charles River Associates, Inc., December 1980.
9. J.F. Curtin, "Effect of Fares on Transit Riding," Highway Research Record 213, Washington, DC, 1968.
10. D.K. Holland, A Review of Reports Relating to the Effect of Fare and Service Changes in Metropolitan Public Transportation Systems, Washington, DC, prepared for FHWA by Center for Urban Programs, St. Louis University, June 1974.
11. E.P. Donnelly, "Preference Elasticities of Transit Fare Increases and Decreases by Demographic Groups," Preliminary Research Report No. 89, Albany, New York State Department of Transportation, Planning Research Unit, August 1975.
12. Grey Advertising, Inc., Transit Marketing Management Handbook - Pricing, Washington, DC, prepared for UMTA by Grey Advertising in conjunction with Chase, Rosen and Wallace, Inc., April 1976.

19. Amenities

Included in the category of amenities are actions which increase the comfort and convenience of the transit patron or which make the transit system more attractive to present or potential users. The nature of these actions is such that it is difficult to quantify their impacts on ridership. Many studies have indicated that provision of passenger amenities has a small but positive impact on ridership (1,2,3,4,5,6,7,8,9,10,11).

These studies and related issues have been discussed in greater detail in a 1979 report (12). That report concluded that a 2% ridership increase would result on transit systems in New York State, given the nature and extent of actions related to passenger amenities in the TSM plans. The report cited a Federal study indicating a 5% ridership increase as an optimistic assessment of the effects of a major amenities program (13). While a 2% ridership increase seems relatively small, it put passenger amenities at the top of transit-related TSM actions in terms of energy savings (12,14).

Considerations

The focus of this study differs from that of the 1979 report in that here the primary concern is providing a general methodology by which specific actions can be evaluated. The 2% ridership increase figure can serve as a reference point, but each type of amenities should be taken into account in the analysis. It is possible that this approach might overlook synergistic effects resulting from the combination of two or more actions. Since it would be too time-consuming to predict the effects of all possible combinations, this analysis will treat each action separately. The local analyst should keep in mind the caveat regarding synergistic effects.

Actions providing passenger amenities include the following:

- air-conditioning on transit vehicles
- features for the handicapped (such as kneeling buses)
- new buses
- bus shelters with appropriate street facilities
- new bus terminals or transfer facilities
- rehabilitation of existing transit terminals/stations
- provisions related to passenger safety.

There is little hard information on actual changes in ridership resulting from provision of amenities. The approach taken here is to develop estimates based on information in the literature where it is available and base other estimates on judgments of relative importance in attracting riders, all the while keeping in mind the 2% figure from the 1979 study.

It has been reported that air-conditioning can increase ridership by 0-2%, while improvements at bus stops (shelters, signs, vending services, phone) can result in a 0-1% ridership increase (8). This suggests that air-conditioning is twice as important as bus shelters in attracting ridership. A default factor of 0.5% is assigned for ridership increase resulting from air-conditioning and 0.25% for ridership increase associated with bus shelters. The factor for air-conditioning presumes that all buses are air-conditioned; the factor for bus shelters presumes that at least 75% of people boarding a given route or system are protected by shelters and that there are additional amenities at heavily-used bus stops. The factors can be adjusted if conditions differ, within the ranges given above.

It is reasonable to assume that new buses will have slightly more impact on ridership than does supplying air-conditioning on existing buses. A default factor of 0.6% is used for the ridership increase resulting from new buses. This factor should be adjusted depending upon proportion of the bus fleet that is new on a given system or route.

One study has indicated that ridership among the mobility-impaired might increase by 12% in response to provision of special features for the handicapped such as kneeling buses (8). This 12% increase among mobility-impaired would result in a 0.4% increase in overall patronage, according to the study. This estimate seems to be high; a more realistic estimate would be a 0.2% increase in overall patronage due to provision of features for the handicapped. The default value used in this analysis is 0.2%, assuming that at least every other bus is so equipped.

New bus terminals or transfer facilities can be assumed to affect ridership to the same degree as bus shelters, so a default value of 0.25% is used to compute ridership increases on routes using the terminal or facility. Rehabilitation of existing terminals or facilities is likely to have slightly less of an effect. A default value of 0.2% is used to gauge the ridership increase resulting from such rehabilitation for the involved routes.

Provisions related to passenger safety may (11) or may not (15) affect ridership; it is likely that existing perceptions of safety play a significant role in determining the effect of actions to increase safety. Safety-related actions may not affect ridership at all if the system is already perceived as relatively safe. If, however, there are major problems with crime and vandalism, actions such as increased police presence, closed-circuit surveillance of stations or changes in station or bus shelter design can alleviate some of the fears of potential riders. However, no set of actions will go far in attracting riders if people believe the system to be unsafe. A cautious estimate of a 0.5% increase in ridership is used as the default value for response to a coordinated program of safety improvements in a situation where transit is perceived to be unsafe. If only some of the safety improvements mentioned above are made, 0.25% is the default value.

If the system is perceived as relatively safe, no change in ridership is assumed. The local analyst must make the judgment as to perceptions of safety.

If all the ridership effects are summed, a net ridership increase of 2.0% is obtained. (This summation takes account of the fact that the effects of air-conditioning are included in the effects of new buses.). This agrees with the 2% figure cited in the 1979 study mentioned earlier (12). With synergistic effects, the ridership increase might total near the 5% maximum cited in the Federal study (13). It is assumed that amenities generally affect only weekday use of transit.

The genral formula for computing energy savings has been derived in the Section 14. Original default values remain unchanged.

Methodology

Step 1: Determine whether the amenities-related action involves new buses (Step 4), air-conditioning of existing vehicles (Step 5), bus shelters (Step 6), features for the handicapped (Step 7), new bus terminals or transfer facilities (Step 8), rehabilitation of existing transit terminals (Step 9) or stations (Step 10) or provisions related to passenger safety (Step 2). Proceed to the appropriate step. Default values developed above are used at each step.
Step 2: Determine, using the analyst's sense of public opinion, whether the transit system is considered relatively safe.
Step 3: If the transit system is considered relatively safe, there is no change in ridership. If the transit system is not considered relatively safe, default values for percentage change in ridership (r_8) are:

$r_8 = 0.25$ if some but not all changes are included.

Step 4: Data needs: Number of new buses (n) on route, total number of buses (b) on route.

Calculate the percentage change in ridership (r_1) due to new buses:

$$r_1 = 0.6 \cdot \frac{n}{b}$$

Step 5: Data needs: Number of air-conditioned buses (a) on route; total number of buses (b) on route.

Calculate the percentage change in ridership (r_2) due to air-conditioning:

$$r_2 = 0.5 \cdot \frac{a}{b}$$

<u>Step 6</u>: <u>Data needs</u> Approximate percentage of riders on route affected by <u>bus shelters</u> (p).

Calculate the percentage change in ridership (r_3) due to bus shelters:

$$\begin{aligned} r_3 &= 0.25 \text{ if } p \geq 75 \\ &= 0.25 \cdot \frac{p}{75} \text{ if } p < 75. \end{aligned}$$

<u>Step 7</u>: <u>Data needs</u>: Number of <u>kneeling buses</u> on route (h); total number of buses (b) on route.

Calculate the percentage change in ridership (r_4) due to features for the handicapped:

$$\begin{aligned} r_4 &= 0.2 \text{ if } \frac{h}{b} \geq 0.5 \\ &= 0.2 \cdot \frac{h}{b} \text{ if } \frac{h}{b} < 0.5 \end{aligned}$$

<u>Step 8</u>: Default value for percentage change in ridership (r_5) for each route using the <u>new bus terminal</u> or <u>transfer facility</u> is 0.25.

<u>Step 9</u>: Default value for percentage change in ridership (r_6) for each route using the <u>rehabilitated terminal</u> is 0.2.

<u>Step 10</u>: <u>Data needs</u>: Percentage of riders on route using <u>rehabilitated stations</u> (q).

Calculate the percentage change in ridership (r_7) due to station rehabilitation:

$$r_7 = 0.2 \cdot q$$

<u>Step 11</u>: <u>Data needs</u>: Present ridership (Ro) on route.

Calculate the change in ridership:

$$R = Ro \cdot \frac{r}{100}$$

where r is the sum of r_x from $x = 1$ to $x = 8$.

<u>Step 12</u>: Using the general formula, calculate energy savings:

$$GS = \frac{\frac{\Delta R \cdot DIV}{OCC} \cdot TL}{MPGa} \cdot CLH$$

with default values:

DIV = auto-transit diversion rate; default = 0.5
OCC = auto occupancy; default = 1.6
TL = length of diverted trip; default = 7.5
MPGa = average auto fuel efficiency; default = 17.7
CLH = factor for car left home; default = 0.6

Since amenities actions do not require additional transit VMT, the energy savings due to ridership increases is the net energy savings. To convert to annual savings multiply by 250. If the local analyst feels that the actions taken affect weekend as well as workday ridership, use 330 as a factor to convert to annual savings.

TSM
ENERGY ANALYSIS WORKSHEET

PASSENGER AMENITIES

A. NEW AND AIR-CONDITIONED BUSES

# NEW OR A/C BUSES ON ROUTE		# BUSES ON ROUTE		% ΔR FOR NEW OR A/C BUSES				% ΔR1
	÷		x		0.6 NEW 0.5 A/C	=		

NOTE: IF NEW BUSES ARE ALSO A/C, USE NEW BUS NUMBER ONLY.

B. KNEELING BUSES

% KNEELING BUSES [ ]
≥50 → % ΔR2: 0.2
<50 →

			% ΔR FOR KNEELING BUSES		% ΔR2	
÷	50	x	0.2	=		

C. BUS SHELTERS

% R AFFECTED BY SHELTERS [ ]
≥75 → % ΔR3: 0.25
<75 →

			% ΔR FOR SHELTERS		% ΔR3
÷	75	x	0.25	=	

D. NEW TERMINALS — % ΔR4: 0.25

E. REHABILITATED TERMINALS — % ΔR5: 0.2

F. REHABILITATED STATIONS

% R USING STATIONS		% ΔR FOR STATIONS		% ΔR6
	x	0.2	=	

G. SAFETY IMPROVEMENTS — % ΔR7 [ ]

0 IF SYSTEM IS CURRENTLY PERCEIVED AS SAFE
0.5 IF ADDED POLICE, CLOSED-CIRCUIT MONITORING AND DESIGN CHANGES ALL PARTS OF PROGRAM
0.25 IF SOME ARE PART OF PROGRAM

%ΔR (Σ%ΔRn)		PERCENTAGE CONVERSION		R		ΔR
	÷	100	x		=	

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		FACTOR FOR CAR LEFT HOME		DAILY NET ENERGY SAVINGS
	x	0.5	÷	1.6	x	7.5	÷		x	0.6	=	

	WORKDAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
x	250	=	

Example

This example is hypothetical, involving a route with an average weekday ridership of 2,400. Fifty percent of the buses currently in use are replaced by new, air-conditioned, kneeling buses. Bus shelters are installed at virtually every stop; shelters in the CBD are heated, and all have benches and public phones. An existing transit terminal which is a major stop on this route is modernized. Among the changes in the terminal is a new closed circuit surveillance system, for there have been several well-publicized crimes at the terminal. Ridership changes and energy savings can be estimated by use of the worksheet.

In this example, amenities result in a ridership increase of 1.2% or 29 riders per day. This results in energy savings of 2.3 gallons daily or 575 gallons of gasoline annually from provision of amenities on this route.

TSM
ENERGY ANALYSIS
WORKSHEET

PASSENGER AMENITIES

A. NEW AND AIR-CONDITIONED BUSES

# NEW OR A/C BUSES ON ROUTE		# BUSES ON ROUTE		% ΔR FOR NEW OR A/C BUSES			$\% \Delta R_1$
50%	÷		x	0.6	0.6 NEW 0.5 A/C	=	0.3

NOTE: IF NEW BUSES ARE ALSO A/C, USE NEW BUS NUMBER ONLY.

B. KNEELING BUSES

% KNEELING BUSES: 50

≥50 → $\% \Delta R_2$: (0.2)

<50 →

% KNEELING BUSES				% ΔR FOR KNEELING BUSES		$\% \Delta R_2$
50	÷	50	x	0.2	=	NA

C. BUS SHELTERS

% R AFFECTED BY SHELTERS: 90

≥75 → $\% \Delta R_3$: (0.25)

<75 →

% R AFFECTED BY SHELTERS				% ΔR FOR SHELTERS		$\% \Delta R_3$
90	÷	75	x	0.25	=	NA

D. NEW TERMINALS $\% \Delta R_4$: ~~0.25~~ NA

E. REHABILITATED TERMINALS $\% \Delta R_5$: (0.2)

F. REHABILITATED STATIONS

% R USING STATIONS		% ΔR FOR STATIONS		$\% \Delta R_6$
NA	x	0.2	=	NA

G. SAFETY IMPROVEMENTS $\% \Delta R_7$: 0.25

0 IF SYSTEM IS CURRENTLY PERCEIVED AS SAFE
0.5 IF ADDED POLICE, CLOSED-CIRCUIT MONITORING AND DESIGN CHANGES ALL PARTS OF PROGRAM
0.25 IF SOME ARE PART OF PROGRAM

$\% \Delta R (\Sigma \% \Delta R_n)$		PERCENTAGE CONVERSION		R		ΔR
1.2	÷	100	x	2,400	=	29

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		FACTOR FOR CAR LEFT HOME		DAILY NET ENERGY SAVINGS
29	x	-0.5	÷	1.6	x	7.5	÷	17.7	x	0.6	=	2.3

	WORKDAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
x	250	=	575

Limitations

There is little quantitative evidence on which to base estimates of the effects of provision of amenities. Past experience in a given locality may indicate that some actions are more or less effective than we have assumed, and the local analyst is encouraged to use his knowledge in this regard to adjust default values. These default values are best estimates drawn from the transportation literature and our judgment of the relative importance of certain actions. If anything, the estimates tend toward the conservative side; ridership increases as high as 18% have been estimated to result from provision of amenities (8). The conservative bias in these estimates is in line with the general finding that provision of amenities has a small but positive effect on transit ridership.

Since provision of amenities does not necessitate increased transit VMT, energy savings resulting from ridership increases are net energy savings for such actions. Provision of amenities is one of the most energy-efficient of all transit-related TSM actions.

References

1. R.H. Pratt, N.J. Pederson and J.J. Mather, Traveler Response to Transportation System Changes, Washinton, DC, prepared for FHWA by R.H. Pratt Associates, Inc., Kensington, MD, February 1977.
2. D.K. Holland, A Review of Reports Relating to the Effect of Fare and Service Changes in Metropolitan Public Transportation Systems, Washington, DC, prepared for FHWA by Center for Urban Programs, St. Louis University, June 1974.
3. J.H. Shortreed (ed.), Urban Bus Transit - A Planning Guide, Waterloo, Ontario, University of Waterloo, May 1974.
4. D.T. Hartgen and G.H. Tanner, "Behavioral Model of Mode Choice," Preliminary Research Report No. 19, Albany, New York State Department of Transportation, Planning Research Unit, March 1970.
5. B. Pushkarev and J. Zupan, Public Transportation and Land-Use Policy, Bloomington, IN, Indiana University Press, 1977.
6. Louis Harris and Associates, New Yorkers Evaluate Their Transportation Systems, New York City, Louis Harris and Associates, April 1978.
7. P. Hernandez, Bus Passenger Waiting Shelters, Sacramento, California Department of Transportation, January 1977.
8. Alan M. Voorhees and Associates, Inc. Handbook for Transportation System Management Planning, Volume 2: Handbook for the Evaluation of Individual Transit-Related TSM Actions, Redford, Texas, prepared for the North Central Texas Council of Governments by Alan M. Voorhees and Associates, Inc., August 1977. Procedures I and M are important for this analysis.
9. R. Krzyczkowski et al, Joint Strategies for Urban Transportation, Air Quality and Energy Conservation, Volume 1: Joint Action Programs, Washington, DC, prepared for UMTA and EPA by INTERPLAN Corporation, Santa Barbara, California, December 1974.
10. N.D. Ferrari and M.F. Trentacoste, "Personal Security on Public Transit," Preliminary Research Report No. 61, Albany, New York State Department of Transportation, Planning Research Unit, May 1974.
11. E. Thrasher and J. Schnell, "Study of Public Attitudes Toward Transit Crime and Vandalism," Transportation Research Record 487. Washington, DC, Transportation Research Board, 1974.
12. J.M. Gross et al, "Energy Impacts of Transportation Systems Management Actions in New York State, 1978-1980," Preliminary Research Report No. 151, Albany, New York State Department of Transportation, Planning Research Unit, May 1979.
13. Office of Technology Assessment, U.S. Congress, Energy, the Economy and Mass Transit, Washington, DC, U.S. Government Printing Office, 1975.
14. D.K. Boyle, "Effects of Small Scale Transit Improvements on Saving Energy," Transportation Research Record 761, Washington, DC, Transportation Research Board, 1980.
15. K. Sinha and F. Roeiner, "Personal Security in Buses and Its Effects on Ridership in Milwaukee," Transportation Research Record 487, Washington,DC, 1974.

20. Monitoring

Virtually any evaluation of the effectiveness of a transit system can be categorized as a monitoring action. For the purposes of this analysis, monitoring actions are defined as those actions involving specific situation, real-time monitoring (such as two-way radio and other communication systems) and broader system-wide monitoring (designed to increase and standardize data collection or to improve the internal efficiency of the transit system.)

This analysis relies heavily on a 1979 analysis done by NYSDOT (1, 2). There has been little work done on the effects of monitoring actions on ridership since that time.

It has been suggested that monitoring actions are necessary to maintain a high level of service and patronage (3), but the direct effects of such actions on ridership are insignificant. System-wide monitoring actions can increase the efficiency of the system and lead to energy savings by reducing bus VMT. As an example, the RUCUS package is a set of computer programs designed to expedite and improve the efficiency of schedule-making for mass transit. Field tests in 6 cities nationwide have shown a decrease in vehicle-hours on the order of 1.3% to 4.8% (4). If it is assumed that average speed is not changed by RUCUS and that vehicle reassignment is not extensive, then these figures can serve as a range of percentage decrease in VMT resulting from increased scheduling efficiency. Other studies have indicated that RUCUS can reduce vehicle requirements by 5-7% (5,6). Again, assuming that vehicle reassignment is not extensive, VMT savings from this reduction in vehicle requirements are within the range mentioned above. A conservative default value of -1.0% is used for percentage change in VMT resulting from implementation of RUCUS or a similar computer package. This default value allows for the likelihood of some vehicle reassignment. Since RUCUS is designed to increase efficiency, it is assumed that the reduction in VMT affects marginal or redundant transit services and so does not have an impact on ridership. Whatever ridership is lost on marginal routes is recouped with even minimal vehicle reassignment.

Section 14 has derived a formula for calculating energy savings resulting from a change in transit VMT; this formula is used in the analysis here. The original default value for average transit fuel efficiency is 4.0 miles per diesel gallon and 1.104 is a conversion factor from diesel gallons to equivalent gallons of gasoline. It is assumed that RUCUS does not significantly affect weekend scheduling, but rather that its effects are felt on weekdays, particularly for peak-hour scheduling. A figure of 250 is used to convert daily savings to annual savings.

Methodology

Step 1: Determine whether RUCUS or some other computerized scheduling package is being implemented. If not, there are no energy effects.

Step 2: Data needs: daily VMT on system (VMT).

Calculate the change in bus VMT:

$$\Delta VMT = \frac{v}{100} \cdot VMT$$

where v is the percentage change in VMT due to computerized scheduling (default = -1.0).

Step 3: Calculate daily energy savings:

$$GS = \frac{-\Delta VMT}{MPGt} \cdot 1.104$$

where MPGt is transit fuel efficiency (default = 4.0 miles per diesel gallon)
Annual energy savings may be obtained by multiplying by 250.

TSM
ENERGY ANALYSIS WORKSHEET

MONITORING ACTIONS

BUS VMT		% ΔVMT DUE TO COMPUTERIZATION		PERCENTAGE CONVERSION		ΔBUS VMT
	x	-1.0	÷	100	=	

ΔBUS VMT		BUS MPG		DIESEL-GASOLINE CONVERSION FACTOR		GAS COSTS
	÷	4.0	x	1.104	=	

GAS SAVINGS		GAS COSTS		DAILY NET ENERGY SAVINGS		WORKDAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
0	-		=		x	250	=	

Example

This example involves a hypothetical system with an average daily bus VMT of 20,000 vehicle-miles. RUCUS is implemented on the system. The example worksheet demonstrates the resultant energy savings.

Systemwide energy savings from the implementation of RUCUS approach 15,000 equivalent gallons of gasoline annually in this example. A reduction in bus VMT can obviously have a direct effect on energy savings.

TSM
ENERGY ANALYSIS WORKSHEET

MONITORING ACTIONS

BUS VMT		% ΔVMT DUE TO COMPUTERIZATION		PERCENTAGE CONVERSION		ΔBUS VMT
20,000	x	-1.0	÷	100	=	-200

ΔBUS VMT		BUS MPG		DIESEL-GASOLINE CONVERSION FACTOR		GAS COSTS
-200	÷	4.0	x	1.104	=	-55.2

GAS SAVINGS		GAS COSTS		DAILY NET ENERGY SAVINGS		WORKDAYS PER YEAR		ANNUAL NET ENERGY SAVINGS
0	-	-55.2	=	55.2	x	250	=	13,800

Limitations

This analysis presumes that RUCUS is used to reduce system-wide VMT. It is conceivable that a transit operator would opt instead for extensive vehicle reassignment. This path could be taken because of congested conditions on certain routes or because of labor agreements. The local analyst must know the parameters within which the operator is functioning and the operator's intentions.

The 1% figure for bus VMT reduction might also be high. The example worksheet shows a daily reduction of 200 vehicle-miles, translating to an annual reduction of 50,000 vehicle-miles. The analysis treats this as redundant or marginal service; it is possible that this potential VMT reduction, even given some vehicle reassignment, is overestimated.

In the long run, increased internal efficiency resulting from all monitoring actions will gradually filter through the transit system and increase operating efficiency. This could well affect not only the energy efficiency of the system but also system ridership. Since this analysis is focused on more immediate effects, long-range considerations have not been addressed here. However, the analyst should be aware of these long-term considerations.

References

1. J.M. Gross et al, "Energy Impacts of Transportation Systems Management Actions in New York State, 1978-1980", Preliminary Research Report No. 151, Albany, New York State Department of Transportation, Planning & Research Unit, May 1979.
2. D.K. Boyle, "Effects of Small-Scale Transit Improvements on Saving Energy," Transportation Research Record 761, Washington, DC, Transportation Research Board, 1980.
3. D.A. Morin, "Neglected High-Achievement TSM Actions," Transportation System Management in 1980: State of The Art and Future Directions, Washington, DC, Transportation Research Board Special Report 190 1980.
4. K.R. Roberts, Vehicle Scheduling and Driver Run Cutting - RUCUS Package Overview, Washington, DC, the MITRE Corporation, May, 1973.
5. Alan M. Voorhees and Associates, Inc., Handbook for Transportation System Management Planning, Volume 2: Handbook for the Evaluation of Individual Transit-Related TSM Actions, Bedford, TX, prepared for the North Central Texas Council of Governments, by Alan M. Voorhees and Associates, August, 1977.
6. D.H. Hinds, "RUCUS - A Comprehensive Status Report and Assessment," Transit Journal, Vol. 5, No. 1, Winter, 1979.

21. Maintenance

Improved maintenance can increase the efficiency, reliability, attractiveness and safety of the transit system and reduce the likelihood of major capital expenditures for rehabilitation in the future. Good maintenance practices can minimize the number of vehicles out of service, reduce operating costs, reinforce the effects of other transit improvements and improve the public's image of the transit system. Unfortunately, there is neither a standard definition of good maintenance practices nor a reliable quantitative measure of maintenance improvements.

Considerations

A 1979 analysis done by NYSDOT hypothesized three ways in which improved maintenance can lead to energy savings (1,2). For the purposes of this analysis, the increase in bus operating efficiency is considered the only means by which energy savings are created by improved maintenance. While it is likely that improved maintenance can extend the lifespan of buses, such second-order energy effects are not considered in this analysis. It is likely that availability of money as opposed to need is the determining factor in the purchase of new buses, and so bus lifespan may not be a vital factor. It is also conceivable that ridership could increase as a result of improved maintenance, but improved maintenance tends to reinforce the effects of other improvements rather than have a direct impact on ridership. Because ridership increases for other transit-related TSM actions have been estimated under "best-case" conditions, it would be redundant to count ridership increases as a direct result of improved maintenance.

The 1979 analysis cited Metropolitan Transportation Authority officials in New York City as sources indicating that an increase in bus fuel efficiency of 0.1 miles per gallon could be expected from improved maintenance (2). Another source indicates that fuel consumption can be reduced up to 5% through engine modifications and energy-conscientious maintenance. (3); 5% of an average bus mpg figure (4.0) is 0.2 miles per gallon. The problem here is that no operational definition of improved or energy-conscientious maintenance is provided. The decision as to whether the improvements in maintenance practice are sufficient to improve the average operating efficiency is left to the local analyst. A conservative default value of 0.05 miles per gallon is suggested as the change in bus MPG resulting from improved maintenance. This value may be used when the local analyst feels that a maintenance schedule for buses is being established or stepped up and that it will, in some ways, increase operating efficiency.

Average bus MPG is assumed at 4.0 miles per diesel gallon. A factor of 1.104 is necessary to convert from diesel gallons to equivalent gallons of gasoline. Given the nature of maintenance actions, annual figures are most appropriate for calculating energy savings.

Methodology

Step 1: Determine whether maintenance improvements which are likely to result in increased operating efficiency are being made. If not, there are no direct energy effects from maintenance actions.
Step 2: Data needs: annual bus VMT on system.

Calculate the energy used on the transit system before the maintenance improvements:

$$ENUSEo = \frac{VMT}{MPGt} \cdot 1.104$$

where MPGt is the average bus fuel efficiency (default = 4.0).

Step 3: Calculate the energy used after the maintenance improvement

$$ENUSE1 \quad \frac{VMT}{MPGt + \Delta MPGt} \cdot 1.104$$

where MPGt is the change in bus fuel efficiency resulting from the maintenance improvement (default = 0.05).

Step 4: Calculate energy savings.

$$GS = ENUSEo - ENUSE1$$

TSM
ENERGY ANALYSIS WORKSHEET

MAINTENANCE

$$\overset{\text{BUS VMT (ANNUAL)}}{\boxed{}} \div \left\{ \begin{array}{l} \overset{\text{BUS MPG}}{\boxed{4.0}} \times \overset{\text{DIESEL-GASOLINE CONVERSION FACTOR}}{\boxed{1.104}} = \overset{\text{ENERGY COSTS, BEFORE}}{\boxed{}} \\ \left(\overset{\text{BUS MPG}}{\boxed{4.0}} + \overset{\Delta\text{MPG DUE TO MAINTENANCE}}{\boxed{0.05}} \right) \times \overset{\text{DIESEL-GASOLINE CONVERSION FACTOR}}{\boxed{1.104}} = \overset{\text{ENERGY COSTS, AFTER}}{\boxed{}} \end{array} \right.$$

$$\overset{\text{ENERGY COSTS, BEFORE}}{\boxed{}} - \overset{\text{ENERGY COSTS, AFTER}}{\boxed{}} = \overset{\text{ANNUAL NET ENERGY SAVINGS}}{\boxed{}}$$

Example

This example involves a hypothetical system with an annual VMT of 6 million vehicle-miles. A new maintenance schedule is established which reduces the time between maintenance overhauls. The accompanying worksheet indicates how to compute the energy savings.

As can be seen by the example worksheet, slightly over 20,000 equivalent gallons of gasoline are saved annually in the hypothetical example by maintenance improvements. This is only 1.2% of the energy used in the original year. This analysis does not consider the cost involved with doing this increased maintenance, so no estimate of the benefit/cost ratio can be developed.

TSM
ENERGY ANALYSIS
WORKSHEET

MAINTENANCE

$$\overset{\text{BUS VMT (ANNUAL)}}{\boxed{6{,}000{,}000}} \div \left\{ \begin{array}{l} \overset{\text{BUS MPG}}{\boxed{4.0}} \times \overset{\text{DIESEL-GASOLINE CONVERSION FACTOR}}{\boxed{1.104}} = \overset{\text{ENERGY COSTS, BEFORE}}{\boxed{1{,}656{,}000}} \\ \left[\overset{\text{BUS MPG}}{\boxed{4.0}} + \overset{\Delta\text{MPG DUE TO MAINTENANCE}}{\boxed{0.05}} \right] \times \overset{\text{DIESEL-GASOLINE CONVERSION FACTOR}}{\boxed{1.104}} = \overset{\text{ENERGY COSTS, AFTER}}{\boxed{1{,}635{,}556}} \end{array} \right.$$

$$\overset{\text{ENERGY COSTS, BEFORE}}{\boxed{1{,}656{,}000}} \quad \overset{\text{ENERGY COSTS, AFTER}}{\boxed{1635{,}556}} = \overset{\text{ANNUAL NET ENERGY SAVINGS}}{\boxed{20{,}444}}$$

Limitations

Information on the effects of improved transit maintenance is sorely lacking. It is plausible that improved maintenance does affect energy use, but there is little quantification of either the degree of improvement in maintenance practice or the degree of its impact on energy use. This analysis has made a relatively conservative estimate of the impact, but much is left to the local analyst's judgment. Until better information becomes available, the accuracy of the results of this technique must rely on the acuity of that judgment.

References

1: J.M. Gross et al, "Energy Impacts on Transportation Systems Management Actions in New York State, 1978-1980," Preliminary Research Report No. 151, Albany, New York State Department of Transportation, Planning & Research Unit, May, 1979.

2. D.K. Boyle, "Effects of Small-Scale Transit Improvements on Saving Energy," Transportation Research Record 761, Washington, DC, Transportation Research Board, 1980.

3. Alan M. Voorhees and Associates, Inc., Handbook for Transportation System Management Planning, Volume 2: Handbook for the Evaluation of Individual Transit Related TSM Actions, Bedford, Texas, prepared for the North Central Texas Council of Governments by Alan M. Voorhees and Associates, Aug., 1977.

22. Marketing and Passenger Information

TSM actions which fall under this category are those which encourage increased use of the transit system by telling the potential rider why (marketing) and how (information) to use the system. Virtually any change in the transit system can be viewed as part of a marketing strategy; in this analysis, marketing actions are defined as efforts to publicize the existence of either the transit system itself or various special programs. Passenger information actions include transit maps, timetables, bus stop signs, system graphics and both telephone and walk-in information center. Marketing and information actions increase the general awareness of the transit system and provide specific aids for its use. As such, these actions attract new riders to transit and encourage increased use among existing riders.

Considerations

There are various opinions regarding the effectiveness of marketing and information actions. Generally, a 0-2% ridership increase has been estimated to result from marketing programs (1,2), with an upper limit of a 2-4% increase (3). Since actions of these types are almost always tied to some other change in service or fare, it is difficult to isolate the effects of marketing and information. Where steps have been taken to isolate these effects, it has been found that the law of diminishing returns quickly reduces the effectiveness of these actions (3,4). Apparently, brief exposure to information concerning the transit system does not change behavioral intentions (5). On the other hand, inadequate knowledge of the system is a deterrent to ridership (5).

What this suggests is that a sustained program of marketing and information actions is necessary in order for these actions to be consistently effective. The potential for aggressive marketing campaigns is generally recognized; for example, the effectiveness of marketing actions in conjunction with a fare decrease is considered to be very high (1,6). A sustained program can increase the general visibility of transit and can guard against the gradual decline in effectiveness noted in many places where short range programs were tried.

Unfortunately for the purposes of this analysis, no study has provided operational definitions of what constitutes a "sustained" program or "brief" exposure. In the absence of specific guidelines with which to gauge the extent of a transit marketing and information program, the best approach is to estimate the ridership response to a "typical" marketing/information package. To judge from the sources previously cited, such a typical package might include 2 of the following actions:

- a coordinated advertising campaign using the media;
- tie-ins with local merchants;
- increased availability of transit maps and schedules;
- coordination and improvement of system graphics;
- establishment of telephone or walk-in information center.

All of these actions increase the visibility of public transit. A media campaign and information centers are judged to be the most effective actions.

A study by Voorhees (1) indicates that marketing programs and air conditioning of buses have roughly similar effects on ridership. In Section 18 of this analysis, a ridership increase of 0.5% was estimated to result from air conditioning of buses; the same figure should be used here for consistency. A 0.5% ridership increase is estimated as the result of a "typical" package of marketing and information actions. Adjustment of this figure due to local conditions or to the extent of the marketing/information actions is left to the judgment of the local analyst.

The formula for computing gasoline savings resulting from ridership increases has been derived in Section 14 of this report. For the analysis in this section, the original default values remain unchanged.

Methodology

Step 1: Determine whether the actions being taken constitute a "typical" marketing/information package. If not, the local analyst may wish to adjust the estimate of ridership increase.
Step 2: Data needs: present daily ridership on route or system (Ro). Calculate the change in ridership resulting from the marketing/information actions:

$$\Delta R = \frac{r}{100} \,.\, Ro$$

where r is the percentage change in ridership (default = 0.5).

Step 3: Using the general formula, calculate the energy savings resulting from the change in ridership:

$$GS = \frac{\frac{\Delta R \,.\, DIV}{OCC} \quad TL}{MPGa} \qquad CLH$$

with variables and default values:

DIV = auto - transit diversion; default = 0.5
OCC = auto occupancy; default = 1.6
TL = length of diverted trip; default = 7.5
MPGa = auto fuel efficiency; default = 17.7
CLH = factor for car left home; default = 0.6

The savings calculated in Step 3 are the net daily energy savings, since these actions do not affect transit VMT. It is assumed that a large portion of the effects on ridership is felt in weekday travel, so a factor of 250 is used to convert daily savings to annual savings. If the marketing program is aimed at non-work travel, a different factor might be more appropriate.

TSM
ENERGY ANALYSIS WORKSHEET

MARKETING/PASSENGER INFORMATION

RIDERSHIP		% ΔR DUE TO MARKETING/INFO		PERCENTAGE CONVERSION		ΔR
	X	0.5	÷	100	=	

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		FACTOR FOR CAR LEFT HOME		DAILY NET ENERGY SAVINGS
	X	0.5	÷	1.6	X	7.5	÷		X	0.6	=	

	WORKDAYS PER YEAR
X	250
	ANNUAL NET ENERGY SAVINGS
=	

Example

Marketing and information actions, like fare collection actions, generally affect the entire transit system. For the fare collection example in Section 18 of this report, daily ridership on the transit system was assumed to be 40,000. This assumption is made here also. The transit operator is planning a major media blitz to publicize the transit system and is also establishing a "Mainline Transit" telephone information center. The energy effects of these actions can be calculated through use of the worksheet. Since these actions fall into this section's definition of a "typical" marketing/information package, the default value of 0.5% is used to estimate ridership increases.

The example worksheet indicates a ridership increase of 200 per day due to the marketing/information program. Resultant energy savings are 15.9 gallons of gasoline daily or 3,975 gallons on an annual basis.

TSM
ENERGY ANALYSIS WORKSHEET

MARKETING/PASSENGER INFORMATION

RIDERSHIP		% ΔR DUE TO MARKETING/INFO		PERCENTAGE CONVERSION		ΔR
40,000	x	0.5	÷	100	=	200

ΔR		TRIP DIVERSION RATE		AUTO OCCUPANCY		DIVERTED TRIP LENGTH		(TABLE 1.3) AUTO MPG		FACTOR FOR CAR LEFT HOME		DAILY NET ENERGY SAVINGS
200	x	0.5	÷	1.6	x	7.5	÷	17.7	x	0.6	=	15.9

	WORKDAYS PER YEAR
x	250
	ANNUAL NET ENERGY SAVINGS
=	3,975

Limitations

There is a lack of solid information on which to base estimates of the effects of marketing/information actions on transit ridership. This analysis tilts toward the conservative side of ranges of ridership increases estimated in other studies, but no account has been taken here of the diminishing effects of marketing actions over time. The local analyst is left with more responsibility to determine ridership changes here than for other transit-related TSM actions. Nonetheless, the "best estimate" approach presented in this section is the preferred alternative given the difficulty in isolating and quantifying these types of actions and the absence of solid information concerning their effects.

References

1. Alan M. Voorhees and Associates, Inc., Handbook for Transportation System Management Planning, Volume 2: Handbook for the Evaluation of Individual Transit-Related TSM Actions, Bedford, TX, prepared for the North Central Texas Council of Governments by Alan M. Voorhees and Associates, August, 1977.
2. J.M. Gross et al, "Energy Impacts of Transportation System Management Actions in New York State, 1978-80," Preliminary Research Report No. 151, Albany, New York State Department of Transportation, Planning Research Unit, May, 1979.
3. Office of Technology Assessment, U.S. Congress, Energy, the Economy and Mass Transit, Washington, DC, U.S. Government Printing Office 1975.
4. R.H. Pratt, N.J. Pedersen and J.J. Mather, Traveler Response to Transportation System Changes, Washington, DC prepared for FHWA by R.H. Pratt Associates, Kensington, MD, February 1977.
5. Ilium Associates, Inc., Transit Marketing Management Handbook: User Information Aid Washington, DC, prepared for UMTA by Ilium Associates, November, 1975.
6. D.K. Holland, A Review of Reports Relating to The Effect of Fare and Service Changes in Metropolitan Public Transportation Systems, Washington, DC, prepared for FHWA by Center for Urban Programs, St. Louis University, June, 1974.

ACKNOWLEDGEMENTS

This report was funded by a grant from the U.S. Department of Transportation, Urban Mass Transportation Administration NY-09-8006, Transportation Energy Planning Procedural Guidance. The views expressed, however, represent those of the authors and not the Urban Mass Transportation Administration or the New York State Department of Transportation.

The authors would like to thank Janis M. Gross, Alfred J. Neveu, and Dr. David T. Hartgen for their timely comments and guidance in the development of this report. Special thanks are due to Diane Davis, Sue Carbone, and Karen Rapp for preparing this manuscript.

Finally, any errors or omissions in this report remain the responsibility of the authors.

☆U.S. GOVERNMENT PRINTING OFFICE: 1982 522-046/8517 1-3

NOTICE

This document is being distributed through the U.S. Department of Transportation's Technology Sharing Program

DOT-I-82-4

TECHNOLOGY SHARING

SPECIAL STUDIES IN TRANSPORTATION PLANNING (SSTP)

PROGRAMS OF THE U.S. DEPARTMENT OF TRANSPORTATION