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BENEFIT-COST ANALYSIS OF INTEGRATED PARATRANSIT SYSTEMS
Volume 6: Technical Appendices

Multisystems, Inc.
Cambridge MA 02138

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FINAL REPORT

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3

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16. Abstract

This study systematically estimates potential impacts of a range of integrated transit/paratransit options and policies in a variety of settings and compares them with impacts of transportation alternatives.

The study concludes that, in general, integrated paratransit with fares closer to fixed-route transit than exclusive-ride taxi will result in net paratransit operating deficits. However, in some instances, the benefits of integrated paratransit options in terms of improved service levels and mobility, reduced auto expenditures and other impacts appear to offset these operating deficits. Necessary factors for this include high paratransit productivities, possibly achieved by implementing hybrid, fixed-route/demand responsive service; and low operating costs, possibly achieved by contracting with private operators. Integrated paratransit was found to have a positive but insignificant impact in reducing automobile usage and ownership, but no measurable impact on vehicle miles travelled, fuel consumption, or emissions. Promising locations for paratransit implementation are those areas with population densities between 3,000 and 6,000 persons per square mile and limited existing transit service. The most promising paratransit concepts appear to be checkpoint many-to-many service, route deviation service, automated doorstop service with high vehicle densities and vanpool service. The results of the study further suggest that paratransit service demand is sensitive to fare; fare increases above $.25 were determined to be counterproductive, while free transfers from feeder services to line haul became an inducement to use paratransit. The study also concluded that digital communications and automated dispatching systems are potentially cost-effective technological innovations.

This is the sixth and last volume in the series of volumes comprising the final report. This volume includes five technical appendices which document the methodologies used in the benefit-cost analysis.

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Preface

Integrated paratransit (IP) service is a concept which involves the integration of conventional fixed-route transit services with flexible, demand-responsive services in order to best serve emerging urban development patterns. Despite the emphasis that has been placed on the analysis and demonstration of paratransit concepts in recent years, there is still considerable confusion and disagreement concerning the impact of paratransit service deployment. To learn more about the capability of IP to meet the transit needs in the urban/suburban environment, the Urban Mass Transportation Administration sponsored a study to identify and define the benefits due to and the costs associated with the deployment of various hypothetical IP systems. The work was performed by Multisystems, Inc. in association with Cambridge Systematics, Inc., and Applied Resource Integration Ltd. under contract to the Research and Special Programs Administration's Transportation Systems Center. Richard Gundersen was Technical Monitor of the study. The Final Report was edited by Larry Levine.

The results of the study are documented in a Final Report which consists of the following six volumes:

Volume 1 - Executive Summary
Volume 2 - Introduction and Framework for Analysis
Volume 3 - Scenario Analyses
Volume 4 - Issues in Community Acceptance and IP Implementation
Volume 5 - The Impacts of Technological Innovation
Volume 6 - Technical Appendices.

This is Volume 6 - Technical Appendices. Multisystems, Inc. had primary responsibility for preparing these technical appendices, with assistance from Cambridge Systematics in a number of sections of Appendices 1 and 2. This volume includes 5 technical appendices which document the methodologies used in the benefit-cost analysis.

METRIC CONVERSION FACTORS

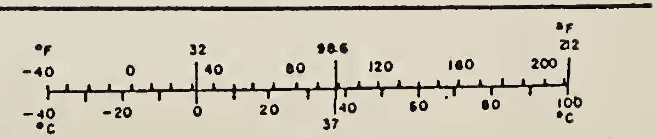
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Appendix 1

Scenario Analysis Methodology

Introduction

The estimation of the impacts of potential transit and taxi services designed in this study required the prediction of patronage and service quality for these systems. Since a wide variety of service concepts are included in the set of scenarios analyzed, a number of distinct methodologies were employed in the analysis. Each of the methods used was tailored to the setting and service option such that maximum use of available information could be employed.

The basic inputs to all the methodologies employed included a description of the transit/taxi system, a description of the interface between conventional transit and the paratransit system, where applicable, and a description of the potential markets that can take advantage of the system. Paratransit and taxi systems are described by the type of service offered (i.e. shared-ride taxi, exclusive-ride taxi, doorstep many-to-one cycled service), hours of operation, vehicles in service, vehicle capacity, and area served. The conventional transit system is described in terms of the origin to destination level of service including in-vehicle travel time, out-of-vehicle travel time, and fare. The coordination between fixed route and flexible transit/taxi options involves specification of the existing fixed route network, level of service provided along each route, and the type of transfers (coordinated or uncoordinated) which can be made by persons traveling outside their demand-responsive service area. The potential markets for the services include not only the population of the service area, but also those persons who might use the paratransit service to reach their employment. Characteristics of these potential markets include such factors as age distribution, auto ownership levels, and household size.

The results of the estimation techniques are user characteristics and numbers and the quality of service provided. Segmentation of users among the special market groups is important as an input to the benefits analysis. The special markets of interest in all analyses included elderly, zero auto households and transportation handicapped. Separate patronage estimates are made for those using intra-community circulation service and those using feeder services to fixed route bus. The service quality outputs for the estimation techniques included wait times and ride times. These values are specific to the types of trips being predicted by the service. The description of trip type included trip purpose and distance of trip.

1.1 Analysis Methodologies

As indicated above, the variety of analyses performed required the use of a number of techniques for forecasting demand and level of service. One primary tool used for many types of services was an equilibrium demand-supply model developed by Cambridge Systematics, Inc. and Multisystems, Inc. (Lerman, et. al., 1977). This demand supply model was estimated on data from existing systems in Rochester, N.Y., and Haddonfield, N.J., and validated on systems in Davenport, Iowa and La Habra, Cal. For scenarios in which the principal paratransit service is a many-to-many dynamic dispatch system, this package (FORCAST) provides the majority of the capabilities required to perform the benefit analysis. To enhance these capabilities, modifications to the base modelling system were made to account for market segmentation and allow other service types to be analyzed. These enhancements will be discussed in complete detail later in this report. Despite the ability to use any paratransit supply model in conjunction with the demand and equilibrium portions of the FORCAST package, it was not always efficient or reasonable to follow this approach in the scenario analysis. In some cases, methodologies external to the FORCAST framework were deemed more applicable.

A number of portions of the study used separate modelling techniques since the services and markets studied were incompatable with the FORCAST model. Included in the set of external analyses were: 1) determination of demand by the transportation handicapped; 2) supply and demand characteristics of route deviation services; 3) demand for vanpool programs, and; 4) feeder services supplying no intra community service. One methodology used in these cases was incremental (pivot point) analysis, which estimated changes in ridership resulting from minor modifications to existing transit systems. Incremental analysis, which will be described in greater detail in Section 1.3, involves the application of elasticities to changes in level of service to determine marginal changes in patronage. In addition, supply characteristics of service were developed outside the FORCAST framework for studying route deviation and vanpool programs.

In both the FORCAST framework and the external methodologies, any modifications to, or development of, predictive tools were validated on data from existing systems when possible. In some cases, however, the lack of a real-world example of a specific system required models to be based entirely on simulated results and/or "expected" sensitivities extrapolated from related experience. Validations will be discussed after complete discussions of the model modifications and development.

Two elements of the service analysis proved to be impossible to perform in a formal, validated method. At present, no models exist for predicting demand which would result from evening or weekend paratransit services. In order to consider the impact of weekend and evening service in at least one scenario, data on weekend/evening ridership on the Ann Arbor Teltran system was used to project ridership in the setting and scenarios most similar to this system. In other settings, scenarios were assigned to include only weekday service. The models for predicting IP demand are also not applicable for prediction of ridership for the under age 16 market segment. The calibration data set for the model did not include a sufficient number of youth to form accurate predictions for these persons. The validations of the FORCAST system, however, did not suggest that the model was consistently under-estimating the total ridership (including youth). For this reason, the ridership predictions resulting from the FORCAST model in its existing form were taken to include ridership for persons under 16 years of age in this study.

1.2 FORCAST Overview

As indicated above, the majority of the analyses were performed using the FORCAST modelling package. For a single DRT service area, this model system executes a series of submodels for determining work and non-work demand (based on level of service) and level of service (based on total demand). The demand submodels are disaggregate logit formulations which determine mode split between auto drive alone, auto shared ride, conventional transit and paratransit modes.[1] The non-work demand submodel also generates frequency of travel and destination choice. The supply submodel is a descriptive model of wait time and origin to destination ride time developed from simulation results. The extended version of the FORCAST model used in this study allows examination of many-to-many dynamically dispatched DRT service, many-to-many cycled service, shared-ride taxi, and exclusive ride taxi service. The accuracy of the many-to-many DRT model has been tested in a number of settings and has proven to be the best currently available (Wilson, 1977). The two demand models and the supply model are controlled by an equilibrium routine which adjusts the productivity of the paratransit service until supply and demand characteristics are consistent. Figure 1.1 illustrates the overall model execution. Equilibrium of supply and demand is determined for each

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[1] For a complete discussion of disaggregate demand modelling techniques, see Ben-Akiva (1973).

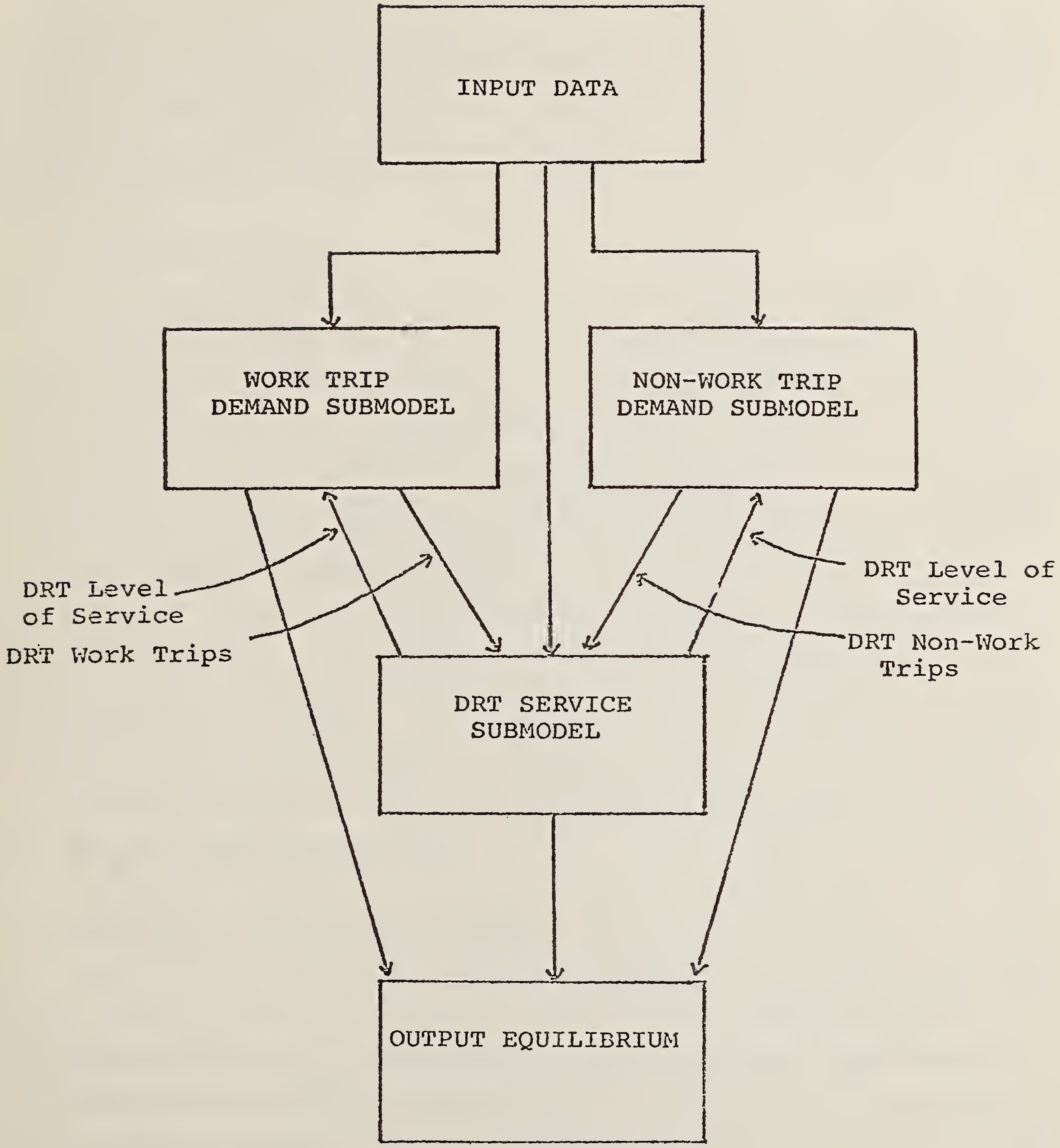

FIGURE 1.1

General Flow of the Model System

user specified time period.[1] The resulting solution to the supply demand/equilibrium process includes paratransit vehicle productivity, total paratransit patronage by period, average paratransit in-vehicle and out-of-vehicle travel times, fare and trip distance. In addition, level of service characteristics are summarized for competing modes.

The FORCAST model system is capable of investigating the impact of paratransit interfaced with line haul bus or other paratransit service modules by providing the capability for individuals to access a service which travels beyond the service area being analyzed. The external transportation system can be any mode and is described in terms of the level of service provided between the transfer point and the zone of origin/destination. To implement this capability, the level of service (wait time and ride time) for the portion of a trip outside the paratransit service area under investigation must be input. This level of service for the "linehaul" portion of the trip is stated independently of demand for the service. If the "linehaul" portion of the trip is made solely on fixed route bus, this is a reasonable assumption since level of service is not strongly impacted by demand. If the portion of the transit trip made outside of the service area includes rides on a paratransit service, it is possible that the level of service input will not be consistent with the demand level and the vehicle fleet size of that service area. For this reason, it may be necessary to adjust the input level of service of the external transportation system to assure consistent supply and demand characteristics.

1.2.1 FORCAST Input

The FORCAST model employs a considerable amount of information to describe the paratransit service being modelled and the market which is eligible to use the system. In addition, inputs specifying

[1] In this study, the time periods used included a.m. peak, midday, and p.m. peak. The beginning and end of each period was specified for each setting based on time of day differences in transit services provided by the setting's transit service in the base case.

the activity system of the urbanized area (both within the service area and external to it) are required. In many cases, specific information regarding the activities within the urban area are unavailable. In these cases, the model can employ default values noted in other areas. Table 1.1, lists the input variables and indicates which are commonly defaulted in the applications of this study.

1.2.2 FORCAST Outputs

The outputs provided by the FORCAST package, as modified for this project, include a description of the mode split of trips made by workers living or employed in the service area and of trips made by the non-working population over 16 living in the service area, as well as the quality of service provided on all available modes. The report on modal ridership is produced for every period analyzed and includes a complete breakdown of trips according to market segment. Market segmentation separates out all combinations of trip purpose, (work, home-originating non-work, and non-home-originating non-work), age category (16-64, 65+), and auto ownership level (0 auto, 1 auto, 2+ autos household). The level of service characteristics presented at each period are in-vehicle travel time (IVTT), out-of-vehicle travel time (OVTT), user cost (FARE), and trip distance (DIST). Figure 1.2 presents a sample of the output produced by the FORCAST model.

1.3 FORCAST - Detailed Description

This section presents a detailed description of the demand and supply models used in conjunction with the FORCAST package. In addition, the results of validation runs performed to test modifications to the methodology are presented.

1.3.1 Demand Models

The demand estimation methodology used in the FORCAST models consists of four distinct components. One of these parts is used to predict the mode split of work trips specified by an origin-destination daily work trip matrix. The remaining three components are

Table 1.1

FORCAST Inputs

- ZONAL DATA INCLUDING:
  - COORDINATES
  - AREAS
  - EMPLOYMENT
  - POPULATION
- A DAILY WORK TRIP TABLE
- THE NUMBER OF NON-WORKERS OVER THE AGE OF 16 IN THE SERVICE AREA
- LEVEL OF SERVICE FOR NON-DRT MODES WHICH ARE AVAILABLE INCLUDING:
  - IN VEHICLE TIMES ON AN O-D BASIS
  - OUT OF VEHICLE TIMES ON AN O-D BASIS
  - FARES ON AN O-D BASIS OR AS AN AVERAGE SYSTEM FARE
- COST INFORMATION FOR DRT EITHER IN O-D FORM OR AS A SINGLE SYSTEM AVERAGE
- NUMBER OF VEHICLES IN SERVICE AND THEIR CAPACITY
- NUMBER OF ANALYSIS ZONES SERVED DIRECTLY BY DRT AND THE NUMBER OF ZONES AVAILABLE THROUGH A FEEDER CONNECTION
- BEGINNING AND ENDING OF EACH ANALYSIS PERIOD
- INITIAL ESTIMATE OF DRT PATRONAGE
- PRECISION OF THE NON-WORK MODEL RESULTS*
- FARE DISCOUNT POLICIES
- PERCENT OF TOTAL POPULATION OVER THE AGE OF 64
- PERCENT OF ELDERLY MAKING WORK TRIPS
- PERCENT OF ELDERLY IN NON-WORKING POPULATION
- AUTO OCCUPANCY OF SHARED RIDE TRIPS*
- WORK TRIP DISTRIBUTIONS BY THE TIME OF DAY*
- AVERAGE NUMBER OF PEOPLE RIDING TOGETHER IN GROUPS ON THE DRT SYSTEM*
- EFFECTIVE VEHICLE FLEET SIZE ADJUSTMENT FACTOR*
- VEHICLE SPEEDS FOR DRT AND AUTO MODES
- LOAD AND UNLOAD DELAYS FOR DRT
- DISPATCHING SYSTEM PARAMETERS
- COST PARAMETERS FOR AUTO ALTERNATIVES
- DISTRIBUTION OF POPULATION OVER HOUSEHOLD SIZE AND AUTO AVAILABILITY
- DISTRIBUTION OF DWELL TIMES AT HOME AND AWAY FROM HOME FOR PERSONS MAKING NON-WORK TRIPS*
- PERCENTAGE OF RESIDENTS WHO DO NOT MAKE WORK TRIPS IN A GIVEN DAY*

*Default values used

16DEC77 14.39.46 FORCAST PAGE 17

FOR62F 5050 (D): MASTER MARKET SEGMENT MATRIX FOR PERIOD 0

TRIP VOLUMES:

			DIRECT*					ACCESS*					
MODEL*	AGE*	AO*	ADA*	SHR*	DRT*	BUS*	TAX	ADA	SHR	DRT*	BUS	TAX	TOTAL
1	1	1	0.0	228.61	6.36	0.0	0.0	0.0	0.00	65.00	0.0	0.0	299.97
1	1	2	1434.11	1676.50	12.89	0.0	0.0	0.00	0.00	115.51	0.0	0.0	3239.01
1	1	3	1924.95	1241.36	3.08	0.0	0.0	0.00	0.00	25.06	0.0	0.0	3194.46
1	2	1	0.0	12.62	0.20	0.0	0.0	0.0	0.00	2.31	0.0	0.0	15.13
1	2	2	24.26	20.54	0.05	0.0	0.0	0.00	0.00	0.54	0.0	0.0	45.40
1	2	3	3.62	2.16	0.00	0.0	0.0	0.00	0.00	0.02	0.0	0.0	5.79
2	1	1	0.0	4.59	18.78	0.0	0.0	0.0	0.0	0.46	0.0	0.0	23.83
2	1	2	161.09	384.30	95.11	0.0	0.0	0.0	0.0	5.48	0.0	0.0	645.99
2	1	3	263.17	655.05	17.43	0.0	0.0	0.0	0.0	1.54	0.0	0.0	937.20
2	2	1	0.0	6.11	22.22	0.0	0.0	0.0	0.0	0.80	0.0	0.0	29.12
2	2	2	33.10	81.51	6.76	0.0	0.0	0.0	0.0	0.41	0.0	0.0	121.79
2	2	3	8.25	20.83	0.04	0.0	0.0	0.0	0.0	0.00	0.0	0.0	29.12
3	1	1	0.0	10.88	5.48	3.18	0.0	0.0	0.0	1.64	0.0	0.0	21.18
3	1	2	389.54	540.09	14.16	26.65	0.0	0.0	0.0	3.80	0.0	0.0	974.25
3	1	3	672.48	791.07	1.96	3.18	0.0	0.0	0.0	0.53	0.0	0.0	1469.22
3	2	1	0.0	13.89	5.28	3.47	0.0	0.0	0.0	1.19	0.0	0.0	23.83
3	2	2	66.12	82.91	0.64	0.89	0.0	0.0	0.0	0.35	0.0	0.0	150.91
3	2	3	33.49	37.98	0.00	0.01	0.0	0.0	0.0	0.00	0.0	0.0	71.48

FOR62F 5090 (I): TOTAL TRIPS = 11261.9

TRIP MODE SPLITS IN PERCENTS:

			DIRECT					ACCESS					
MODEL	AGE	AO	ADA	SHR	DRT	BUS	TAX	ADA	SHR	DRT	BUS	TAX	TOTAL
1	1	1	0.0	2.02996	0.05646	0.0	0.0	0.0	0.00000	0.57721	0.0	0.0	2.66362
1	1	2	12.73425	14.88648	0.11443	0.0	0.0	0.00000	0.00000	1.02570	0.0	0.0	28.76086
1	1	3	17.09265	11.02273	0.02738	0.0	0.0	0.00000	0.00000	0.22254	0.0	0.0	28.36531
1	2	1	0.0	0.11209	0.00174	0.0	0.0	0.0	0.00000	0.02054	0.0	0.0	0.13437
1	2	2	0.21544	0.18239	0.00047	0.0	0.0	0.00000	0.00000	0.00479	0.0	0.0	0.40310
1	2	3	0.03211	0.01916	0.00002	0.0	0.0	0.00000	0.00000	0.00016	0.0	0.0	0.05144
2	1	1	0.0	0.04077	0.16672	0.0	0.0	0.0	0.0	0.00409	0.0	0.0	0.21158
2	1	2	1.43038	3.41245	0.84455	0.0	0.0	0.0	0.0	0.04866	0.0	0.0	5.73604
2	1	3	2.33684	5.81654	0.15481	0.0	0.0	0.0	0.0	0.01370	0.0	0.0	8.32188
2	2	1	0.0	0.05425	0.19729	0.0	0.0	0.0	0.0	0.00707	0.0	0.0	0.25860
2	2	2	0.29394	0.72381	0.05999	0.0	0.0	0.0	0.0	0.00367	0.0	0.0	1.08141
2	2	3	0.07327	0.18493	0.00039	0.0	0.0	0.0	0.0	0.00001	0.0	0.0	0.25860
3	1	1	0.0	0.09657	0.04870	0.02826	0.0	0.0	0.0	0.01454	0.0	0.0	0.18807
3	1	2	3.45892	4.79575	0.12575	0.23666	0.0	0.0	0.0	0.03377	0.0	0.0	8.65084
3	1	3	5.97131	7.02430	0.01738	0.02828	0.0	0.0	0.0	0.00474	0.0	0.0	13.04601
3	2	1	0.0	0.12332	0.04686	0.03080	0.0	0.0	0.0	0.01060	0.0	0.0	0.21158
3	2	2	0.58715	0.73623	0.00565	0.00789	0.0	0.0	0.0	0.00307	0.0	0.0	1.33999
3	2	3	0.29734	0.33727	0.00001	0.00011	0.0	0.0	0.0	0.00001	0.0	0.0	0.63474

Figure 1.2
Sample Output

FOR62F 5130 (D): SUMMARY MARKET SEGMENT MATRIX FOR PERIOD 0

TRIP VOLUMES:

MODEL	AGE	AO	DIRECT ADA	DIRECT SHR	DIRECT DRT	DIRECT BUS	DIRECT TAX	ACCESS ADA	ACCESS SHR	ACCESS DRT	ACCESS BUS	ACCESS TAX	TOTAL
1	0	0	3306.94	3181.79	22.58	0.0	0.0	0.00	0.00	208.45	0.0	0.0	6799.76
2	0	0	465.61	1152.40	160.34	0.0	0.0	0.0	0.0	8.69	0.0	0.0	1787.05
3	0	0	1161.63	1476.82	27.52	37.39	0.0	0.0	0.0	7.52	0.0	0.0	2710.87
0	1	0	4045.34	5532.45	175.26	33.02	0.0	0.00	0.00	219.04	0.0	0.0	10805.10
0	2	0	168.84	278.56	35.18	4.37	0.0	0.00	0.00	5.62	0.0	0.0	492.57
0	0	1	0.0	276.70	58.31	6.65	0.0	0.0	0.00	71.40	0.0	0.0	413.06
0	0	2	2108.23	2785.86	129.61	27.54	0.0	0.00	0.00	126.09	0.0	0.0	5177.32
0	0	3	2905.96	2748.45	22.52	3.20	0.0	0.00	0.00	27.16	0.0	0.0	5707.28
0	0	0	5014.19	5811.00	210.44	37.39	0.0	0.00	0.00	224.66	0.0	0.0	11297.66

TRIP MODE SPLITS IN PERCENTS:

MODEL	AGE	AO	DIRECT ADA	DIRECT SHR	DIRECT DRT	DIRECT BUS	DIRECT TAX	ACCESS ADA	ACCESS SHR	ACCESS DRT	ACCESS BUS	ACCESS TAX	TOTAL
1	0	0	30.07	28.25	0.20	0.0	0.0	0.00	0.00	1.85	0.0	0.0	60.38
2	0	0	4.13	10.23	1.42	0.0	0.0	0.0	0.0	0.08	0.0	0.0	15.87
3	0	0	10.31	13.11	0.24	0.33	0.0	0.0	0.0	0.07	0.0	0.0	24.07
0	1	0	43.02	49.13	1.56	0.29	0.0	0.00	0.00	1.94	0.0	0.0	95.94
0	2	0	1.50	2.47	0.31	0.04	0.0	0.00	0.00	0.05	0.0	0.0	4.37
0	0	1	0.0	2.46	0.52	0.06	0.0	0.0	0.00	0.63	0.0	0.0	3.67
0	0	2	18.72	24.74	1.15	0.24	0.0	0.00	0.00	1.12	0.0	0.0	45.97
0	0	3	25.80	24.40	0.20	0.03	0.0	0.00	0.00	0.24	0.0	0.0	50.68
0	0	0	44.52	51.60	1.87	0.33	0.0	0.00	0.00	1.99	0.0	0.0	100.32

Figure 1.2
Sample Output
(continued)

16DEC77 14.39.46 FORCAST PAGE 19

FOR63B 2100 (I): LOS SUMMARY FOR PERIOD 0

	DIRECT ADA	DIRECT SHR	DIRECT DRT	DIRECT BUS	DIRECT TAX	ACCESS ADA	ACCESS SHR	ACCESS DRT	ACCESS BUS	ACCESS TAX	TOTAL
TRIP TOTALS	5013.87	5810.36	210.41	37.39	0.0	0.00	0.00	224.65	0.0	0.0	11296.68
LOS TOTALS											
IVT	99457.69	105754.19	2791.74	826.86	0.0	0.00	0.00	10236.70	0.0	0.0	219067.06
OVT	10026.67	34851.96	3607.40	766.80	0.0	0.00	0.00	5967.45	0.0	0.0	55220.29
FAR	203411.00	77680.00	9639.98	1359.81	0.0	0.00	0.00	16697.32	0.0	0.0	308788.00
DIST	29062.06	27735.12	348.70	124.79	0.0	0.00	0.00	1890.46	0.0	0.0	59161.13
LOS AVERAGES											
IVT	19.84	18.20	13.27	22.12	0.0	35.70	36.25	45.57	0.0	0.0	19.39
OVT	2.00	6.00	17.14	20.51	0.0	10.04	14.58	26.56	0.0	0.0	4.89
FAR	40.57	13.37	45.82	36.37	0.0	80.98	40.63	74.32	0.0	0.0	27.33
DIST	5.80	4.77	1.66	3.34	0.0	8.12	7.07	8.42	0.0	0.0	5.24

SINOFF 6700 (INFORMATION): FORCAST ENDED AT 14.57.42 (RETURN CODE= 0)

SINOFF 7000 (WARNING): FILE URD.LOG NOT AVAILABLE.

*Models: 1 - Work, 2 - Home-Origin Non-Work, 3 - Non-Home-Origin Non-Work, 0 - Total

Ages: 1 - 16-64, 2 - 65+, 0 - Total

AO (Auto Ownership): 1 - Ø Autos, 2 - 1 Auto, 3 - 2+ Autos, 0 - Total

Direct: ADA - Auto Drive Alone
SHR - Auto Shared Ride
DRT - Flexible Transit/Taxi Circulation Option
BUS - Conventional Transit
Access: DRT - Flexible Transit/Taxi Feeder Option

Figure 1.2
Sample Output
(continued)

used to determine the characteristics of non-work trips made in the community. Among the characteristics estimated by these portions of the model system are frequency of travel, mode split, and destination choice. The principal methodology employed for the estimation of mode split of both work and non-work trips and destination choice for nonwork trips, is based on disaggregate choice theory. Frequency of travel was determined by the estimation of time between departures both at home and non-home locations.

The disaggregate choice model employed to estimate mode split and destination in each of the demand methodology components is the multinomial logit model.[1] The theory behind this model is quite complex, but its logic is straightforward. Each alternative available to an individual has a measure of desirability associated with it. This measure, termed a "utility", is computed as a function of attributes (such as wait time, side time, etc.) of that alternative. For the multinomial logit formulation, this utility takes the form:

$$V_{jt} = \sum_{i} a_i \, b_{ijt} \qquad [1-1]$$

where V_{jt} = utility of alternative j for individual t

a_i = a calibrated coefficient indicating the importance of attribute i

b_{ijt} = the value of attribute i observed by person t for alternative j.

Given the utility for each of the available alternatives, the probability of an individual choosing a specific alternative, is determined by equation [1-2] below:

$$P_t(m) = \frac{e^{V_{mt}}}{\sum_{i \epsilon C_t} e^{V_{it}}} \qquad [1-2]$$

where $P_t(m)$ = probability of person t choosing alternative m

V_{mt} = utility of alternative m to person t

C_t = set of alternatives available to person t.

[1]Detailed reviews of dissaggregate choice theory and the multinomial logit model can be found in a variety of references including McFadden (1973, 1974), Ben Akiva (1973) and Lerman (1975).

The alternatives available to one person are not necessarily those available to others. For instance, the choice of driving an automobile is not an option for an individual who cannot drive or does not have an auto available.

The set of alternatives available in the work choice model includes only the modes available for the work trip. Utility functions for the following modes have been developed for the work trip:

- auto drive alone, (ADA)
- auto shared-ride, (SHR)
- doorstep many-to-many, (DRT)
- shared ride taxi, (SRT)
- conventional transit (BUS)
- doorstep many-to-one cycled service (MTO)
- checkpoint many-to-many, (CDRT)
- DRT access to conventional transit, and (ACC)
- exclusive ride-taxi, (ERT)

Of these modes, only the first four were fully developed prior to this project by Lerman, et. al. (1977). The remaining models were developed by this study team based on interim results of the DRT patronage project, the evaluation of expected model sensitivities, and calibration (at an aggregate level) on existing data. When feasible, these new mode utility functions were validated on real-world systems. These validations are presented later in this chapter.

The work trip utilities/functions are specified in Tables 1.2 and 1.3. Table 1.2 presents the definition of attributes used in the work trip models. Note that some of these attributes pertain only to a specific set of modes. Table 1.3 lists the values of the constants associated with the attributes. In several cases, the coefficient is only relevant for a specific mode. In these cases, a modal subscript is included with the attribute abbreviation. The DRT work utility function is as follows:

$$U_{DRT} = 2.085 + .0.7529/DIST - .0507\ IVTT - .2275OVTT/DIST - .010PTC + 0.2\ AGE1 - 0.8\ AGE2 \qquad [1\text{-}3]$$

Table 1.2

Notation for Work Models

Variable	Definition
CONST	A 0,1 constant term (always subscripted)
AALIC	Autos per household member with a drivers' license
AGE1	1 if under 16 years old, 0 otherwise
AGE2	1 if over 65 years old, 0 otherwise
SEX	1 if male, 0 if female
IVTT	In-vehicle time (in minutes)
OVTT	Out-of-vehicle time (in minutes)
OPTC	Out-of-pocket cost (in cents)
DIST	Distance of trip (in miles)

Subscript	Definition
ADA	Auto drive alone
SHR	Auto shared ride
BUS	Fixed-route bus
DRT	Doorstep many-to-many
SRT	Shared ride taxi
MTO	Doorstep many-to-one cycled
CRT	Checkpoint many-to-many
ACC	Paratransit access to fixed route bus
ERT	Exclusive ride taxi

Table 1.3

Coefficients of Work Mode Split Models

Variables	Subscripts*	Coefficient
CONST	ADA	-3.51
CONST	SHR	0.0507
CONST	BUS	-0.5
CONST	DRT, SRT, MTO, CRT	2.085
CONST	ERT	1.085
AALIC	ADA	6.642
AALIC	SHR	4.608
SEX	ADA	3.352
SEX	SHR	2.413
(1/DIST)	BUS, DRT, SRT, MTO, CRT, ERT, ACC	0.7529
DIST	SHR	-0.2716
IVTT	-	-0.05075
OVTT/DIST	-	-0.2275
OPTC	-	-0.0100
AGE1	DRT, SRT, MTO, CRT	0.2
AGE1	DRT, SRT, MTO, CRT	-0.2
AGE2	ERT	-0.8
AGE2	ERT	0.8

*a subscripted variable implies this factor is included only in the utility functions for the modes in the subscript. An unsubscripted variable is included in all modal utility functions.

The non-work choice model estimates the probability an individual will choose a specific mode on which to take a trip, and also predicts the zone of destination. The set of alternatives consists of all combinations of mode and destination zone which are available to an individual. The potential modes available to the population is the same as that listed above in the description of the work trip model. The destination can be either home (if the individual is not at home) or any of the zones defined by the analyst to be in the area of interest. Separate models are used to estimate mode-destination choice based on the location of the individuals. A home-origin model and a non-home origin model apply different values to attributes for choices. Tables 1.4 and 1.5 present the definitions of the attributes and their coefficients in a manner similar to that used to describe the work mode split model.

The final component of the non-work forecasting methodology is a distribution which determines the length of time a member of the non-work population spends at his present location. A number of distributions were calculated by Lerman, et. al. (1977) based on data collected from Rochester. The "dwell time" distributions are functions of:

- the age of individual,
- the location of individual,
- whether individual has already made a trip that day, and
- the auto ownership of household.

These distributions were not adjusted under this project and are, therefore, not presented in this text. Readers interested in specification of the dwell time distributions are directed to Lerman, et. al. (1977) for a complete discussion.

1.3.2 Supply Models

Within the FORCAST framework, this study performed analyses of five distinct service concepts. The five modes included in this set include:[1]

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[1] The last three modes represent extended capabilities of the FORCAST model system developed under this project.

Table 1.4

Notation for Non-Work Models

Variable	Definition
CONST	A 0,1 constant term (always subscripted)
AA16	Autos per household member over 16 years
AGE1	1 if under 16 years old, 0 otherwise
AGE2	1 if over 65 years old, 0 otherwise
SEX	1 if male, 0 if female
IVTT	In-vehicle time (in minutes)
OVTT	Out-of-vehicle time (in minutes)
OPTC	Out-of-pocket cost (in cents)
DIST	Distance of trip (in miles)
POP	Total population of zone
TOTEMP	Total employment of zone
RWEMP	Retail and wholesale employment in zone
RWEST	Number of retail and wholesale establishments
AREA	Zonal area, in square miles
HOME	1 if destination is home, 0 otherwise

Subscripts	Definition
ADA	Auto drive alone
SHR	Auto shared ride
BUS	Fixed-route bus
DRT	Doorstep many-to-many
SRT	Shared ride taxi
MTO	Doorstep many-to-one cycled
CRT	Checkpoint many-to-many
ACC	Paratransit access to fixed route bus
ERT	Exclusive ride taxi

Table 1.5

Coefficient of Non-Work Mode Split Models

Variables	Subscripts*	Home Originating Model Coefficient	Non-Home Originating Model Coefficient
CONST	ADA	-7.223	-3.035
CONST	SHR	-7.338	-2.991
CONST	BUS	-0.5	-0.5
CONST	CRT	-1.0	-1.0
CONST	ERT	-1.1	-0.5
AA16	ADA	7.450	8.608
AA16	SHR	7.577	8.178
AGE1	DRT, SRT, MTO, CRT	0.2	0.2
AGE1	ERT	-0.2	-0.2
AGE2	DRT, SRT MTO, CRT	-0.8	-0.8
AGE2	ERT	0.8	0.8
(IVTT+OVTT)	-	-0.141	-0.0573
ln(OPTC)	-	-1.484	-0.934
POP/AREA	-	-0.768×10^{-4}	-0.250×10^{-5}
TOTEMP/AREA	-	0.236×10^{-4}	0.118×10^{-4}
HOME	-	-	2.663
ln(AREA)	-	1.0	1.0

*a subscripted variable implies this factor is only included in the utility functions of the modes in the subscript. An unsubscripted variable is included in all utility functions.

- doorstep many-to-many DRT,
- shared-ride taxi,
- checkpoint many-to-many DRT,
- exclusive ride taxi, and
- many-to-one cycles DRT.

In each case, the major inputs to the model are the number of vehicles in service, size of the service area, and the level of patronage of the service. The two outputs of all models are the systemwide wait times experienced by patrons, and the origin to destination ride times.

Level of service for the first three modes listed above are based on the same functional forms. These forms were developed as part of the DRT demand study (Lerman, et. al. 1977) for the many-to-many and shared ride taxi modes.[1] These models take the form of equations [1-4] and [1-5] below.

$$WT = (1 + \alpha + \beta) \frac{f_a}{2 V_{eff}} \sqrt{\frac{A}{kn \times N}} \exp\left(k_1 \sqrt{\frac{A + 4}{kn \times N + 12}} \lambda^{k_2}\right) \quad [1-4]$$

$$RT = \frac{f_a L}{V_{eff}} \exp k_3\left(\frac{A}{N}\lambda\right)^{k_4} - \frac{L}{\bar{L}} \beta WT / (1 + \alpha + \beta) \quad [1-5]$$

Where:

- WT = Wait Time
- RT = Ride Time
- λ = Effective Productivity (Trips per vehicle-hour)
- A = Area (sq. mi.)
- N = Vehicle Fleet Size
- V_{eff} = Effective Vehicle Speed
- f_a = Street Network Adjustment Factor
- kn = Fleet Adjustment Factor
- α = Computer Dispatch Factor
- β = Wait Time-Ride Time Tradeoff Factor
- L = Trip Length
- $\bar{L}$ = Average Systemwide Trip Length

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[1] Detailed description of this model and the adjustment factors are presented in Flusberg and Wilson (1976) and Menhard, et. al.(1978)

The coefficients (k_1 through k_4) were calibrated on simulation results for each type of service. Table 1.6 presents the calibrated coefficients for each of these models.

Table 1.6

Supply Model Constants

	k_1	k_2	k_3	k_4
Doorstep MTM	0.22	0.9	0.0843	0.7
Shared-Ride Taxi	0.20	1.0	0.0843	0.7
Checkpoint MTM[1]	0.14	0.9	0.39	0.7

The exclusive-ride taxi model is similar to that of shared-ride taxi service, except that it includes a term to correct for the requirement that only one demand can be served by a taxi at a given time and recognizes that ride time is equal to that of auto. As a result of the single demand requirement, wait times of exclusive-ride taxi services increase more quickly than those of shared-ride, and there is a demand level at which service is no longer feasible. To implement this correction, a penalty function was added to the wait time predicted by the shared ride taxi model. The penalty function takes the form indicated in equation [1-6] below.

$$WT_p = 0.59 \left[-\ln \left(\frac{60-PROD\ (WT+\overline{RT})}{60}\right)^{2.39}\right] \times WT \qquad [1\text{-}6]$$

where:

PROD = productivity (demands/vehicle-hour)

$\overline{RT}$ = average ride time

WT = wait time

$0 < PROD\ (WT + RT) < 60$

---

[1]The checkpoint many-to-many model was calibrated only for area sizes of approximately eight square miles and vehicle fleet sizes of approximately nine. The model, as specified above, predicted within 1% of the simulated wait and ride time for all except one run. The checkpoints in all runs were assumed to be spaced one quarter of a mile apart in a square grid patterns. Service areas in the scenarios analyzed were designed to be reasonably close to the characteristics of the calibration data set to minimize errors.

This penalty function has the property that it equals zero when the productivity approaches zero. When the productivity times the combined wait and ride times (productive time) is greater than 60 (the time available to serve demands) the system is no longer in steady state and service is infeasible. The penalty function approaches ∞ as the productive time approaches the available time. The taxi model was calibrated on a set of simulations performed by Gerard (1974). The model predicted within 3% of all simulated runs reported.[1] The validation of the taxi demand model is presented later in this report.

The final supply model used in conjunction with the FORCAST system is for many-to-one cycled service. This model was developed to analyze the service provided by multiple service areas serving a conventional transit system. In addition, the model allows analysis of services in which patrons are allowed to transfer between DRT service areas which have a joint transfer point. The supply model for the individual service area is based on work performed by Daganzo, et. al. (1977) and modified by Menhard, et. al. (1978). The model, derived analytically and validated in Ann Arbor, Michigan,[2] is detailed in Figure 1.3. Readers interested in the development of this model are directed to Daganzo, et. al. (1977) for a theoretical treatment. A major difference between this and other DRT supply models is the input data required. The cycled service model predicts the complete origin to destination wait and ride times (including line-haul portions) based on the headways of the DRT and fixed route services and cycle time of DRT vehicles in each service zone, in addition to the inputs required for the other types of service.

1.3.3 FORCAST Validations

In the process of the scenario analysis, three validations were performed on the FORCAST model to test the reliability of various portions of the model. The first validation (with data from La Habra, Cal.) was performed to test: 1) the split between

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[1] In fact, the developed taxi model predicted better than the analytic taxi model presented in Gerrard (1974) for all simulated services.

[2] Daganzo (1977) validated the supply side of this model for Ann Arbor. Further validation of both supply and demand portions of the FORCAST model system are presented in the next section of this report.

Definitions

C = Cycle time

L = rendezvous time

R = distribution phase

G = collection phase

G' = time spent in collection during collection phase

LO = layover time at transfer point

A = area size

Veh = vehicle fleet size

v = average speed of bus

Apv = area size ÷ vehicle fleet size

b_r = alighting time

b_g = boarding time

r = traffic route factor

λ_a = arrival rate inbound (patrons fro distribution) per vehicle

λ_b = arrival rate outbound (patrons for collection) per vehicle

x* = the steady state value of number of persons waiting at home

τh = waiting time at home

τ'_a = riding time during distribution

τ'_b = riding time during collection

τ_r = waiting time at the rendezvous

Δ = correction for the stochastic nature of inbound arrival process

Y = number of passengers collected during collection phase

$\Phi(.)$ = standardized normal cumulative distribution function

$\phi(.)$ = standardized normal density function.

Distribution Time

$$R \approx \lambda_a C b_r + \frac{1.01 r \sqrt{Apv}}{v} (\Delta \sqrt{\lambda_a C + 0.5} - \sqrt{0.5})$$

$$\text{with } \Delta = 1 - \frac{\lambda_a C}{8(\lambda_a C+).5)^2}$$

Figure 1.3

Many-to-One Supply Model

Collection Time

$$G = C-L-R$$

$$G' \approx \min\{G,\ \lambda_b . C . b_g + \frac{1.01r\sqrt{Apv}}{v}(\sqrt{\lambda_b C+0.5} - \sqrt{0.5})\}$$

Steady State Pickup Pool Size

$$x^{*\prime} \approx x^* + \max\{0,\ \lambda_b C - Y'\}$$

$$x^* \approx |\max\{0,\ \frac{0.5+\lambda_b C-k^2}{2k}\}|^2 + \lambda_b C$$

$$k = \frac{v}{1.01r\sqrt{\Delta}}\left[G-\lambda_b\ Cb_g\right]$$

with $Y' \approx x^* - [x^*-Y]\Phi(\frac{x^*-Y}{\sqrt{Y}}) - \sqrt{Y}\phi(\frac{x^*-Y}{\sqrt{Y}})$

$$Y \approx \lambda_b C + \max\{0,\ k-\sqrt{\lambda_b C+0.5} + \sqrt{0.5}\}$$

Expected Level of Service

$$E(\tau_h) = \frac{x^{*\prime}}{\lambda_b} - C/2Veh + G'/2$$

$$E(\tau_b') = \frac{L+G'}{2}$$

$$E(\tau_a') = \frac{L+R}{2}$$

$$E(\tau_r) = LO/2$$

Figure 1.3 (Cont.)

elderly and non-elderly DRT patrons; 2) ridership predicted on the fixed route bus model, and; 3) the DRT access to fixed route bus model. Two additional validations were performed (with data from the Ann Arbor Teltran system), one to test the applicability of FORCAST to predict patronage for cycled service, given a new supply model for this service, and the other to test the exclusive-ride taxi supply and demand models. The results of all three validations are indicated in Table 1.7.

The validations presented here suggest that the FORCAST model is quite reliable. The patronage predictions in the validations were well within the 0 to ± 30% accuracy range reported by Lerman, et. al. (1977). In addition, the breakdown of ridership among the market segments, (which should be extremely difficult to accomplish because of the disaggregate nature of the breakdown), has proven to be quite acceptable, with the exception of the overprediction of elderly patronage on the Ann Arbor Teltran System. The over-estimation in this case may be attributed to the number of transfers required to use this system, or possibly to the fact that Teltran is viewed as a youth oriented service by the local population.

1.3.4 Sketch-Planning Model

As part of the previous project which developed the FORCAST package, a sketch planning model was developed to predict the demand for doorstep many-to-many service based on population, area, fare structure, vehicle fleet size, and results from a detailed analysis of service in a similar area.[1] This sketch planning model was used to reduce the requirements to perform detailed analyses for all service areas in some settings.

In these cases, a representative set of the zones to be analyzed were selected based on differences in auto ownership, employment density and age characteristics of the resident population. Detailed analyses of these zones were performed using the FORCAST model. The remaining zone riderships were based on these runs and the sketch planning model. The distribution of ridership according to market segment was assumed to be the same as in the detailed FORCAST results.

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[1] A detailed description of the sketch planning technique is presented in Lerman et al (1977).

Table 1.7

Validation Results

	La Habra[1] Predicted	La Habra[1] Actual	Ann Arbor 1[2] Predicted	Ann Arbor 1[2] Actual	Ann Arbor 2[2] Predicted	Ann Arbor 2[2] Actual
Paratransit:						
Patronage	280	360	2310	2250	NA	NA
% Elderly	27%	28%	17%	4%	NA	NA
% Ø Car Households	57%	NA	23%	28%	NA	NA
% Work Trips	45%	NA	34%	30%	NA	NA
% Feeder to/from Fixed Route bus	0	2	60%	65%	NA	NA
Wait time	18.1 min.	21.4 min.	19 min.	18 min.	NA	NA
Transfer time	NA	NA	2.5 min.	4.1 min.	NA	NA
Conventional transit:						
Patronage	590	794	3875	4150	NA	NA
% Elderly	83%	NA	21%	NA	NA	NA
% Ø Car Households	21%	NA	26%	NA	NA	NA
% Work Trips	33.9%	NA	25%	30-35%	NA	NA
Exclusive Ride Taxi:						
Patronage	NA	NA	NA	NA	1866	1500-2000
% Elderly	NA	NA	NA	NA	32%	22%*
% Ø Car Households	NA	NA	NA	NA	20%	39%*
% Work Trips	NA	NA	NA	NA	29%	36%*

* Indicates actual data not available for validation site, but U.S. statistics presented.
NA = Not Applicable/Not Available

[1] Data provided for May 1977 by DAVE Systems, Inc.

[2] Data derived from Ann Arbor Evaluation Report (Neumann, et. al. 1977) and supplied by Ann Arbor Transportation Authority.

1.4 Demand and Supply Predictions Not Using FORCAST

The FORCAST model was not appropriate for the analysis of all services considered. Services analyzed outside the FORCAST framework include:

- Transportation handicapped (TH) services, (and TH ridership in general)
- Route deviation services,
- Vanpool programs, and
- Many-to- one service exclusively for work trips.

The analyses employed for each of these scenarios are described below.

1.4.1 Transportation Handicapped Demand

The estimation of demand by the transportation handicapped (TH) involved two steps: 1) estimation of the eligible TH population, and 2) multiplication of the population by trip rates for the type of service provided. These results were then adjusted to account for any supply constraints which existed.

Estimation of the TH population was based on the number of elderly in the service area, the number of institutionalized, and the ability of the service provided to serve TH with various disability types. The types of disabilities considered included:

- confined to house (cannot use conventional transit)
- use wheelchair (cannot use conventional transit)
- needs help from another person, (cannot use conventional transit)
- uses other aid, (cannot or has difficulty using conventional transit)
- has trouble getting around, (has difficulty using conventional transit).

TH population for each of these categories was calculated separately as a proportion of the non-elderly population and the elderly population, based on national statistics.[1]

Demand was estimated by multiplying the TH population by an estimated trip rate. These trip rates were based on data from areas which have previously operated similar-type services. The major problem in using this approach is that few services exist which are not supply constrained. This characteristic results in the phenomenon that trip rates increase in proportion to the vehicle fleet size for most systems. For this reason, most data from existing TH systems cannot be used to predict true equilibrium demand. One system which appears not to be supply constrained in PROJECT MOBILITY (PM) in Minneapolis, Minn. There is no proof that PM trip rate of .302 weekly trips/eligible TH person is a long-run demand rate, but the ridership on that system has leveled off to a situation of excess capacity (except in the peak). The PM trip rate was therefore used to project demand for special TH services. Figure 1.4 presents the trip and service rates for PROJECT MOBILITY and several other systems.

1.4.2 Route Deviation Service

The analysis of route deviation service employed an incremental analysis because there was no clear method of analyzing the service within the context of FORCAST. Incremental analysis provides a methodology for calculating change in ridership along an existing bus route based on the change in level of service along the route, and the base ridership on the route. When route deviation service is implemented along a previously existing fixed route line, patrons generally note lower wait times and walk times. Disadvantages are also noted in the fact that vehicles deviating from existing routes require a greater amount of time to travel between points. As a result,

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[1] See for example, Crain and Associates (1976).

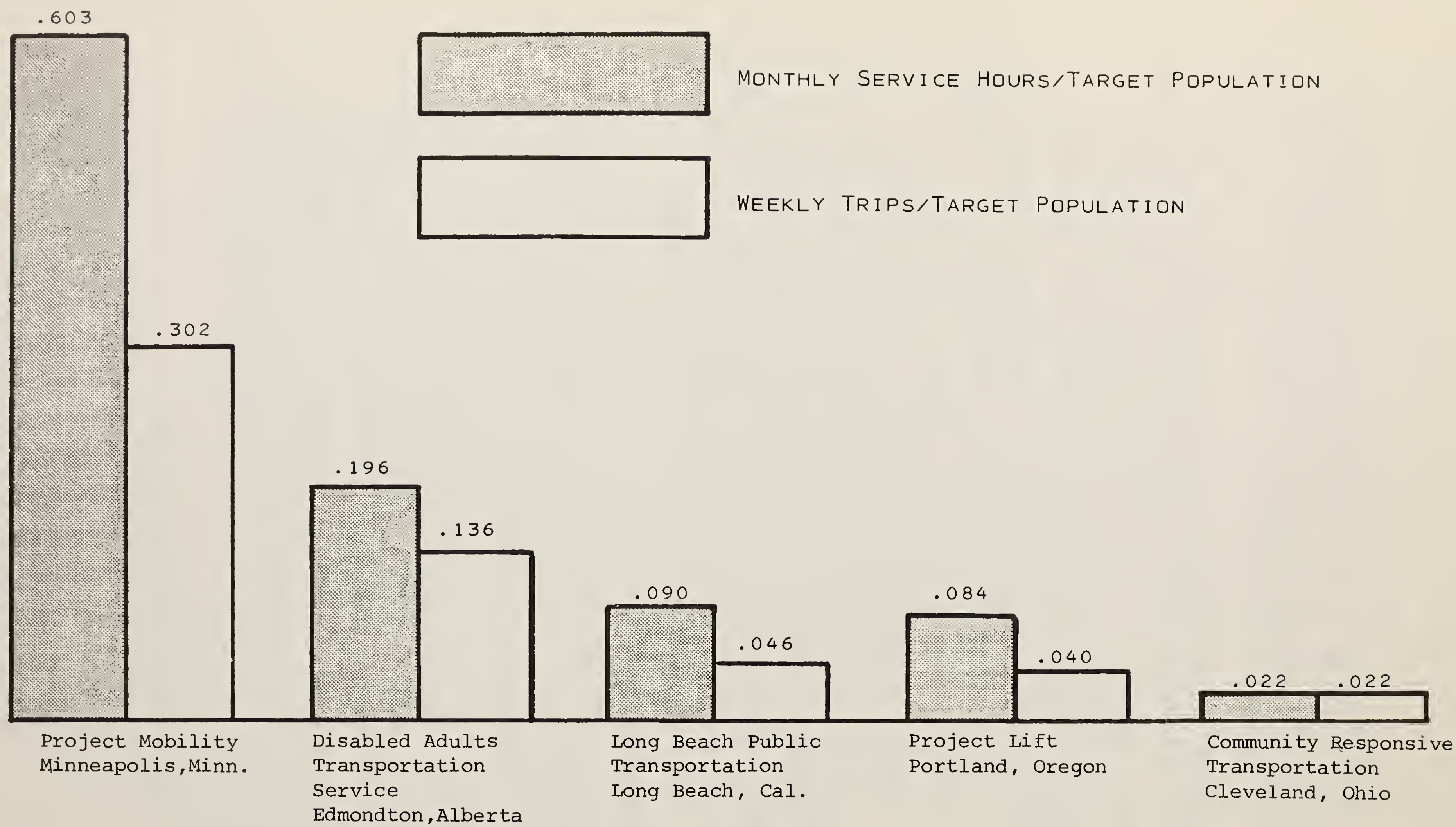

FIGURE 1.4 TRIP RATES AND SERVICE RATES

both in-vehicle travel times and the cost of maintaining the same headway along a route are increased.

The level of service changes and cost of allowing deviation service depend on the habits of individuals regarding doorstep dropoff, and the time required to make the dropoffs. Figure 1.5 presents the supply model used to estimate changes in wait time, ride time, and vehicle run time. Note that the doorstep and non-doorstep service demand is an input to this model. Since demand is a function of level of service characteristics, an iterative search for consistent demand and supply characteristics was supplied.

To estimate the demand, it was first necessary to predict the portion of patrons requesting doorstep service, and the portion picked up along the route. The submodal split calculation for doorstep and on-route pick-up is based on data from the checkpoint deviation service in Merrill, Wisconsin.[1] Selection of deviation service is a function of age, distance from the route, and fare differential between route and deviation service. The percent requesting doorstep service as a function of age and distance from the nearest checkpoint in Merrill is shown in Table 1.8 below. (The data indicated only slight differences between functions on the pick-up and drop-off end of the trip. Since merging of the data set allows a symmetrical calculation of mean out-of-vehicle time, these differences are not taken into account in the methodology used).

Table 1.8

Percent Requesting Doorstep Service: Merrill Checkpoint Deviation System

	DISTANCE				
	<1/8 mi.	1/8 mi.- 1/4 mi.	1/4 mi.- 1/3 mi.	1/3 mi.- 3/5 mi.	>3/5 mi.
Age 65 and under	8%	52%	89%	98%	100%
Age 65 and over	11%	74%	88%	98%	100%

[1] Flusberg (1977)

BUSSPD - Base bus speed
STPX - Average block length
RTELEN - Route length
FREQ - Runs/hour
V_N - Volume/hour of non-doorstep passengers
V_D - Volume/hour of doorstep passengers
NDZ - Number of deviation zones
A - Service area
TPFRS - Time per fixed route stop
TDPS - Time per deviation stop

AVERAGE STOPS ON FIXED ROUTE (ASFR)

$$\text{ASFR} = (\text{RTELEN/STPX}) \left[1-\exp\{(V_N \times \text{STPX})/(\text{FREQ} \times \text{RTLEN})\}\right]$$

AVERAGE FIXED ROUTE RUN TIME (ASFRRT)

$$\text{AFRRT} = \text{RTELEN/BUSSPD} + \text{ASFR (TPFRS)}$$

AVERAGE NUMBER OF DEVIATIONS PER RUN (ADPR)

$$\text{ADPR} = \text{NDZ} \left[1-\exp\{V_D/(\text{FREQ} \times \text{NDZ})\}\right]$$

AVERAGE NUMBER OF PASSENGERS PER DEVIATION (APPD)

$$\text{APPD} - V_D/(\text{FREQ} \times \text{ADPR})$$

AVERAGE TIME PER DEVIATION (ATPD)

$$\text{ATPD} = L + (\text{APPD} \times \text{TPDS}) + \frac{R(\text{Area Shape})\sqrt{A/\text{NDZ}}}{\text{BUSSPD}} \left(\sqrt{\text{APPD} + 0.5} - \sqrt{0.5}\right)$$

AVERAGE DEVIATION RUN TIME (ADRT)

$$\text{ADRT} = \text{ATPD} \times \text{ADPR}$$

AVERAGE RUN TIME (ART)

$$\text{ADRT} = \text{ATPD} \times \text{ADPR}$$

TRAVEL TIME FACTOR (TTP)

$$\text{TTF} = \text{ART/AFRRT}$$

Figure 1.5

Route Deviation Supply Model

The data presented above is based on a specific fare structure; therefore, it is necessary to adjust these mode splits for the specific scenario being analyzed. An incremental analysis based on the submodal split in the table presented above can be made by assuming the decision to request deviation service is made in a sequential manner. First, the individual must decide if he/she would request deviation service on the trip end furthest from the route.

That is, the first decision is made for the portion of the trip (pickup and dropoff) which would have the largest walk distance. The percent requesting doorstep service is then adjusted based on the fare differential as follows:

$$\%doorstep = \frac{FD^{\circ} - FD}{FD^{\circ}} \; e \; \%doorstep^{\circ}$$

where FD° = the fare differential in Merrill
FD = the calculated fare differential
e = elasticity with respect to fare, and
$\%doorstep^{\circ}$ = percent deviation based on Merrill data.

The second decision is conditional on the results of the first decision, since the fare differential depends on the base fare before that decision. For those persons deciding not to be dropped off at their door in the first case, the fare differential remains the same as calculated above. For those who decided to request the first deviation, the fare differentials are calculated as the second deviation charge divided by the sum of the base fare and first deviation charge. The adjustment of the percent requesting doorstep service from the existing data is performed according to the formula above.

Given the sub-modal split for doorstep and on-route pick-up, the change in out-of-vehicle travel time can be calculated based on the average walk distance to the route of those requesting doorstep service. The change in fare is also determined based on the percentage of doorstep pick-up. The change in in-vehicle travel time (IVTT) must be estimated by the analyst. Given these changes in level of service, the change in ridership is evaluated based on elasticities of -1.0, -0.5, and -0.33 for OVTT, IVTT, and fare respectively.

At this stage, the actual change in in-vehicle travel time is calculated by the supply model presented in Figure 1.5. When this calculation is within an acceptable level of accuracy, the equilibrium changes in ridership and costs have been calculated.

1.4.3 Vanpool Analysis

To analyze vanpool demand, an unsuccessful attempt was made to calibrate a regression model on existing vanpool data.[1] The alternative method was to use the data in Miller (1976), plus data updates through telephone conversations with the representatives of companies served by the vanpool, to develop a range of mode splits for reasonable successful vanpooling systems. Furthermore, key characteristics of these programs were noted and employed in the design of scenario vanpool options. The factors included in the list of important vanpool system design characteristics are size and location of the employer, availability of public transit, and the commitment of the employer to the promotion of the program. Like other successful vanpool operations, the one in "Southern Belle" was implemented at a large, suburban employer which presently has only limited public transit service available. An estimate was made of the number of employees who reside in the geographical service area which has been defined for Setting 1. Survey data available from existing programs show that participation rates vary from 1% or 2% to about 50%. An average figure of 10% was chosen based on a comparison of size and location characteristics of the firms. This percent was applied to a group of employees whose eligibility was determined by the geographic distribution of residences, distance from work, staggered work hours, and availability of transit.

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[1]This analysis proved unsuccessful for two major reasons: 1) data were available for only a small number of existing vanpool programs and only at a very aggregate level; and 2) the majority of vanpool programs were supply constrained, such that the actual ridership did not represent the potential demand, but rather the number of vehicles provided by the company. This second aspect of current vanpools is indicated by the existence of waiting lists for virtually all programs. Market penetration models were calibrated based on employment at site, fare structure, average van round trip length, and number of vans. Without the number of vans factor, no model formulation was found with an R^2 greater than 0.35. Furthermore, the signs and magnitudes of the calibrated coefficients appeared to be unreasonable.

To determine vanpool supply, the assumption was made that average vehicle occupancy would be consistent with the data available from Miller (1976). These data indicate vehicle occupancies between nine and twelve. The analysis for "Southern Belle" used an average vehicle occupancy of ten. Other data on vanpool programs are presented in Table 1.9.

1.4.4 Many-to-One Feeder Service Exclusively for Work Trips

In analyzing the scenarios for "Metropolis" it was decided to employ a less data intensive methodology to determine the ridership on feeder services during the peak periods. Projections for this setting existed for boardings and mode of access at a number of line-haul rapid transit and express bus stations. Since the destinations are restricted to a relatively small area by the linehaul service provided, aggregate predictions of changes in ridership are expected to be relatively accurate. Using this data and elasticities developed from the work mode split model available in the FORCAST model, changes in ridership on access mode and linehaul given the introduction of feeder service were calculated. To calculate the change in level of service (LOS) for any mode, the following equation is used:

$$\Delta LOS_m = .0507\ \Delta IVTT_m - .2275\ \Delta OVTT_m/DIST_m - .01\ \Delta OPTC_m \qquad [1\text{-}7]$$

where the variables are as defined as before and subscript indicates the mode. For transit, considered to include conventional transit and paratransit, the level of service after implementation of paratransit is calculated as the log sum of the exponentiated utilities defined by the work mode split model.

Given the changes in LOS for each mode, the new mode split can be calculated as:

$$P_a(m) = \frac{e^{\Delta LOS_m}\ P_b(m)}{\sum_{i \in C_t} e^{\Delta LOS_i}\ P_b(i)}$$

where $P_a(m)$ = mode split of work trips after change in transit service,

$P_b(m)$ = mode split of work trips before change in transit service, and

C_t = modes available to the target population.

This formulation can be used to calculate both the changes in access

Table 1.9

Summary of Vanpool Program Data

Firm	Number of Vans		Number of Riders		Employees Eligible		Current Waiting List	Currently Expanding	Incentives Provided
	1975	1977	1975	1977	1975	1977			
Aerospace Corp. El Segunda, Cal.	11	19	110	197	6,000	3,000	Yes	Yes	PK; PU
American Can Co. Greenwich, Conn.	1	2	11	18	1,800	2,000	?	Yes	None
CENEX St. Paul, Minn.	15	20	165	180	700	800	No	No	PK; PU; DF
Continental Oil Co. Houston, Texas	10	28	103	336	1,400	1,400	Yes	Yes	PK; PU; DF
Cooper Woodruff Amarillo, Texas	4	0	40	0	4,000	4,000	-------	(Disbanded due to "lack of interest")	-------
Erving Paper Mill Erving, Mass.	6	6	130	125	300	340	Yes	No	None
General Mills Minneapolis, Minn.	15	20	165	225	1,800	1,600	Yes	Yes	PK; PU; 11th + Free*
Hoffman-La Roche Nutley, N.J.	16	29	120	290	6,000	7,000	Yes	Yes	PK; PU; DF

*Above 10 passengers, no extra charge
**At multiple sites
PK - Priority Parking
PU - Personal Use (usually at small fee)
DF - Driver Free

Table 1.9

Summary of Vanpool Program Data

(continued)

Firm	Number of Vans		Number of Riders		Employees Eligible		Current Waiting List	Currently Expanding	Incentives Provided
	1975	1977	1975	1977	1975	1977			
Ralph M. Parsons Pasadena, Cal.	31	33	310	300	4,000	5,000	Yes	Yes	PU
Scott Paper Co. Philadelphia, Pa.	2	1	19	9	1,500	1,500	No	No	PU
Sperry Rand Phoenix, Arizona	10	11	120	132	3,100	3,600	Yes	No	PK; 10th + Free
TVA Knoxville, Tenn.	22	130 (163)**	264	1,430 (1,750)**	3,200	3,000 (20,000)**	Yes	Yes	$11/month subsidy; PK
Texas Instruments Dallas, Texas	10	14	120	160	15,000	20,000	Yes	Maybe	PK; PU; 9th + Free
3M Company St. Paul, Minn.	75	92	780	1,030	10,000	10,000	Yes	Yes	PK; PU
Winnebago Co. Forest City, Iowa	15	31	250	700	2,700	3,000	Yes	No	PK; DF

*Above 10 passengers, no extra charge
**At multiple sites
PK - Priority Parking
PU - Personal Use (usually at small fee)
DF - Driver Fee

and linehaul service. The change in LOS for the linehaul portion of the transit trip is the sum of any change in linehaul service plus the change in transit access level of service.

Appendix 2
Impact Estimation

Introduction

The purpose of this appendix is to outline the methodologies used to calculate the benefits and costs of each scenario, as presented in the impact-incidence matrices. Each category of impacts will be discussed, in the order in which they are presented in the impact-incidence matrices. In Appendix 3, example of the benefits calculations of the first IP scenario of Setting 1, "Southern Belle", is presented. Two impacts which were estimated through lengthy procedures (consumer surplus and change in auto ownership) are not detailed in this example. Instead, an abbreviated example is included within the discussion of the development of these impacts in this chapter.

2.1 Mobility

In an equilibrium analysis framework (i.e., where travel volume and system performance are each represented as partially dependent on the other), merely the level of utilization, or demand, can be interpreted as a valid evaluation measure, (see, for example, Bhatt, 1971). This holds true for analyzing IP operations, and is especially true for an examination of the differential impacts on various impact groups (such as the elderly). In order not to distort the consequences of IP, the change in ridership which is accounted for by <u>induced</u> trips (trips which would not otherwise have been made at all), as distinct from diverted trips which would have been made on other modes, is also provided.

The number of new transit trips was estimated by comparing setting and scenario attributes with those of existing paratransit systems and developing diversion statistics for the system of interest. Table 2.1 presents diversion data from a variety of paratransit systems in the U.S. The breakdown of total new transit trips into the market segments was performed by assuming new transit trips are proportional to the market segments representation in the entire user population. These percentages are outputs of the estimation techniques described earlier.

To determine the total number of induced trips, the same set of diversion data used. It was assumed that induced trips were more likely to be generated among the special markets than by the average person who has more options available. Special markets were assumed to account for between 50% and 80% of the induced trips depending on their representation in the service area population and user population. The rate of induced trip per patron for special markets fell between two and four times that of the general population. The special market induced trips were divided among the individual special markets in proportion to their representation in the special market user population.

2.2 Consumer Surplus

A primary measure of user benefits for this project is consumer surplus, which incorporates all changes in direct travel costs, travel times, and out-of-vehicle (e.g., wait) times. The classic definition of consumer surplus is usually expressed at the level of an individual consumer, and then aggregated to the set of all consumers. The definition might be phrased as the difference between what an individual consumer is willing to pay for a good or service (e.g., a trip), and what he or she actually does pay. Willingness to pay is typically measured by the "demand curve" for the good or service under study (transportation, in this case).

Table 2.1

Former Mode of DRT Patrons (%)

Site/Service	No Trip (Induced)	Driver	Auto Pass.	Total	Taxi	Bus	Walk	Other*
Ann Arbor	26	NA**	NA	37	10	NA	23	4
Batavia DRT	17	6	15	21	30	6	15	11
Batavia Subscription	6	8	34	42	18	3	26	5
Benton Harbor	34	NA	NA	43	2	NA	15	6
Haddonfield	22	NA	NA	25	26	11	16	-
Ludington	14	NA	NA	23	20	-	30	13
Merrill	13	20	11	31	21	-	35	-
Midland	18	NA	NA	39	10	-	25	8
Niles	8	NA	NA	8	34	-	40	10
Rochester (Monday)	21	5	29	34	9	18	17	1
Rochester (Saturday)	37	4	26	30	8	7	13	5
Santa Clara	14	NA	NA	62	5	NA	19	-
Xenia	19	NA	NA	36	NA	-	34	11

* Includes bicycle, hitchhike, no response.

** NA indicates data not available.

Sources: Ewing, Reid and Nigel Wilson, Innovations in Demand-Responsive Transit, MIT Center for Transportation Studies, 1976.

Figure 2.1 illustrates how consumer surplus can be represented.

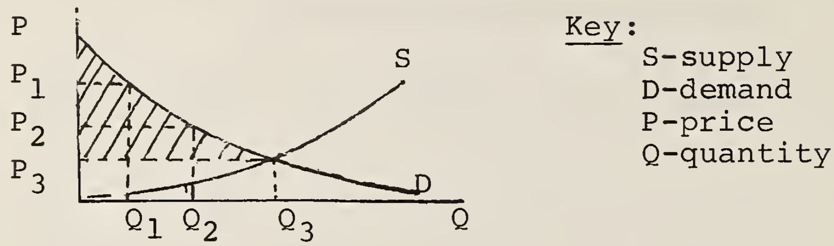

Figure 2.1 Consumer Surplus

Figure 2.1 shows that, at market equilibrium conditions, all consumers are required to pay price P_3, even though there are many consumers who are willing to pay more than P_3, as evidenced by the slope of the demand curve, D. In fact, only the consumer of the Q_3rd unit pays exactly the price at which he or she values the commodity or service received. The consumer of the Q_2nd unit would be willing to pay $P_2 - P_3$; similarly, the consumer of the Q_1st unit would have paid P_1 if he or she were so required, and therefore benefits even more (by $P_1 - P_3$). The shaded area under the demand curve and above the equilibrium price P_3 represents the aggregate consumer surplus of all individuals who purchase Q_3 units.

If an alternative production process is implemented (i.e., a new transportation system in our analogy) which lowers the cost of providing any given quantity of the commodity of service in question, then this change (in association with an unchanged demand curve) will result in a new equilibrium condition, and a change in consumer surplus.

The shaded area in Figure 2.2 illustrates an example of such a change in consumer surplus.

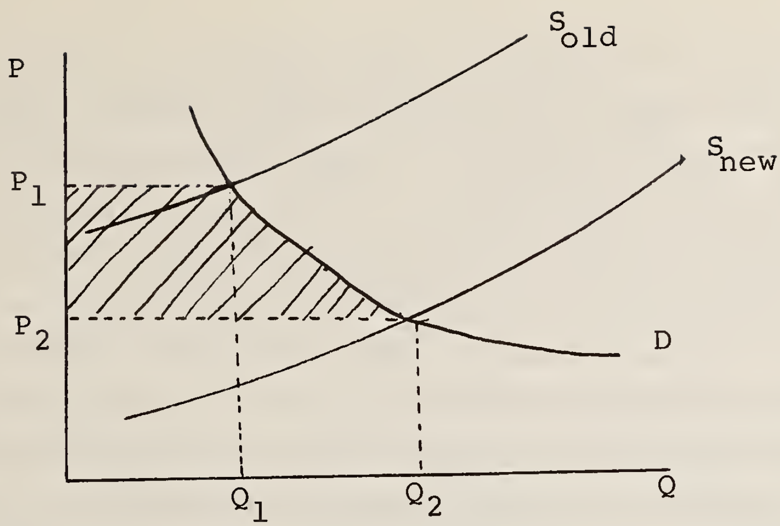

Figure 2.2 Change In Consumer Surplus

The measure of consumer surplus has been fairly widely used to evaluate large scale public capital investments (such as highways) where changes in consumer surplus, suitably discounted over time, serve as an estimate of a portion of the benefits of a particular alternative. The use of consumer surplus for the evaluation of public transit options has been relatively minimal, and limited generally to the evaluation of major capital improvements, such as the construction of heavy rail transit, which has some basic economic similarities to highways. See, for example, Foster and Beesely, (1969) and Watanatada et. al., (1975) for example applications to heavy rail and conventional bus transit respectively.

The utilization of consumer surplus for the analysis of public transit options requires a reinterpretation of the meanings of the concepts of price, quantity, and the supply curve (although the concept of the demand curve in the context of transportation analysis is very close to its definition in the economic literature). The idea of "quantity" should be thought of as volume, perhaps segmented by time-of-day, origin-destination pair, socio-economic characteristics, etc. The supply curve is not the traditional economic supply curve which indicates the quantity of goods or services a producer is willing to offer at a given selling price. Rather, the supply curve is, in this context, more akin to the concept of a production curve; it represents the "cost" of serving a given demand, where "cost" is a measure of the performance of the transportation system which is delivered to the system's users.[1] The performance of the transportation system is, in turn, an aggregated measure of a vector of items such as fare, wait time, ride time, walk time, convenience, reliability, comfort, safety, etc.; in short, all the components of the level-of-service offered by the transportation system. Finally, the inverse of transportation system performance, (level-of-service or impedance) is the appropriate analogy to the economic concept of "price". Given these analogies, the supply curve indicates the level of impedance offered by a transportation system (e.g., IP) at any given volume level. Similarly, the demand curve indicates the volume resulting from a transportation system performing at any given level of impedance. Simultaneously solving for the point at which the supply and demand curves meet results in the "equilibrium" conditions of a particular volume level travelling at a particular level-of-service, or impedance.

In this project, use has been made of a number of existing supply and demand models to derive the equilibrium conditions for each scenario analyzed. To be consistent with the methodologies used to determine demand, the performance of the transportation system is measured with the utility functions used in the logit demand model. These utility functions determine the value of a transportation choice as a function of the level of service attributes, the individual's socioeconomic status, and characteristics of the trip's destination.[2] Unfortunately it is impossible

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[1]In many ways, the terms "performance curve" and "performance model" are conceptually more attractive and accurate than the more commonly used "supply curve" and "supply model".

[2]The utility functions used in this project have been described in Appendix 1. A complete discussion of the logit demand prediction methodology can be found in Ben-Akiva (1973).

to completely specify all factors which impact an individual's perception of his evaluation of the performance of a transportation mode. Therefore, the value of a transportation service can be evaluated only in terms of the systematic portion of the utility function. (The systematic portion consists of all but the random error term of the utility function).

To determine the value of IP implementation on the "impedance" or "level of service" of the transportation system as a whole, it is necessary to measure the expected utility associated with an individual's trip both with and without the IP implementation (or before and after any change in the transportation system). Given the value of the systematic portion of the utility function for each mode available in the transportation system and the distribution of the unknown components of the utility,[1] Lerman and Ben-Akiva (1977) have proven that the expected value of the maximum utility for the logit formulation is the natural log of the sum of the exponentiated systematic utilities for each available mode. In mathematical form, this expected utility is:

$$E\,[\max_{j \in C_t} U_{jt}] = \ln \sum_{j \in C_t} e^{V_{jt}} + K$$

where

U_{jt} = total utility of the transportation option j to person t

V_{jt} = systematic portion of the utility for travel option j to person t

K = constant

C_t = set of options available to person t.

The change in consumer surplus can therefore be calculated as the difference between expected maximum utility in the before case and

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[1]The distribution of the error term ε (unknown components) of the logit formulation of the utility function is a Weibull distribution with a cumulative distribution function of

$$P(\varepsilon \leq \omega) = e^{-e^{(a+\omega)}}$$

the expected maximum utility in the case after implementation. Note that this procedure is effectively estimating the change in systemwide utility, or the (log) sum of utilities of all transportation modes.

The discussion above indicates the methodology which would be used to calculate the consumer surplus of the change in the transportation system for an individual specific trip. It is necessary to aggregate over all trips for the purpose of calculating total consumer surplus resulting from IP implementation. The straightforward methodology to aggregate to systemwide impact would be to determine the consumer surplus for each trip and then add all calculated value to consumer surplus. Because this is impractical, characteristics of the "average" trip were developed for each trip purpose, and these characteristics were applied to all trips made for that purpose. The expected maximum utility was then calculated (for the base case and for the IP or extended conventional mode scenarios) for a typical trip by each market segment[1] and for each trip purpose[2]. The difference between the before and after values were then multiplied by the total number of trips per year made by the market segment (for each trip purpose) to obtain the change in consumer surplus.

In developing the level of service on individual modes for the various trip purposes, it was assumed that in-vehicle travel time is proportional to trip distance for each mode, out-of-vehicle travel time is constant for each mode, and out-of-pocket travel costs were proportional to distance for auto and conventional taxi modes and constant for each other mode. Using these assumptions and the output from the FORCAST model (or other supply models

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[1] Market segments are broken down by age and auto ownership.

[2] In many IP scenarios, the level of service and modes available for individuals was dependent on the trip length. Short trips could use the circulation service while long trips were provided with a new feeder option. In these cases, the change in consumer surplus was calculated for each of these trip types in addition to being divided according to market segment and trip type.

when FORCAST was not used), which includes the average level of service and trip distance for patrons of each mode, the level of service for each mode was calculated. Peak period average trip distance was used as the descriptor of the average work trip, and off-peak average trip distance was used as the average of the non-work trip descriptor.

Finally, after aggregate market segment consumer surplus was developed for each mode, the values of consumer surplus were converted into dollars 1) first converting non-work utility units into work utility units, based on the relative coefficients of in-vehicle travel time (IVTT) within the utility functions, and; 2) converting the work utility units into dollars based on the work utility coefficient for out-of-pocket costs (OPTC). Note that, in this methodology, a minute of IVTT for the non-work trip has the same value as a minute of IVTT for the work trip. Once consumer surplus is converted into dollars, it is possible to sum over various market segments to obtain total annual consumer surplus resulting from the change in the transportation system. An example of the calculation of consumer surplus is presented in Figure 2.3 for the zero-auto, non-elderly work trips made in part of Setting 1. The after case is the IP service provided under Scenario A in 1980.

This methodology has a number of advantages which result in better estimates of consumer surplus in this case than would the application of standard methods. Clearly one advantage is the resulting consistency between the level of demand predicted and the benefit to consumers. It is not necessary to assume a specific value of time for the individuals who make use of the new transit services. Instead, this impact and other factors are explicitly addressed within the formulations of the utility functions used to project demand for services. In addition, a number of problems and paradoxes are avoided. One example is the "bus paradox". This phenomena is noted when a new transit service is added in an area in which a travel alternative (usually auto) that provides better service already exists. Generally, the transit service will attract

I. Input Data

Average Trip Distance = 4.11 mi.

	$IVTT_m$		$OVTT_m$		$OPTC_m$		$DIST_m$
	Before	After	Before	After	Before	After	
(Auto Drive Alone)	14.32	14.32	2.00	2.00	22.57	22.57	4.52
(Auto Shared Ride)	14.48	14.48	6.00	6.00	7.83	7.83	3.92
Fixed Route Bus	22.97	22.97	34.00	99.00	30.00	30.00	4.12
Circulation DRT	--	10.45	--	10.13	--	50.00	1.97
Feeder DRT	--	31.14	--	25.98	--	57.50	6.02

Worktrips/day for non-elderly, auto ownership ∅ = 203

II. Calculation of Trips which can be Served by Circulation DRT and Feeder DRT

$$\% \text{ Circulation} = \frac{(\text{average trip distance} - \text{average feeder trip distance}) \times 100}{(\text{average circulation trip distance} - \text{average feeder trip distance})}$$

$$\% \text{ Circulation} = \frac{(4.11 - 6.02) \times 100}{(1.97 - 6.02)} = 47.2\%$$

% Feeder = 100 - % Circulation = 100 - 47.2 = 52.8%

III. Calculation of Average Level of Service for Circulation DRT and Feeder DRT

1. $IVTT'_m = IVTT_m/DIST_m \times DIST_{circulation}$

2. $OVTT'_m = OVTT_m$

3. $OPTC'_m = \begin{cases} OPTC_m/DIST_m \times DIST_{circulation} & \text{for Auto Modes} \\ OPTC_m & \text{for Bus, DRT} \end{cases}$

Figure 2.3

Sample Calculation of Consumer Surplus

For Setting #1 IP Scenario A

Work Trips, Non-Elderly, Auto Ownership ϕ

(Zones 1 & 2)

Circulation LOS	IVTT'		OVTT'		OPTC'		DIST'
	Before	After	Before	After	Before	After	
Auto Drive Alone	6.24	6.24	2.00	2.00	9.84	9.84	1.97
Auto Shared Ride	7.27	7.27	6.00	6.00	3.93	3.93	1.97
Fixed Route Bus	10.98	10.98	34.00	99.00	30.00	30.00	1.97
Circulation DRT	--	10.45	--	10.13	--	50.00	1.97

Feeder LOS	IVTT'		OVTT'		OPTC'		DIST'
	Before	After	Before	After	Before	After	
Auto Drive Alone	19.07	19.07	2.00	2.00	30.06	30.06	6.02
Auto Shared Ride	22.23	22.23	6.00	6.00	12.02	12.02	6.02
Fixed Route Bus	33.56	33.56	34.00	99.00	30.00	30.00	6.02
Feeder DRT	--	31.14	--	25.98	--	57.50	6.02

IV. Calculation of Utilities[1]

U_{ada} = -3.51 -.05075IVTT'-.2275 OVTT/DIST'-0.1 OPTC'+ 1.136

U_{shr} = 0.0507-.05075IVTT'-.2275OVTT/DIST'-.01OPTC'+ 0.818-.2716 DIST'

U_{bus} = 0.5 - .05075 IVTT'- .2275 OVTT/DIST'- .01OPTC'+ .7529/DIST'

U_{drt} = 1.085-.05075 IVTT'- .2275 OVTT/DIST'-.01OPTC'+ .7529/DIST'+ 0.2

U_{feeder} = -.05075 IVTT'- .2275 OVTT/DIST'- .01OPTC'+ 0.2

Circulation Utility		Before	After
	Auto Drive Alone[2]	--	--
	Auto Shared Ride	-0.767	-0.767
	Fixed Route Bus	-4.901	-12.408
	Circulation DRT	--	-0.533

Feeder Utility		Before	After
	Auto Drive Alone[2]	--	--
	Auto Shared Ride	-2.240	-2.240
	Fixed Route Bus	-3.662	-6.119
	Feeder DRT	--	-2.938

[1] See Appendix 1 for definition of variables. Each utility must be calculated for trips which can be served by the circulation service and trips which can be served by the feeder service.

[2] Unavailable to no auto market segment.

Figure 2.3 (Cont.)

V. Log Sum Exponential Utility ($\Delta \ln \sum e^{u}$)

	Before	After
Circulation	-.7511	0.050
Feeder	-2.0239	-1.822

VI Consumer Surplus

	$\Delta \ln \sum e^{u}$	Trips/day	Consumer Surplus[1]/day
Circulation	.7561	96	72.58
Feeder	.2019	107	21.60
Total	--	--	94.18

Consumer Surplus/year = 251 x Consumer Surplus/day

= 251 x 94.18 = 23,639

[1]In work utility units which are equivalent to $1.00

Figure 2.3 (Cont.)

riders and, as a result, increase the average wait and ride times of all trips made. If one were calculating consumer surplus based solely on these average levels of service, the result would be a net reduction in consumer surplus. Such an evaluation would be incorrect since no one would alter their travel patterns in a manner that would degrade the quality of service for that trip. Similar problems are encountered when IP replaces conventional transit. Even when IP service is better than the previous transit alternative, no increase in consumer surplus would be attributed to persons who were diverted from auto modes. For these reasons, a methodology which only considers the change in measurable travel times and costs between the old and new modes (and ignores unobserved factors associated with individual travel option values) will tend to underpredict the benefits of the service provided. In the procedure used for estimating consumer surplus in this study, the addition of a new mode with worse average service levels than auto will still result in a net increase in systemwide utility, since the natural logarithm of the sum of the utilities is being calculated.

Unfortunately, it is not possible to calculate the change in consumer surplus for those portions of the analysis which did not use a logit demand model for prediction of demand.[1] Thus, special consumer surplus was not calculated for the transportation handicapped and vanpools services. This implies that the benefits from these services are underestimated.

2.3 Coverage

While "mobility" measures the amount of trip making which would actually take place in a particular scenario, and "consumer surplus" measures the quality of the trip making which would take place, "coverage" measures the opportunity for trip making which could take place as a result of the implementation of IP. Coverage refers to the spatial availability of transit service, and is measured by the

[1]The estimation of all demand except that of the transportation handicapped and vanpool programs were based on logit demand models. See Appendix 1 for a complete discussion of demand estimation techniques.

population of the service area residing in areas accessible to service. For conventional fixed route transit, for example, the population within a quarter-mile of the route (one-eigth of a mile for the elderly population and one-sixteenth mile for the transportation handicapped) were considered "covered". The coverage estimates were derived by direct measurement. All residents within the service area of a doorstep DRT service were treated as covered.

In addition to spatial coverage, described above, temporal coverage is also necessary to describe the increased opportunity to use public transportation. Temporal coverage presented in terms of the number of days per week in which service is provided, as well as the hours of operation.

2.4 Vehicle Miles of Travel

Vehicle miles of travel (VMT), by itself, is a measure of urban area congestion. Perhaps even more importantly, VMT is an important input factor for the calculation of fuel consumption and air pollution impacts. VMT of the transit system, the auto mode, and the local taxi fleet can all change in response to the implementation of IP. Trucks, school buses, and other modes were not considered, because there should be no change in their VMT.

The change in the VMT produced by the transit mode was calculated directly from the specifications of the scenario. Each scenario specified the number of paratransit vehicle hours added to base case transit service, and any changes conventional transit service provided along specified routes. The change in paratransit VMT was calculated as a product of the vehicle hours provided times the average speed (including stops) expected for the specific setting and scenario. Average speed was developed in the supply model, based on the productivity of the IP service and the non-stop average speed of the area. Since the productivity varied only slightly between alternatives, it was generally unnecessary to recalculate average vehicle speed for each alternative. The average IP vehicle speeds obtained in this study varied between 8 miles per hour in extremely dense, congested areas, to 18 miles per hour on local streets in relatively uncongested areas. The calculation of VMT changes resulting from fixed route elimination was simply performed by multiplying the number of runs on a route by the round trip distance on that route, and including a small proportion of deadhead mileage (usually around 10%). Transit VMT was defined to include all paratransit services, even when provided through a private taxi operator.

The change in taxi VMT results from reduced patronage on the exclusive-ride services. Ridership reductions were determined from the diversion statistics developed for existing paratransit services (see Table 2.1). Given the patronage loss, the change in the number of taxis on the road was based on data from Control Data Corporation (1976) indicating the average number of passengers carried per cab per year. Further data on annual VMT per cab was then used to calculate change in VMT for exclusive-ride taxi operations. Table 2.2 presents some of the data on taxi operations used in this study.

The change in taxi VMT for the extended taxi alternative was calculated in a different manner. Since most of these scenarios completely specified the taxi service offered, VMT changes could be developed directly. In other cases, the change in VMT was based on the expected use of new vehicles. In some cases, the vehicles were assumed to be put into service in proportion to the existing number of vehicles provided during each time period in the base case. When a general user-side subsidy was provided and vehicle fleet size increased, this assumption was made. In cases where there was no change in fare structure, only in the number of vehicles provided, additional vehicles were added only during peak service hours. Time of day distributions of taxis operating was obtained from data on a taxi company in New Haven, Connecticut.

The change in auto VMT is comprised of three components:

1. Reduction in auto ownership (see section on automobile expenditure impacts).

2. Reduced chauffer trips (see section on chauffer trips), and

3. Diversion of former drivers who do not sell an automobile.

Table 2.2

Data on Taxicab Operations

	Number of Taxicabs in Fleet							
	Less than 10	10-24	25-49	50-74	75-99	100-200	200 and Over	All Operators
Annual Passengers Per Taxicab (000) 1975	15.4	15.4	12.9	12.6	19.5	8.5	9.2	10.3
Passengers Per Trip 1975	1.31	1.56	1.61	1.47	1.81	1.29	1.43	1.46

Source: Taxicab Operating Characteristics, Control Data Corporation and Wells Research Company, 1977

It was assumed that, for each auto eliminated, 2000 miles previously driven in that auto would be eliminated while the remaining miles would be shifted to the primary auto in that household. For each chauffer trip eliminated, VMT equal to the average IP trip distance was assumed eliminated. The VMT reduction resulting from former drivers who did not eliminate an automobile was calculated using the following procedure.

1. Former auto trips were determined based on the diversion statistics developed from data on existing systems.

2. Former auto-driver trips were calculated as 40% of the auto trips diverted (with the remainder passenger trips), based on several DRT user surveys in Merrill, Rochester and Batavia.

3. The number of drivers represented by former auto driver trips was calculated based on 2.2 drivers per daily non-work trip, and 1.65 drivers per daily work trip based on Rochester PERT data from surveys in 1975-1977 (unpublished).

4. Drivers who eliminate autos and thus whose VMT changes have already been calculated are subtracted from the total.[1] This assumes that all persons who eliminate autos use the IP system, which should result in a conservative estimate (i.e., lower reduction in VMT).

5. The number of driver trips eliminated (for drivers who do not eliminate autos) is calculated based on weekly trips per driver from statistics in 3) above.

6. VMT eliminated equals the average (IP or new transit) trip distance multiplied by the number of trips eliminated by persons who formerly used auto but did not reduce the number of autos owned.

The total auto VMT change is the sum of the three components.

2.5 Fuel Consumption and Pollution Emissions

Factors for scaling VMT to gallons of fuel consumed and grams of various chemicals emitted were based on available and projected vehicle characteristics. Table 2.3 presents the factors employed in this study along with the available base data. Van and bus data in this table were used for both 1980 and 2000.

[1] If the number of autos forgone is greater than the number of auto drivers, no VMT was assumed to be eliminated by drivers who did not eliminate autos.

Table 2.3

Factors for Fuel Consumption and Pollution Emissions

	Fuel Consumption (gallons/mile)			Pollution Emissions (grams/mile) CO				HC				NOx			
	1972*	1980**	2000**	1972*	1980**	1990*	2000**	1972*	1980**	1990*	2000**	1972*	1980**	1990*	2000**
Auto[a]	0.070	0.059	0.029[1] 0.025[2]	69	45	16	3.4	10	6	2	0.4	5	3	1	1
Taxi[a]	--	0.100	0.040	--	70	--	11	--	10	--	1.2	--	4.2	--	2
Van[a]	0.090	0.125	0.050	94	86	--	15	13	12	--	1.5	6	5	--	2
Small Bus[b]	0.134	0.134	0.080	120	120	--	25	17	17	--	3.5	8	8	--	3
Medium Bus[c]	0.091	0.091	0.050	--	11	--	5	--	15	--	3.5	--	14	--	10
Large Bus[c]	0.167	0.167	0.100	11	11	--	5	15	15	--	3.5	14	14	--	10

[a]25 mph, arterial travel, gasoline engine

[b]20 mph, 0% grade, gasoline engine

[c]20 mph, 0% grade, diesel engine

*Source: Deleuw Cather (1975)

**Estimates used in impact analysis

[1]Auto ownership level 1

[2]Auto ownership level 2

2.6 Employment

The implementation of an IP system will affect the number (and type) of jobs by impacting at least two components of the employment market: the new vehicles and vehicle hours of service associated with IP and/or conventional transit would require additional drivers, maintenance personnel, dispatchers, call takers, etc.; and the competition of the improved transit system will reduce taxi patronage, resulting in a decrease in taxi employment.

The estimation of employment impacts on the transit industry is based on the service hours, service type, and number of vehicles provided. The driver requirements in the transit industry are determined assuming each driver works a total of 1920 hours per year. It is assumed that an additional 10% of the revenue vehicle hours are required for deadheading and driver changes. The number of dispatchers and call-takers required to handle demand-responsive systems is dependent on the demand rate and the number of vehicles in service. One dispatcher was assumed to handle up to 12 vehicles under manual dispatching and up to 25 vehicles under computerized dispatching. One call-taker was required for every forty demands per hour under either computerized or manual dispatching system. Maintenance personnel in the transit industry are hired at the rate of one maintenance worker per 60 to 90 thousand miles on a conventional transit vehicle and one per 80 to 110 thousand miles for smaller vehicles used in flexible transit operations.[1] The number of administrative personnel used to control a transit service is dependent on the make-up of the service. Services using multiple carriers, offering several types of service, or offering service in non-adjacent portions of the community generally require more administrative personnel per employee than other types of systems. The average ratio of administrative personnel to other personnel is approximately 1:20 (although it is much higher for systems with fewer than 20 vehicles).

[1] These data were derived from VMT and maintenance personnel data from a variety of conventional transit and paratransit services from whom cost data were collected. Sites include Ann Arbor, La Habra, and Cleveland.

In the taxi industry, it is assumed that taxi drivers (on IP service) drive 2500 hours per year. Again a small portion of driver hours are required for deadheading. Dispatching for shared-ride services requires approximately the same number of employees in the taxi industry as in the transit industry. One maintenance employee is required per 75,000 taxi vehicle miles.

Employment in the exclusive-ride taxi industry is calculated based on the number of cabs eliminated. For every cab eliminated, one and one-half drivers lose their jobs. This figure is consistent with data from the taxi industry developed from CDC (1976). Changes in exclusive-ride taxi services analyzed in this project have been relatively small. Therefore, in most cases, the impacts have been assumed to result in no change in the dispatching, administrative, or maintenance personnel. There were some exceptions to this in the extended taxi alternatives, where change in these personnel categories were assumed to be slightly less than proportional to the change in revenue.

The change in employment payroll in both the transit and taxi industry (for IP service) was based on employee hours and wage rates for the settings using local data on setting specific wage rates. The employment payroll figure does not include fringe benefits. In the case of exclusive-ride taxi, employment payroll is assumed to include 45% of the revenue collected from fares plus a 15% tip.

Note that, in considering the taxi industry, it was assumed that all drivers work on a commission basis. This is clearly no longer the case; the trend appears to be towards more and more driver leasing arrangements, and even driver owner arrangements where drivers are dispatched by a common "taxi broker" (which is usually the former fleet operator). Because the owner-driver relationship is changing rapidly, and because it may vary from company to company within a given setting, it was felt to be beyond the scope of the study to attempt to distinguish between different arrangements.

2.7 Automobile Expenditures

This category measures changes in automobile expenditures resulting from changing patterns of automobile ownership. All forgone autos are assumed to be "second" cars, with an average value of $4,000 (in 1977 dollars). Eliminated second cars are assumed to "transfer" all but 2000 annual miles to the household's "first" car, and the 2000 eliminated miles is costed at the rate of 8¢ per mile.

The methodology used to forecast the impact of IP on changes in auto ownership utilizes a previously estimated disaggregate joint model of auto ownership and work trip mode split. This full model is fairly cumbersome and contains a fixed route mode choice model which is not appropriate to DRT system work trips. However, a demand forecasting technique known as pivot-point (or incremental) analysis was used to circumvent both of these problems. The approach predicts revised auto ownership based on existing auto ownership and changes in level of service, rather then employing the full transportation auto ownership/demand model system based on detailed household, zonal, and level of service data. By employing a "pivot-point" approach, data and computational requirements are greatly reduced; no knowledge of detailed socioeconomic and level of service data for each household or zone is required. Only existing estimates of auto ownership levels and proposed changes in level of service are necessary.

The underlying model represents a household's choice of both auto ownership level (0, 1, 2+ autos) and mode to work (drive alone, shared ride and transit)[1]. The new choice probabilities depend only on the original, base choice probabilities and the changes in the level-of-service attributes; this implies that, in forecasting, one need not know the absolute values of all the independent variables in the function both before and after the change.

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[1] Note that the alternative of driving alone and not owning an automobile is assumed to be an invalid alternative.

In order to operationalize the pivot-point approach into a practical forecasting procedure, the following items are necessary:

1. a previously calibrated disaggregate, joint auto ownership/mode-to-work model, which includes variables that adequately reflect the impact of an integrated paratransit program;

2. a procedure for aggregating household level forecasts to the study area level; and

3. a method for predicting the response of households that did not have transit in the base case, but do have it under an integrated paratransit system.

In this study, a model previously estimated and validated by Cambridge Systematics, using data from Washington, D. C., was selected. This model (described in greater detail in Cambridge Systematics (1976)) has the following features:

1. It includes in-vehicle time, out-of-vehicle time and out-of-pocket costs for work travel as separate level of service measures in its utility function.

2. The coefficients of the level of service to work variables are very close in magnitude to those obtained in other studies using totally different data sets from other cities.[1] (e.g., Golob and Burns (1977). This provides a strong basis for the validity and geographical transferability of the models and their use in this analysis.

3. The model includes variables reflecting how the relative cost and time on non-work travel by auto and transit influence auto ownership decisions: i.e., the decision on how many autos to own depends not only on work travel, but on characteristics of the household and its non-work travel patterns.

Procedures for aggregating individual (disaggregate) forecasts to obtain areawide totals range from using a single, "typical"

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[1]As one example, Cambridge Systematics' coefficient for transit travel time was .06, while Golob and Burns study cited above had a value of .05.

household to represent all households in an urban area, to the enumeration of the choice probabilities for a representative sample of households in the study areas separately (Koppelman (1975)).

The tradeoff is, of course, between the cost of the analysis and the accuracy of the results. Because of limitations in both budget and available data, a relatively simple approach, somewhere between these two extremes has been selected. This approach is inexpensive yet hopefully reasonably accurate. The study area population is aggregated into only two groups, those who have transit available to them in the base case, and those who do not. This type of segmentations has been shown to be the most important in obtaining accurate forecasts. Within each group, a forecast for the "average" household (i.e., a household with the average income, average level of service to work by each mode, etc.) is used.[1]

The one remaining problem in applying this procedure is the question of how to handle the households who did <u>not</u> have the transit alternative in the base case. It is impossible to pivot from a case in which there is a zero probability (i.e., everyone took autos). (This is analogous to using an elasticity to estimate the demand change resulting from a fare increase above a current free fare system. The percentage change in fare cannot be calculated.) This was resolved by assuming that those without transit available would first shift to a point where the choice probabilities would be the same as those households who had transit available in the base case. The pivot point is then applied to this case in a manner similar to the way it is applied for those who did have transit available. (Of course, the levels-of-service may be different and therefore the resultant choice probababilities or mode splits will also be different.) In other words, the actual change in auto ownership for the group without transit is then computed as the difference between the forecasts from the assumed pivot point

[1]The potential errors in this procedure are discussed in detail in Koppelman (1975). His results indicate that using a small number of groupings reduces the error in aggregation to a level less than the error inherent in the model itself.

and the actual auto ownership of then on-transit served subpopulation.[1]

The major strength of the pivot point approach is that it uses only a sub-set of all the model parameters and base case data to make forecasts. As long as the pivot point actually reflects base case conditions, only the changes in utilities affect the predictions. This feature greatly enhances the prospects for geographical transferability of the model.

The most significant weakness in the particular approach outlined above is the simplicity of the approach used to aggregate the household level forecasts. For this reason, the estimated changes in auto ownership (and their corresponding benefits) should be viewed as first cut estimates rather than relatively precise forecasts.

The application of this procedure for the scenario presented in this study required the following inputs:

- Before and after level of service by available modes for "typical" work and non-work trips,
- Before IP mode split to work by auto ownership level,
- The distribution of auto ownership of persons and served by household,
- The average household income per year,
- The average household size, and
- The number of households with and without transit available for work and non-work trips before and after the IP implementation.

Many of these data items could be determined directly from previously generated model inputs, or model outputs. Level of service, however, for a typical trip was determined based on the average trip length and modal level of service characteristics. The out-of-vehicle travel time for each mode was assumed to be equal to that reported

[1]The implicit assumption here is that the behavior of the group without transit in the base case would be the same as the group with transit if the non-transit group were offered the same level of service.

for the average trip by that mode. In vehicle-travel time was based on the average modal speed and the distance of the average trip. Calculation of average fare was based upon the structure of charges for the mode. If fare was distance related, average fare per mile times distance was used. If a flat fare structure existed, the flat fare was used in the calculations.

To determine the change in service attributes for the transit mode when paratransit service has been added, the composite level of service was developed as the log of the sum of the exponentials of the utility functions as defined in the model presented below.[1] This methodology is consistent with the logit formulation of the auto ownership model, assuming the constants for conventional and flexible transit services are the same in this model.[2]

One data item not available directly from the FORCAST model outputs was the before mode split of work trips. To develop this input, the after mode split (available from FORCAST output) was adjusted such that users of new services were added to the mode from which they were diverted. This adjustment was based on the diversion statistics described earlier. Since mode split was required for each auto ownership level, it was necessary to assume that the diversion statistics remained constant for all households, that auto diverted trips were derived totally from auto shared ride for zero auto households, and that auto diverted trips from 1 to 2+ auto households were diverted from auto drive alone and auto shared ride based on the mode split for these modes in the after case. It was further assumed that no work trips were induced or diverted from walk or taxi as a result of the transit service. The adjustment of the before mode split has very little impact on the results of the auto ownership forecasting methodology; therefore, any assumptions need not be strictly justifiable. In the case where the FORCAST model was not used to project ridership on the transit system, a before mode split had previously been developed to determine the after ridership.

[1]This method of developing the composite level of service was discussed in great detail previously in the Consumer Surplus section of this appendix.

[2]The model was actually calibrated for conventional transit only since no other form of transit was present in the calibration data set.

The only data item for which no information was available was the difference between auto ownership characteristics of the population with and without transit available. For this reason, a conservative assumption was made. Both segments of the population were assumed to have the same auto ownership characteristics. In reality one would expect those without transit to have a higher auto ownership level; thus, these persons are more likely to eliminate autos when transit is implemented than would be predicted. On the other hand, households with transit available would likely have lower than average auto ownership; thus, there would likely be a smaller change from this group than would be predicted. Since the former impact would be substantially greater, one would expect these estimates of auto ownership to be low. This bias, however, is small in comparison to the errors produced from the employed aggregation procedure.

The specific formulation of the auto ownership model is:

$$P^{*(a,m)} = \frac{e^{\Delta V_{am}} P^{B}(a,m)}{\sum_a \sum_m e^{\Delta V_{am}} P^{B}(a,m)}$$

where: ΔV_{am} is the change in the systematic component of the utility of the alternative with auto ownership level a and mode m

$P^{*(a,m)}$ is the forecast distribution.

The change in the utilities are estimated using the existing models. Let all the level of service variables be denoted with an asterisk to denote the new values for the future conditions. Change in utilities are given by:

$$\Delta V_{am} = -.0129\ (IVTT^{*}_{m} - IVTT_{m})$$

$$-\frac{.0795}{DIST}\ (OVTT^{*}_{m} - OVTT_{m})$$

$$+ 1.55 \ln \left(\frac{INC - 800 \cdot HHSIZE - 1000 \cdot a - 250 \cdot OPTC^{*}_{m}}{INC - 800 \cdot HHSIZE - 1000 \cdot a - 250 \cdot OPTC_{m}}\right)$$

$$- \begin{Bmatrix} 0 \text{ if } a = 0 \\ 1.99 \text{ if } a = 1 \\ 2,80 \text{ if } a = 2+ \end{Bmatrix} (R^{*} - R)$$

where:

$$R = \frac{+.0164\ (IVTT'_D) + .0633\ (OVTT'_D) + .0757\ (OPTC'_D/CODE)}{+\ .0164\ (IVTT'_T) + .0633\ (OVTT'_T) + .0757\ (OPTC'_T/CODE)},$$

$$CODE = \begin{cases} 1 \text{ if } 0 < INC \leq 3000 \\ 2 \text{ if } 3000 < INC < 4000 \\ 3 \text{ if } 4000 < INC < 6000 \\ 4 \text{ if } 6000 < INC < 8000 \\ 5 \text{ if } 8000 < INC < 10{,}000 \\ 6 \text{ if } 10{,}000 < INC < 12{,}000 \\ 7 \text{ if } 12{,}000 < INC < 15{,}000 \\ 8 \text{ if } 15{,}000 < INC < 20{,}000 \\ 9 \text{ if } 20{,}000 < INC < 25{,}000 \\ 10 \text{ if } INC > 25{,}000 \end{cases}$$

R* is defined the same way as R, but using the new values of non-work level of service.

m = modal subscript modes include auto drive alone (D or ADA), auto shared ride (SHR), and transit (T).

$IVTT_m$ = in-v icle travel time for mode m for work trips in before case

$OVTT_m$ = out-of-vehicle travel time for mode m for work trips in before case

INC = household income (1968) dollars

HHSIZE = household size

a = auto ownership level (0, 1, 2+ autos/household)

$OPTC_m$ = out-of-pocket travel cost for mode m for work trips in before case.

IVTT*, OVTT*, OPTC* = level of service characteristics for work trips in after case

IVTT', OVTT', OPTC' = level of service characteristics for non-work trips in before case

IVTT'*, OVTT'*, OPTC'* = level of service characteristics for non-work trips in after case

An example of the calcuation of the change in auto ownership for one of the services provided in Scenario A of Setting 1 is presented in Figure 2.4. Most calculations are illustrated for

I. <u>Input Data</u>:

Level of Service:

Work

	IVTT		OVTT		OPTC		DIST
	before	after	before	after	before	after	
Auto Drive Alone	13.02	13.02	2.00	2.00	20.52	20.52	4.11
Auto Shared Ride	15.18	15.18	6.00	6.00	8.21	8.21	4.11
Fixed Route Bus	22.91	22.91	34.00	99.00	30.00	30.00	4.11
Paratranist	-	21.26	-	25.98	-	55.00	4.11

Non-Work

	IVTT		OVTT		OPTC		DIST
	before	after	before	after	before	after	
Auto Drive Alone	9.28	9.28	2.00	2.00	15.32	15.32	3.06
Auto Shared Ride	11.19	11.19	6.00	6.00	6.10	6.10	3.06
Fixed Route Bus	17.79	17.79	34.00	99.00	30.00	30.00	3.06
Paratransit	-	14.24	-	7.64	-	50.00	3.06

Households impacted = 14140 Household Income = $9600

Household size = 2.7

Work Mode Split at before auto ownership level with paratransit implemented.

	Auto Ownership			Modal Diversion (normalized to include just these modes)
Mode	0	0	2+	
Auto Drive Alone	0	.1548	.2480	} .95
Auto Shared Ride	.0331	.2600	.2401	
Fixed Route Bus	0	0	0	.05
Paratransit	.0169	.0352	.0118	
All	.05	.45	.50	

Figure 2.4

Sample Calculation of Auto Ownership Change Portion of Setting #1, Scenario A

II. Redistribution of Paratransit Mode Split

Mode Split before for Fixed Route bus at auto ownership level a = available Bus mode split at auto ownership level a + % paratransit mode split for auto ownership level a

Remainder of paratransit mode split for the auto ownership level is divided among the auto modes according to their frequency of use

For auto ownership level 1 in this example:

Mode split fixed route bus = 0 + .05 x .0352 = .0018

Remaining paratransit mode split = .0352 - .0018 = .0334

ADA mode split = .0334 x .1548/(.1548+.2600) + .1548 = .1672

SHR mode split = .0334 x .2600/(.1548+.2600) + .2600 = .2809

The entire before mode split matrix is:

	Auto Ownership		
Mode	0	1	2+
Auto drive alone	0	.1672	.2538
Auto shared ride	.0491	.2809	.2456
Fixed route bus	.0009	.0018	.0006
all modes	.05	.45	.50

III. Calculation of Non-Work portion of Δ Van

$$R = \frac{N}{D} \qquad R^* = \frac{N^*}{D^*}$$

where $N = .0164\ IVTT_{ADA} + .0633\ OVTT_{ADA} + .0757\ OPTC_{ADA}/CODE$

$D = .0164\ IVTT_{BUS} + .0633\ OVTT_{BUS} + .0757\ OPTC_{BUS}/CODE$

$N^* = .0164\ IVTT'_{ADA} + .0633\ OVTT'_{ADA} + .0757\ OPTC'_{ADA}/CODE$

$$D^* = \ln\left[e^{(.0164\ IVTT'_{BUS} + .0633\ OVTT'_{BUS} + .0757\ OPTC'_{BUS}\ KODE)} + e^{(.0164\ IVTT'_{DRT} + .0633\ OVTT'_{DRT} + .0757\ OPTC'_{DRT}\ KODE)}\right]$$

Figure 2.4 (Cont.)

where "'" indicates an "after" level of service and all level of service refers to non-work trips

For this example:

$$N = N^* = +.0164(9.28) + .0633\ (200) + .0757\ (20.52/5) = 0.5895$$

$$D = +.0164(17.79) + .0633(34.00) + .0757\ (30.00/5) = 2.8981$$

$$D^* = -\ln\ (e^{-6.794} + e^{-1.632}) = -\ln\ (.971) = 1.624$$

$$R = .2034 \qquad R^* = .3629$$

IV. Calculation of Work portion of $\Delta\ V_{am}$

$$W_{am} = .0129\ IVTT_m - .0795\ OVTT_m/DIST + 1.55\ln\ (INC\text{-}800HHSIZE\text{-}1000a\text{-}2.50\ OPTC_m)$$

for before modes including ADA, SHR, BUS

$$W'_{am} = \begin{cases} .0129\ IVTT'_m - .0795\ OVTT'_m/DIST + 1.55\ln\ (INC\text{-}800HHSIZE\text{-}1000a - 250\ OPTC'_m) & \text{for auto modes} \\ \ln \left[e^{(-.0129\ IVTT'_{BUS} - .0795\ OVTT_{BUS}/DIST + 1.55\ln(INC\text{-}800HHSIZE\text{-}1000a\text{-}250\ OPTC'_{BUS})} + e^{(.0129\ IVTT'_{DRT}/DIST + 1.55\ln\ (INC\text{-}800HHSIZE\text{-}1000a\text{-}250\ OPTC'_{DRT})} \right] & \text{for transit} \end{cases}$$

In this example for households with one auto,

$$W_{1,ADA} = -.0129(13.02) - .0795(2.00/4.11) + 1.55\ln(9600\text{-}800\ (2.7)\text{-}1000\text{-}2.50(30)\ ) = 13.783$$

$$W_{1,SHR} = 13.264$$

$$W_{1,Transit} = 12.623$$

$$W'_{1,ADA} = 13.783$$

Figure 2.4 (Cont.)

$W'_{1,SHR} = 13.264$

$W'_{1,Transit} = \ln [e^{11.366} + e^{12.784}] = 13,000$

V. Calculation of ΔV_{am}

$$\Delta V_{am} = W'_{am} - W_{am} - \begin{matrix} 0 \text{ if } a=0 \\ 1.99 \text{ if } a=1 \\ 2.80 \text{ if } a=2+ \end{matrix} \quad (R^* - R)$$

In this example the matrix of ΔV_{am} is

	auto ownership		
mode	0	1	2+
ADA	0	-.3174	-.4466
SHR	0	-.3174	-.4466
T	+.3767	+.0231	-.0597

VI. Calculation of new mode split

Applying the transformation procedure described in the text, this example results in an after work mode split of:

	auto ownership		
mode	0	1	2+
ADA	0	.1742	.2330
SHR	.0598	.2928	.2254
T	.0013	.0026	.0009
all	.0611	.4696	.4693

VII. Calculation of change in auto ownership

Δ Autos = (Avg autos/HH after - Avg Autos/HH after) x HH

Δ Autos = (1.408 - 1.45) x 14140 = -591 autos

Figure 2.4 (Cont.)

only one auto ownership = mode to work cell of the mode split table. Given the ΔV_{am} for all cells, the total change in auto ownership resulting from this part of the service is calculated.

For special services solely for the transportation handicapped, it was assumed there is no change in automobile ownership.

2.8 Chauffeur Trips

Currently, a significant portion of automobile travel is made for the purpose of serving pasengers; that is, transporting passengers to and from bus stops, rapid transit stations, retail establishments, and other final destinations. These are trips which the driver makes exclusively to meet the needs of the passengers and which would not otherwise occur. Very little data is available on the impact of transportation service on chauffer trips. To provide a rough estimate, data from large scale home interviews conducted in the 1960's (Boston, Chicago) were used. These data suggested that 25% of all automobile trips with more than one passenger are "serve passenger trips". The data also indicate that approximately 44% of all auto diverted transit trips are from auto-shared ride category. Therefore, 11% of all auto diverted trips for each scenario were assumed to have previously been chauffeur trips. The number of diverted from auto were determined based on the methodology described under the mobility section of this appendix.

2.9 Operator Impacts

The cost of operating IP was calculated by examining the factor inputs (labor and materials) required by the scenario specification, and multiplying by the unit costs appropriate to the factor inputs (e.g., wage rates cost of fuel, etc.). Revenue was derived directly from the scenario results, which included both patronage and average fare. Capital costs were annualized based on assumptions concerning the useful life of the various categories of required capital equipment and assuming steady state rolling replacement of the needed capital equipment. Assumptions regarding the life and costs of all equipment are included in Appendix B of Volume 3: Scenario Analysis.

The calculation of costs for privately operated paratransit services was based on either a flat rate per hour contract or a flat rate plus some portion of the revenue received. Flat rate contracts generally include a managment fee representing approximately 10% of the gross contract cost, although in one scenario the management fee was estimated at 20% for consistancy with a contract actually existing in the base case.

In calculating the taxi operating costs for the extended taxi services, cost of service was broken down into components proportional to vehicles, vehicle miles, administrative services, and revenue (or man-hours). The percent of total costs within each of these categories was developed from data from a taxi company in New Haven, Connecticut. Table 2.4 presents the portion of costs related to these factors. The percent increase in each of these attributes was calculated relative to the base case service. Multiplying percent increase in cost factor by the percent of total cost represented by the cost factor and adding yields the total increase in the cost of the service.

Table 2.4

Distribution of Taxi Costs

Factor	% of Total Cost
Vehicles	13.5
Vehicle miles	16.6
Revenue	52.6
Administrative Support	17.3

2.10 Competing Provider Impacts

Impacts on transportation providers who may compete with IP for patronage were explicitly reported. These competitors include the set of taxi operators, private parking lot/garage operators, and social service agency specialized transportation providers.

Impact on taxi operators was calculated based on the number of taxi trips diverted to the modified transit service. This value was determined based on the diversion statistics developed to estimate mobility impacts. The number of passengers was divided by average taxi occupancy (from CDC and Wells (1976)) to estimate the number of taxi trips foregone. This figure, along with the average taxi fare for diverted trips, was used to estimate the change in revenue. The change in taxi profit was calculated based on the assumption that effectively 17.9% of the lost revenue would have been profit. This percentage in turn is based on the assumptions that:

1) the taxi company makes a 5% profit in the base case, (national average from CDC and Wells (1976), and;

2) 17% of the taxi costs are fixed and therefore do not go down in proportion to the revenue lost (from the New Haven taxi company data). Base case taxi statistics were calculated assuming revenue is directly proportional to the number of taxis operating, and cost is 95% of revenue. Note that totals were given for all taxi companies in a given area; no attempt was made to disaggregate.

Only CBD parking lot/garage operators were assumed to be affected by IP; therefore, the portion of IP patronage whose former mode was auto, whose purpose was non-work travel, and who travelled to the CBD were isolated, based on model results. This number, combined with an auto occupancy factor, the local site specific parking fee structure, and parking duration for work and non-work trip figures derived from TRB (1971), yielded estimates of lost revenue. Where local data were available on the extent to which parking lots were municipally operated, revenue losses were apportioned to private and municipal lots.

The method used to measure the impact on social service providers was based on the assumption that the opportunity cost savings are associated with what it would have cost to serve additional riders in the absence of the patronage diversion to IP. Since many social service agencies utilize volunteer labor, cost per vehicle hour was assumed to be $6.00. Since a high degree of personal assistance is typically required when transporting social service agency clients, productivities of 2 passengers per hour were assumed. Diversion of handicapped persons to IP service was based on the number of persons served (average of TH) and the characteristics of the service (e.g., whether wheelchair lifts were available; whether transfers were required, etc.).

2.11 Major Employer Impact

Major employers were assumed to provide parking to at least a portion of their workers. To the extent that former auto drivers are diverted to IP, major employers can reduce the number of parking spaces required. This represents a direct savings to such employers. The number of spaces that can be eliminated is thus based on the diversion from CBD bound auto work trips. For CBD employers, savings were calculated based on local prevailing CBD parking rates, and on the premise that employers would no longer have to procure parking. For non-CBD employers, local land cost data were utilized to calculate the opportunity cost savings. One acre is sufficient to park 100 autos. Parking savings resulting from the initiation of vanpools were based on projected ridership levels, and data on previous modes of van pool riders (Miller 1976) which suggest that, in most cases 80% of van pool drivers formerly drove their own vehicle (This number is adjusted to reflect diversion from carpool to van pool).

2.12 Local Government Impacts/Federal Government Impacts

The operating deficit was apportioned on an equal basis between the local and federal government, based on an assumption of Section 5 funding. The capital cost of the IP system was divided on a 20% local, 80% federal basis. Local governments impacts also included lost revenue from public parking facilities, as noted earlier.

Appendix 3
Example of Impact Estimation

Introduction

This appendix presents the calculations performed to generate the entries in the impact-incidence matrix for IP Scenario A of Setting 1 - "Southern Belle". It serves to illustrate numerically the methodology explained verbally in the previous appendix. All data which vary between settings and/or scenarios are listed separately in the beginning of each impact worksheet, with a reference to its source, where applicable. Most data incorporated directly into the calculations remained constant across settings and scenarios.

Due to the variation in the scenario designs and the format of the data made available by local setting transit authorities, the methodology explained in this appendix was modified appropriately when applied to other settings. For example, Setting 1 was the only city in which a vanpool was included in the IP design. In other scenarios, private operators were designated as the operating entity, special services were implemented for the elderly and handicapped, and service was altered between peak and off-peak periods. Differences such as these required modifications to the approach explained here. Adjustments were also made to auto ownership and cost assumptions for the year 2000. Therefore, this appendix merely presents one sample calculation of the entries in an impact-incidence table.

3.1 Derivation of Basic Inputs for Impact-Incidence Matrices

Before proceeding to the worksheets which detail the calculation of the benefits and the costs, it is necessary to explain the assumptions and data sources employed in the derivation of the inputs.

The FORCAST DRT demand model generates a large amount of information. The data extracted from each scenario printout and utilized in the benefit-cost calculations include: trip totals (separated between direct and access; DRT and bus); average trip distances (specified for both direct and access trips); average fares (specified for both direct and access trips); number of trips by the elderly, persons from 0-auto households, and those belonging to both groups; and the split between work and non-work trips. The way in which some of these data are used is described below.

3.1.1 IP Trip Demand Estimates

First the derivation of the annual ridership for Scenario A (1,306,000) will be explained. The IP design for Scenario A consists of three checkpoint many-to-many zones and one checkpoint route deviation zone. The FORCAST demand model was used to predict the trip demand for two of the three DRT zones. Figures 3.1 and 3.2 display the summary pages of the model printout for zones 1 and 2, respectively. Since the relevant characteristics of the third zone (population and density) were similar to those of zone 1, the demand for the zone 3 was estimated using the sketch planning tool described in Appendix 1 of this volume. For the checkpoint route deviation zone, first demand for regular transit service was approximated based on the population and density of the area, and an assumed route headway. Then pivot-point analysis was used to determine the demand for check-point service.

The predicted ridership figures for each zone, separated between direct DRT trips and access DRT trips, are displayed below.

Estimated Daily IP Trips
Setting 1 - Scenario A

Zone	Direct DRT Trips	Access DRT Trips	Totals
1	1615	602	2217
2	353	252	605
3	1547	575	2122
4			260
			5204

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23NOV77   9.44.40              FORCAST                    PAGE   26
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FOR63B 2100 (I): LOS SUMMARY FOR PERIOD 0

	DIRECT					ACCESS					
	ADA	SHR	DRT	BUS	TAX	ADA	SHR	DRT	BUS	TAX	TOTAL
TRIP TOTALS	16899.66	23572.38	[redacted]	131.83	0.0	0.00	0.00	[redacted]	0.0	0.0	42820.33
LOS TOTALS											
IVT	218701.87	316421.50	15848.27	2287.10	0.0	0.00	0.00	18390.73	0.0	0.0	571649.37
OVT	33785.52	141441.31	14948.49	2868.59	0.0	0.00	0.00	14719.42	0.0	0.0	207763.19
FAR	348197.62	171535.31	75727.31	3646.17	0.0	0.00	0.00	32930.36	0.0	0.0	632036.69
DIST	69659.12	85786.37	3122.29	389.90	0.0	0.00	0.00	3574.51	0.0	0.0	162532.12
LOS AVERAGES											
IVT	12.94	13.42	9.82	17.35	0.0	27.07	28.37	30.55	0.0	0.0	13.35
OVT	2.00	6.00	9.26	21.76	0.0	17.66	21.91	24.45	0.0	0.0	4.85
FAR	20.60	7.28	46.90	27.66	0.0	35.40	17.46	54.71	0.0	0.0	14.76
DIST	4.12	3.64	1.93	2.96	0.0	5.77	5.42	5.94	0.0	0.0	3.80

SINOFF 6700 (INFORMATION): FORCAST ENDED AT 10.15.52 (RETURN CODE= 0)

SINOFF 7000 (WARNING): FILE URD.LOG NOT AVAILABLE.

Figure 3.1

Sample Model Output

Setting #1 - Scenario A - Zone 1

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FOR63B 2100 (I): LOS SUMMARY FOR PERIOD 0

	X----DIRECT---- ADA	SHR	DRT	BUS	TAX----XX	X----ACCESS---- ADA	SHR	DRT	BUS	TAX----X	TOTAL
TRIP TOTALS	6486.06	9577.67	[redacted]	39.87	0.0	0.00	0.00	[redacted]	0.0	0.0	16708.19
LOS TOTALS											
IVT	72339.94	104229.12	2316.47	775.37	0.0	0.00	0.00	6154.45	0.0	0.0	185815.25
OVT	12967.64	57452.90	3400.97	989.43	0.0	0.00	0.00	6661.98	0.0	0.0	81472.75
FAR	122860.87	62390.18	16302.07	1272.34	0.0	0.00	0.00	13814.55	0.0	0.0	216639.87
DIST	24564.50	31188.15	480.37	127.90	0.0	0.00	0.00	1332.72	0.0	0.0	57693.63
LOS AVERAGES											
IVT	11.15	10.88	6.57	19.45	0.0	19.40	17.64	24.43	0.0	0.0	11.12
OVT	2.00	6.00	9.64	24.82	0.0	18.30	20.81	26.45	0.0	0.0	4.88
FAR	18.94	6.51	46.22	31.92	0.0	30.51	14.03	54.84	0.0	0.0	12.97
DIST	3.79	3.26	1.36	3.21	0.0	4.91	4.25	5.29	0.0	0.0	3.45

SINOFF 6700 (INFORMATION): FORCAST ENDED AT 19.54.40 (RETURN CODE= 0)

SINOFF 7000 (WARNING): FILE URD.LOG NOT AVAILABLE.

Figure 3.2

Sample Model Output

Setting #1 - Scenario A - Zone 2

The annual ridership for Scenario A was calculated by multiplying the daily total (5204 trips/day) by 251 days (average number of working days per year). This factor (251 days) was used in all IP settings except "College Town" where the IP system was designed to operate for 365 days per year.

3.1.2 Local Transit, Taxi and Parking Rate Data

When available,annual transit data on operating cost, revenue, ridership, vehicle miles and vehicle hours, were collected from the transit authorities of the seven cities included in the analysis. The public operator also supplied information on the number of employees by job category, wage rates, the size of the vehicle fleet, mileage and ridership by route, and estimates of costs per vehicle-mile and per vehicle-hour.

Local taxi companies were contacted to determine the number of taxicabs operating in the area and the fare structure. Annual taxi ridership and revenue figures were unavailable from local sources; therefore, they were estimated from national taxi survey data.

Parking rates at municipal garages were obtained from local operators.

3.1.3 Former Mode of IP Passengers

The former mode distribution for trips made on the IP service is a critical input in the calculation of the benefit-cost impacts. The determination of this distribution for each setting took into consideration such factors as: 1) the availability of transit before IP; 2) the results of surveys on former mode which have been conducted on existing demand responsive systems (see Appendix 2 for a summary of the results of surveys); 3) FORCAST demand model results on the split between work and non-work trips; and 4) the demographic and geographical charcteristics of the area. To illustrate, the derivation of the "Southern Belle" former mode distribution will be explained here. Note, that the characteristics of each scenario make the derivation of each former mode distribution unique.

The first estimate to be determined is the percentage of IP riders who formerly would have made their trip by bus. The areas served by integrated paratransit in Setting #1, "Southern Belle" are virtually unserved by public transportation at the present time. One section of a route, 4 miles in length, operating on hour headways was shortened and replaced in the IP design. Also, two other routes operating only during the peak hours were replaced. We assumed that these transit passengers would transfer to the IP service; they would comprise about 2% of the total IP ridership.

The second estimate to be determined is the percentage of riders who formerly would have made their trip by auto. The model results for Scenario A indicate that 58% of all IP trips were work trips. Without the availability of public transportation, we assumed that 90% of these were formerly made by auto. Of the remaining non-work trips (42%), we assumed that one-third of them were made by auto. Combining these two results gives an overall estimate of 66% for former auto trips.

The survey data from existing DRT systems (Table 2.1 of this report) show that both the percentage of induced trips and the percentage of trips formerly made by taxi fall in the range of 5% - 35%.

After determining the bus and auto percentages, only 32% of the IP trips remained to be distributed. It was decided that 12% would be a reasonable estimate for former taxi trips given the suburban characteristics of the service zones. The remaining 20% was split between induced and walk trips.

The resulting former mode distribution used for the 1980 "Southern Belle" IP scenario is:[1]

Auto	66%
Bus	2%
Taxi	12%
Walk	10%
No Trip	10%

[1]Distributions for other settings and scenarios are listed in Appendix B of Volume 3.

3.1.4 Vanpool Demand

Vanpooling was introduced in the "Southern Belle" IP system as a feasible transit alternative for employees commuting to a large employer located about 14 miles from the CBD, which has a commuting work force of 17,000. This number exceeds the threshold needed to guarantee that there are sufficient numbers of persons with similar residential locations and similar working hours for vanpool formations. In order to estimate the demand for vanpooling to this site, we looked at statistics from existing programs. A summary of the results of two surveys conducted over the last three years on existing vanpool programs (one by the study team) is contained in Appendix 1 of this volume. An explanation of the predicted demand (10%) for vanpooling from the large employer in "Southern Belle" can also be found in Appendix 1. Of 17,000 employees, it was estimated that approximately 5000 both live within the urbanized area of Setting 1 and work similar shifts which could be readily served by vanpool. As a result, it was estimated that 500 employees would participate in a vanpool program. At 10 passengers per van, this program would utilize 50 vans.

3.1.5 Transportation Handicapped Demand

The combined population of the four service zones in Scenario A is 102,000. It was estimated that 2068 persons with mobility limitations due to chronic conditions live in these four areas. This estimate was generated by applying the following TH incidence rates to the population: <18 years of age, 0.00276; 18-64 years of age, 0.02108; >65 years of age, 0.16416. These rates were derived from the 1972 National Health Survey. The table below shows the number of TH in the four service zones by age category.

Age	Percent of Population	TH Incidence Rate	Number of TH
<18	38%	0.00276	107
18-64	57.7%	0.02109	1241
>65	4.3%	0.16416	720
		TOTAL	2068

Data on trip generation rates for transportation handicapped persons is contained in Appendix 1 of this volume. These data were considered in deriving the trip generation rate for the checkpoint service in "Southern Belle". The weekly trip rate for PROJECT MOBILITY (PM) in Minneapolis (.302) was successively reduced (to .09) to account for the differences between the PM system and the one designed for "Sourthern Belle". These differences are: PM operates seven days a week including evenings, whereas the IP system is designed for daytime operation five days a week; the PM system provides doorstep service, whereas the IP system requires that the client walk to a checkpoint; and; the PM system is a special service for the TH, whereas the IP system is available to the general public.

The impact worksheets which follow are ordered to correspond to the presentation of the impact categories in the impact-incidence tables. All results which were either transferred to the tables or used in the calculation of the percentage change are identified by a small box to distinguish them from intermediate results. All final figures are annual estimates.

A number of abbreviations are used to simplify the equations and calculations. They are:

K - one-thousand
HH - household
E - elderly
TH - transportation handicapped.

3.2 MOBILITY IMPACT

- Setting/Scenario Data

A. Model Results[1]

Annual IP ridership: 1306K

Percent IP ridership elderly: 11%

Percent IP ridership from 0-auto households: 17%

Percent IP ridership both elderly and from 0-auto households: 5%

B. Other Sources

Number of transportation handicapped in service area:[2] 2170

Percent of induced trips:[3] 10%

Percent of former bus trips:[3] 2%

Number of persons in vanpool program:[4] 500

- Calculations

A. Calculate total trips on new transit service

1) Annual vanpool trips

$$\text{ANNUAL VANPOOL TRIPS} = \text{NUMBER OF PERSONS IN VANPOOL PROGRAM} \times 2 \text{ TRIPS/DAY} \times 251 \text{ DAYS/YR}$$

$$251K = 500 \times 2 \times 251$$

2) $$\text{TOTAL NEW TRANSIT TRIPS} = \text{ANNUAL IP RIDERSHIP} \times \left(1 - \text{\% FORMER BUS TRIPS}\right) + \text{ANNUAL VANPOOL TRIPS}$$

$$\boxed{1531K} = 1306K \times (1 - 2\%) + 251K$$

B. Calculate new transit trips for special markets.

1) Elderly

$$\text{ELDERLY TRIPS} = \text{\% ELDERLY} \times \left(\text{TOTAL NEW TRANSIT TRIPS} - \text{VANPOOL TRIPS}\right)$$

$$\boxed{140.8K} = 11\% \times (1531K - 251K)$$

[1] See Section 3.1 of this appendix.

[2] See Section 3.1.5 of this appendix.

[3] See Section 3.1.3 of this appendix.

[4] See Section 3.1.4 of this appendix.

2) 0-Auto Households

$$\text{0-AUTO HH TRIPS} = \text{\% 0-AUTO HH} \times \left(\text{TOTAL NEW TRANSIT TRIPS} - \text{VANPOOL TRIPS}\right)$$

$$\boxed{217.6K} = 17\% \times (1531K - 251K)$$

3) Transportation Handicapped

Assume a trip rate of .09 trips per week for checkpoint many-to-many and route deviation service.[1]

TH TRIPS = # TH x TRIP RATE/WK x 52 WKS

$$\boxed{10.2K} = 2170 \times .09 \times 52$$

4) Total new transit trips for special markets (with overlap).

$$\text{TOTAL NEW TRIPS: SPECIAL MARKETS} = \left[\text{\% E} + \text{\% 0-AUTO} - \text{\% E AND 0-AUTO}\right] \times \text{ANNUAL IP RIDERSHIP} + \text{TH TRIPS NOT E OR 0-AUTO}$$

$$304.4K = (11\% + 17\% - 5\%) \times 1306K + 4K$$

C. Calculate total induced trips

TOTAL INDUCED TRIPS = % INDUCED x ANNUAL IP RIDERSHIP

$$\boxed{130.6K} = 10\% \times 1306K$$

D. Calculate induced trips for special markets.

1) Assume 70% of all induced trips are made by the three overlapping special markets: elderly, 0-auto, and transportation handicapped.[2]

TOTAL INDUCED TRIPS BY E, TH, 0-AUTO = 70% x TOTAL INDUCED TRIPS

$$91.4K = 70\% \times 130.6K$$

2) Allocate the induced trips to the three special markets on the basis of the relative trip-making rates of these three groups on the IP service.

---

[1] Explained in Section 3.1.5 of this appendix.

[2] Data on DRT systems reveal that the percentage of induced trips made by these three special market groups is higher than the percentage of induced trips made by all persons. The 70% assumption varied between settings depending on the size of the special market groups utilizing the new IP service.

INDUCED TRIPS FOR SPECIAL MARKET = NEW TRANSIT TRIPS FOR SPECIAL MARKET ÷ TOTAL NEW TRIPS ALL SPECIAL MARKETS x TOTAL INDUCED TRIPS BY E, TH AND 0-AUTO

a) For E

[42.3K] = 140.8K ÷ 304.4K x 91.4K

b) For TH

[3.1K] = 10.2K ÷ 304.4K x 91.4K

c) For 0-AUTO

[65.3K] = 217.6K ÷ 304.4K x 91.4K

3.3 CONSUMER SURPLUS

Estimates of consuler surplus were generated by the consumer surplus model described in Section 2.2 of Appendix 2.

3.4 IMPACT ON SPATIAL COVERAGE

- Setting/Scenario Data[1]

Transit route mileage before IP: 44 mi.

Area served by transit before IP: 18 sq. mi.

Overlap area[2] before IP for each group assuming that the elderly will walk 1/8 mile, transportation handicapped persons will walk 1/16 mile, and others will walk 1/4 mile to the bus stop.

Overlaps: E - 2 sq. mi.

TH - 0 sq. mi.

0-auto, others - 7 sq. mi.

Population (000) of each market group in specified areas.

	Urbanized Area	Area Served by Transit before IP	3 DRT Zones	Route Deviation Zone
E	14.2	10.1	3.8	.6
TH	4.5	2.2	1.3	.2
0-auto	29.2	21.0	7.1	1.1
Others	168.8	72.8	88.4	13.7

[1]Derived from local transit data.

[2]To avoid double counting, an overlap area was computed for each client group. It measures the area which is within the designated walking distance of more than one transit route.

- Calculations

A. Estimate population of each market group covered by transit before IP.

$$\text{POPULATION OF MARKET GROUP COVERED} = \left[\left(\text{ROUTE MILEAGE} \times 2 \times \text{WALK DISTANCE OF MARKET GROUP}\right) - \text{OVERLAP AREA FOR MARKET GROUP}\right] \div \text{AREA SERVED BY TRANSIT} \times \text{POPULATION OF EACH MARKET GROUP IN AREA SERVED}$$

1) Elderly

5.1K = [(44 x 2 x .125) - 2] ÷ 18 x 10.1K

2) Transportation Handicapped

.67K = [(44 x 2 x .0625) - 0] ÷ 18 x 2.2K

3) Persons from 0-auto households

17.5K = [(44 x 2 x .25) - 7] ÷ 18 x 21.0K

4) Others

60.7K = [(44 x 2 x .25) - 7] ÷ 18 x 72.8K

B. Estimate percent of each market group covered by transit before IP.

% OF MARKET GROUP COVERED = POPULATION OF MARKET GROUP COVERED ÷ POPULATION OF MARKET GROUP IN URBANIZED AREA

1) Elderly

36% = 5.1K ÷ 14.2K

2) Transportation Handicapped

15% = .67K ÷ 4.5K

3) Persons from 0-auto households

60% = 17.5K ÷ 29.2K

4) Others

36% = 60.7K ÷ 168.8K

C. Estimate population of each market group covered in IP service areas.

$$\text{POPULATION OF MARKET GROUP COVERED} = \left[\text{POPULATION OF GROUP IN 3 DRT ZONES} \times \text{\% COVERAGE (ESTIMATED)}\right] + \left[\text{POPULATION OF GROUP IN ROUTE DEVIATION ZONE} \times \text{\% COVERAGE (ESTIMATED)}\right]$$

1) Elderly

   3.4K ≐ (3.8K x 80%) + (.6K x 60%)

2) Transportation Handicapped

   .6K = (1.9K x 30%) + (.2K x 20%)

3) Persons from 0-auto households

   8.0K = (7.1K x 100%) + (1.1K x 80%)

4) Others

   94.9K = (83.4K x 100%) + (13.7K x 80%)

D. Estimate population of each market group in IP service area previously served by transit (one route was shortened) and subtract from above figures to yield new transit passengers.

1) Elderly	3.4K - .1K =	3.3K
2) TH	0.6K - 0 =	0.6K
3) Persons from 0-auto HH	8.0K - .5K =	7.5K
4) Others	94.9K - 10.1K =	84.8K

E. Estimate percent of each market group covered after IP.

% AFTER (MARKET GROUP) = [POPULATION BEFORE (MARKET GROUP) + NEW POPULATION SERVED (MARKET GROUP)] ÷ POPULATION IN URBANIZED AREA (MARKET GROUP)

1) Elderly

59% = (5.1K + 3.3K) ÷ 14.2K

2) Transportation Handicapped

29% = (.7K + .6K) ÷ 4.5K

3) Persons from 0-auto households

86% = (17.5K + 7.5K) ÷ 29.2K

4) Others

86% = (60.7K + 84.8K) ÷ 168.8K

TEMPORAL COVERAGE

Temporal coverage as defined by the scenario description includes the operating hours of 6:30 am to 6:30 pm on weekdays, Monday through Friday.

3.5 IMPACT ON VEHICLE MILES TRAVELED (VMT)

- Setting/Scenario Data

A. Model Results[1]

Annual IP ridership: 1306K

Percent of IP trips which are work trips: 58%

Average length of diverted auto trips: 3 mi.

B. Other Sources

Diversion from auto[2]: 66%

Average length of all auto trips[3]: 4.7 mi.

Number of households in urbanized area: 56,000

Change in auto ownership[4]: 77.5 autos foregone/year

Decrease in exclusive-ride taxicabs required[5]: 14

Number of before transit vehicle miles[6]: 906.6K mi.

Change in transit VMT[7]: van +1064K mi.

: bus +126.8K mi.

- Calculations

Auto

A. Calculate auto vehicle miles traveled before IP was implemented.

BEFORE AUTO VMT = # OF HOUSEHOLDS x AUTO TRIPS/HOUSEHOLD/YEAR x AVERAGE AUTO TRIP LENGTH

335,580K mi. = 56K HH x 1275 trips/HH/yr x 4.7 mi.

---

[1]See Section 3.1 of this appendix.

[2]See Section 3.1.3 of this appendix.

[3]Estimated considering the size of the urbanized area.

[4]Derived using the model for calculating the change in auto ownership which is described in Appendix 2, Section 2.7. Vanpooling accounted for 2.5 of the 77.5 autos foregone.

[5]See Section 3.13 - Taxi Impacts

[6]Provided by local transit authority

[7]Derived from the system design.

B. Calculate reduction in auto VMT due to the following four factors.

1) Change in auto ownership

DECREASE IN VMT FROM AUTOS FOREGONE = AUTOS FOREGONE/YR. x 2000 MI.

155K Mi. = 77.5 x 2000 mi.

2) Less chauffeuring[1]

a) NUMBER OF CHAUFFEURED TRIPS ELIMINATED = 11% x ANNUAL IP RIDERSHIP x % DIVERSION FROM AUTO

[94.8K] = 11% x 1306K x 66%

b) CHAUFFEURED MILES ELIMINATED = NUMBER OF CHAUFFEURED TRIPS ELIMINATED x AVERAGE LENGTH OF DIVERTED AUTO TRIPS

284.5K mi. = 94.8K x 3 mi.

3) Diversion of former drivers who didn't give up autos (excluding vanpool)[1]

a) AVERAGE PERSONS USING IP SYSTEM/ DAILY RIDERSHIP = [1.65 PERSONS/ DAILY WORK TRIP x % OF IP TRIPS- WORK TRIPS] + [2.2 PERSONS/ DAILY NON-WORK TRIP x % OF IP TRIPS - NON-WORK]

1.88 = (1.65 x 58%) + (2.2 x 42%)

b) # OF DIVERTED DRIVERS = % OF DIVERTED AUTO TRIPS FORMERLY MADE BY DRIVERS[2] x % DIVERTED FROM AUTO x AV. PERSONS USING IP SYSTEM/DAILY RIDERSHIP ÷ 251 DAYS

2582 = 40% x 1306K x 66% x 1.88 ÷251

---

[1] See Sections 2.4 and 2.8 of Appendix 2 for an explanation of this methodology.

[2] Data from DRT systems in Merrill, Wis., Batavia, N.Y., and Rochester, N.Y. were used to derive the estimate that 40% of all diverted auto trips were formerly made by drivers. This estimate was not changed between settings or scenarios.

c) # OF DIVERTED[1] DRIVERS WHO DIDN'T GIVE UP AUTOS = # OF DIVERTED DRIVERS - MIN (AUTOS FOREGONE/YR , # OF DIVERTED DRIVERS)

2504.5 = 2582 - min (77.5, 2582)

d) VMT AVOIDED - DIVERSION OF FORMER DRIVERS = # OF DIVERTED DRIVERS WHO DIDN'T GIVE UP AUTOS ÷ AV. PERSONS USING IP SYSTEM/DAILY RIDERSHIP x AVERAGE DIVERTED AUTO TRIP LENGTH x 251 DAYS

1003.1K mi. = 2504.5 ÷ 1.88 x 3 x 251

4) Calculate auto VMT eliminated due to vanpooling.

Assumptions:

- 10 persons/van
- 50 vans in program
- average round trip direct distance/van: 20 miles
- 8 additional vehicle miles required/day to pick-up and drop-off passengers
- 8 out of 10 persons formerly drove alone

REDUCTION IN AUTO VMT: VANPOOLING = # OF FORMER DRIVERS/VANPOOL x ROUND TRIP DISTANCE x # OF VANPOOLS x # OF WORKING DAYS/YR

2008K mi. = 8 x 20 mi. x 50 x 251

C. Calculate total reduction in auto VMT.

TOTAL REDUCTION IN AUTO VMT = REDUCTION FROM AUTOS FOREGONE + REDUCTION FROM LESS CHAUFFEURING + REDUCTION FROM DIVERSION OF DRIVERS + REDUCTION FROM VANPOOLING

3450.6K mi = 155K mi + 284.5K mi. + 1003.1K mi. + 2008K mi

[1]To avoid double counting, the drivers who gave up cars are subtracted out since their mileage reduction has been accounted for in Step B (1).

Transit

A. Calculate change in transit VMT

1) Calculate additional transit vehicle miles due to vanpooling.

VANPOOL VMT	=	# OF VANS	x	AVERAGE ROUND TRIP VAN DISTANCE	x	NUMBER OF WORKING DAYS/YR.
351.4K mi	=	50	x	28 mi.	x	251

2) Calculate total change in transit VMT.

TOTAL CHANGE IN TRANSIT VMT	=	VANPOOL VMT	+	IP VAN VMT	+	CHANGE IN BUS VMT
1542.2K	+	351.4K mi.	+	1064K mi.	+	126.8K mi.

Taxi

A. Calculate before taxi VMT.

BEFORE TAXI VMT = # TAXIS BEFORE x 42K MI/YR[1]

5460K mi. = 130 x 42K mi.

B. Calculate reduction in taxi VMT.

REDUCTION IN TAXI VMT	=	# CABS LOST DUE TO IP	x	42K MI/YR
588K mi	=	14	x	42K mi.

---

[1] Average annual miles per cab assumed for all scenario analyses. Statistic was taken from Taxicab Operating Characteristics, Control Data Corporation and Wells Research Company, 1977.

3.6 FUEL CONSUMPTION/EMISSIONS IMPACTS

A computer program was written to apply the fuel consumption and emissions factors presented in Section 2.5 of Appendix 2 to the change in vehicle miles for each vehicle type. Since the approach is straightforward, the calculations will not be shown here.

3.7 EMPLOYMENT IMPACTS

• Setting/Scenario Data

Decrease in exclusive-ride taxicabs required:[1] 14

Average taxi jobs per cab: 1.5

• Calculations

A. Compute impact on taxi employees

1) CHANGE IN TAXI JOBS = CHANGE IN TAXICABS x AV. # JOBS/TAXI

[-21] = -14 x 1.5

2) CHANGE IN TAXI EMPLOYMENT PAYROLL = TAXI REVENUE LOST x 60%[2]

[-$128.4K] + -$214.1K x 60%

B. Compute impact on transit employment

	# Jobs	Direct Compensation	Payroll ($000)
Drivers	62	@ $7300	455
Maintenance	17	@ $8400	143
Dispatchers	5	@ $8350	41.8
Ordertakers	5	@ $7300	36.5
Administrators/ Managers	2	@ $10,400	20.8
TOTALS	[+91]		[+697.1]

---

[1]See section 3.13 of this appendix.

[2]Sum of: 45% (gross receipts) + 15% (tips)

3.8 AUTOMOBILE EXPENDITURES IMPACT

- Setting/Scenario Data

Change in auto ownership[1]: 77.5 autos foregone/yr.

Total households in urbanized area[2]: 56,000

Average autos/household[2]: 1.24

Average autos/2 car households[2]: 2.17

Auto ownership distribution for urbanized area[2]:

autos/HH	%
0	19
1	44
2	31
3+	6

- Calculations

A. Compute capital savings

CAPITAL SAVINGS/YR. = \$4K/AUTO X # AUTOS FOREGONE/YR

\$310K = \$4K x 77.5

B. Compute operating cost savings

OPERATING COST SAVINGS = # AUTOS FOREGONE/YR x 2000 MI/YR x \$0.08/MI

\$12.4K = 77.5 x 2K x \$0.08

---

[1]Derived using the model for calculating the change in auto ownership; it is described in Appendix 2, Section 2.7. Of the 77.5 autos foregone, 2.5 autos resulted from the vanpool program.

[2]Estimated using 1970 U.S. Census data. For some settings, projections of autos and households per census tract (or other subdivision) were available for the years 1980 and 2000 from local planning agencies.

C. Compute auto expenditures before

1) Compute total autos before IP

TOTAL AUTOS BEFORE = #HH x AV. AUTOS/HH

69,440 = 56,000 x 1.24

2) % of before autos that are new (used)

a)

$$\%\ \text{NEW} = \frac{\%\ \text{HH w/1 OR MORE CARS}}{\%\ \text{HH w/1 OR MORE CARS} + \%\text{HH w/ 2 OR MORE CARS} * (\text{AV. AUTOS/ 2 CAR HH} - 1)}$$

$$65\% = \frac{81\%}{81\% + 37\% * (2.17-1)}$$

b) % USED = 1 - % NEW

35% = 1 - 65%

3) Compute before capital costs

a) NEW (USED) CAPITAL COSTS = % NEW (USED) TOTAL AUTOS BEFORE x TOTAL AUTOS BEFORE x CAPITAL COST/ NEW (USED) AUTO

i) New Autos

$31,595K = 65% x 69,440 x $7K

ii) Used Autos

$ 9,722K = 35% x 69,440 x $4K

b) TOTAL CAPITAL COSTS = NEW AUTO COSTS + USED AUTO COSTS

[$41,317K] = $31,595K + $9,722K

4) Compute before operating costs

a) NEW (USED) OPERATING COSTS = % NEW (USED) TOTAL AUTOS BEFORE x TOTAL AUTOS BEFORE x MILES/ YR NEW (USED) x COST/MI NEW (USED)

i) New Autos

$32,500K = 65% x 69,440 x 12K mi. x $0.06

ii) Used Autos

$24,300K = 35% x 69,440 x 8K mi. x $0.08

b) TOTAL OPERATING COSTS = NEW AUTO COSTS + USED AUTO COSTS

| $48,050K | = $32,500K + $24,300K

3.9 OPERATING COST IMPACT

- Setting/Scenario Data

A. Computed From Scenario Design

Annual van vehicle miles: +1064K mi. (excludes vanpool)

Annual additional bus vehicle miles: route deviation 96.4K mi.
additional buses 30.4K mi.

Annual additional vehicle hours: van 106,424
bus 8,785
total 115,209

B. Data obtained from setting Transit Authority

Before operating cost: $881K

Non-labor cost per vehicle mile for bus: $0.27

Labor costs (rates below assume 20% for fringe benefits):

drivers - $4.21/hr.
maintenance - $4.74/hr.
dispatchers - $9600/yr
order-takers - $8400/yr.
administrators/managers $12,000/yr.

- Calculations

A. Compute non-labor costs

ANNUAL NON-LABOR COST = ANNUAL VEHICLE MILES x COST/VEHICLE MI.

1) Van

$132.9K = 1064K x $0.1249

2) Bus

$ 34.2K - 126.8K x $0.27

TOTAL NON-LABOR COSTS = VAN + BUS

$167.1K = $132.9K + $34.2K

B. Compute labor costs

Assumptions

- no additional driver hours assumed for this setting (transit authority employees not unionized)
- one maintenance person per 70,000 veh.-mi.
- one dispatcher and one ordertaker per 12 vehicles (checkpoint service)

Drivers -	115,209 veh.-hr. x $4.21/hr	= $485,030
Maintenance -	17 x 2080/hrs/yr x $4.74/hr	= $167,606
Dispatchers -	5 x $9600/yr	= $ 48,000
Order-takers -	5 x $8400/yr	= $ 42,000
Administrators/ Managers	2 x $12,000/yr	= $ 24,000
		$766,636

C. Compute total operating cost

TOTAL OPERATING COST = NON-LABOR COST + LABOR COST

$933.7K = $167.1K + $766.6K

3.10 REVENUE IMPACT

- Setting/Scenario Data

A. Model Results[1]

Annual IP ridership: 1306K

Additional annual bus trips generated by IP service: 74.8K

Average IP DRT fare: $.49 (including transfers)

Average bus fare: $.29 (including transfers)

B. Other Data

Bus trips lost through implementation of IP service: 25.1K (one route shortened)

Before revenue[2]: 440K

- Calculations

A. Estimate change in annual revenue

1) DRT Service Revenue

REVENUE = ANNUAL NEW TRIPS x FARE/TRIP

$639.9K = 1306K x $.49

2) Revenue from additional bus trips

$$\text{REVENUE} = \left(\begin{array}{l}\text{ADDITIONAL}\\ \text{BUS TRIPS}\end{array} - \begin{array}{l}\text{LOST BUS}\\ \text{TRIPS}\end{array}\right) * \text{FARE/TRIP}$$

$14.4K = (74.8K - 25.1K) * $.29

3) Total change in revenue

$$\begin{array}{l}\text{TOTAL CHANGE}\\ \text{IN REVENUE}\end{array} = \begin{array}{l}\text{DRT}\\ \text{REVENUE}\end{array} + \text{ADDITIONAL BUS TRIPS REVENUE}$$

654.3K = 639.9K + 14.4K

---

[1] See section 3.1 of this appendix.

[2] Obtained from local transit authority.

3.11 CAPITAL COST IMPACT

- Setting/Scenario Data

Number of buses before IP[1]: 26

Number of vans for IP service[2]:

regular 38 + 4 spares

lift-equipped 6

Number of additional buses required for IP service: 4

- Calculations

A. Estimate annual capital costs before IP.

Equipment	# of Units	Unit Price ($000)	Life (yrs)	Annual Cost ($000)
Buses	26	65	12	140.8
Fareboxes	26	2.41	15	4.2
Additional Space (Storage, Maintenance, Office, etc.)		520	50	10.4
Additional Equipment (Maintenance, bus washer, etc.)		68	20	3.4
		Total Before Capital Cost		158.8

[1]Obtained from local transit authority.

[2]Based on design of IP system.

B. Estimate change in capital costs.

Equipment	# of Units	Unit Price ($000)	Life (yrs)	Annual Cost ($000)
Vans:				
regular	42	14.5	3	203.0
lift-equipped	6	18.5	3	37.0
Buses	4	65	12	21.7
Fareboxes	4	2.41	15	.6
Van Radios	48	1.0	20	2.4
Central Radio	1	5	20	.3
Additional Space (storage/maintenance, dispatching)		560	50	11.2
Additional Equipment (maintenance, bus washer, etc.)		73	20	3.7
		Total Change in Capital Cost		279.9

3.12 IMPACT ON TAXI OPERATORS

- Setting/Scenario Data

A. Model Results[1]

Annual IP ridership: 1306K

Average taxi trip length: 3.0 mi.

B. Other Sources

Diversion from taxi[2]: 12%

Number of cabs in setting[3]: 130

Taxi fare for average trip[3]: $1.90

Average taxi occupancy for setting: 1.39

- Calculations

A. Calculate reduction in taxi revenue.

1) Compute decrease in passengers

DECREASE IN TAXI PASSENGERS = ANNUAL IP RIDERSHIP x % FORMER TAXI

156.7K = 1306K x 12%

2) Compute decrease in taxi revenue

DECREASE IN TAXI REVENUE = DECREASE IN PASSENGERS ÷ AV. TAXI OCCUPANCY x AV. TAXI FARE

$214.1K = 156.7K ÷ 1.39 x $1.90

---

[1] See section 3.1 of this appendix.

[2] See section 3.1.3 of this appendix.

[3] Fare structure obtained from local taxi companies; average trip length taken from model output.

B. Calculate percent change in taxi revenue

1) Estimate total before taxi passengers.[1]

$$\text{TOTAL BEFORE TAXI PASSENGERS} = \sum_{\text{ALL CABS}} (\text{PASSENGERS/CAB} \div \text{OCCUPANCY RATE})$$

1053.3K = (65 cabs x 12.6K ÷ 1.47) + (65 cab x 10.0K ÷ 1.31)

2) Compute total before taxi revenue

TOTAL BEFORE TAXI REVENUE = TOTAL BEFORE TAXI PASSENGERS x AV. TAXI FARE

$2001.2K = 1053.3K x $1.90

3) Compute percent change

% CHANGE IN REVENUE = CHANGE IN TAXI REVENUE ÷ TOTAL BEFORE TAXI REVENUE

-10.7% = -$214.1K ÷ $2001.2K

C. Calculate change in profit

Assumptions:

. 5% profit margin

. 86.2% of costs are variable

1) Compute after cost

a) CHANGE IN COST = CHANGE IN REVENUE ÷ 1.05 x .862

-$175.8K = $-214.1K ÷ 1.05 x .862

b) BEFORE COST = BEFORE REVENUE ÷ 1.05

$1905.9K = $2001.2K ÷ 1.05

c) AFTER COST = BEFORE COST + CHANGE IN COST

$1730.1K = $1905.9K + ($-175.8K)

[1] Average annual passengers per cab and occupancy rates were derived from estimates reported in Taxicab Operating Characteristics, prepared by Control Data Corporation and Wells Research Company for the U.S. Department of Transportation.

2) Compute change in profit

a) AFTER PROFIT = BEFORE REVENUE + CHANGE IN REVENUE - AFTER COST

$57.0K = $2001.2K + (-$214.1K) - $1730.1K

b) BEFORE PROFIT = BEFORE REVENUE - BEFORE COST

$95.3K = $2001.2K - $1905.9K

c) CHANGE IN PROFIT = AFTER PROFIT - BEFORE PROFIT

$-38.3K = $57.0K - $95.3K

D. Calculate percent change in profit.

% CHANGE IN PROFIT = CHANGE IN PROFIT ÷ BEFORE PROFIT

-40.2% = $-38.3K ÷ $95.3K

E. Compute change in number of taxi cabs required.

CHANGE IN TAXICABS = CHANGE IN REVENUE ÷ TOTAL BEFORE REVENUE x TOTAL BEFORE CABS

13.9 = $-214.1K ÷ $2001.2K x 130

3.13 PARKING IMPACTS

• Setting/Scenario Data

A. Model Results[1]

Annual IP ridership: 1306K

B. Other Sources

Diversion from auto[2]: 66%

Percent former auto trips going to CBD: 27%

Percent of above trips which are work trips: 90%

Average parking duration for non-work trips[3]: 1.1 hrs (based on city size)

Average hourly parking rates for setting (non-work trips):[4]

25¢ first hour

20¢ each additional hour

Average monthly parking rates (work trips): $15/mo.

Number of vanpools: 50 (10-passenger vans)

• Calculations

A. Calculate number of autos whose passengers diverted to IP.

# AUTOS DIVERTED	=	ANNUAL IP RIDERSHIP	x	% DIVERTED FROM AUTO	÷	AVERAGE AUTO OCCUPANCY

615.7 = 1306K x 66% ÷ 1.4

---

[1]See section 3.1.1 of this appendix.

[2]See section 3.1.3 of this appendix.

[3]Based on city size. Adapted from Highway Research Board Special Report 125, Parking Principles, 1971, p. 14.

[4]Obtained from local data.

B. Calculate number of former autos which were traveling to the CBD for work (non-work) trips.

\# CBD BOUND AUTOS: WORK (NON-WORK) = # AUTOS DIVERTED x % TO CBD x % CBD WORK (NON-WORK)

1) Work

149.6K = 615.7K x 27% x 90%

2) Non-work

16.6K = 615.7K x 27% x 10%

C. Calculate impacts on private (public) parking lot operators and on major employers.

1) Compute lost revenue and rental savings for work and non-work trips.

a) WORK-TRIP PARKING REVENUE = WORK-TRIP AUTOS ÷ # ANNUAL WORKING DAYS x ANNUAL PARKING CHARGE

$107.3K = 149.6K ÷ 251 x $180

b) NON-WORK PARKING REVENUE = # NON-WORK TRIPS x PARKING CHARGE FOR AV. DURATION

$7.5K = 16.6K x $ .45

2) Allocate lost revenue and rental savings. Assumptions made for this setting are indicated by equations. Assumptions differed between settings.

a) Private lot operators

REVENUE LOST PRIVATE LOTS = 2/3 NON-WORK REVENUE + 1/3 WORK REVENUE

$40.8K = (2/3 x $7.5K) + (1/3 x $107.3K)

b) Public lots

REVENUE LOST PUBLIC LOTS = 1/3 NON-WORK REVENUE + 1/6 WORK REVENUE

$20.4K = (1/3 x $7.5K) + (1/6 x $107.3K)

c) Major employer impacts

i) RENTAL SAVINGS = 1/2 WORK REVENUE

| $53.7K | = 1/2 x 107.3K

ii) Annual opportunity cost savings resulting from fewer parking spaces required (vanpool program). Assume one van replaces eight cars.

SAVINGS = # VANPOOLS x NET PARKING SPACES SAVED/ VANPOOL ÷ AV. PARKING SPACES/ ACRE x ANNUALIZED COST/ACRE

$2.1K = 50 x 7 ÷ 100 x $600

iii) Change in parking spaces required/subsidized.

REDUCTION IN PARKING SPACES = [EMPLOYER RENTAL SAVINGS ÷ ANNUAL RENTAL CHARGE] + DECREASE IN PARKING SPACES DUE TO VANPOOL PROGRAM

650 = ($54,000 ÷ $180) + 350

3.14 IMPACT ON SOCIAL SERVICE AGENCY PROVIDERS

- Setting/Scenario Data

  Annual IP ridership[1]: 1306K

  Percent of IP ridership diverted from social service provider:[2] 0.2%

- Calculations

  A. Compute number of riders diverted from social service providers

  # DIVERTED = ANNUAL IP RIDERSHIP x % DIVERTED

  [2.6K] = 1306K x 0.2%

  B. Compute opportunity cost savings. Assume $3/passenger saved

  $ SAVED = # DIVERTED x COST/PASSENGER

  [$7.8K] = 2.6K x $3

---

[1]See section 3.1.1 of this appendix.

[2]Estimated based on total TH trips which represent 0.8% of total IP trips.

3.15 FEDERAL/LOCAL GOVERNMENT IMPACTS

These estimates were derived from the IP Operator Impacts category by applying a 50%/50% split to net operating costs and a 80%/20% split to annual capital costs.

Appendix 4

Sensitivity Analysis

Introduction

The results of the analyses conducted as part of this study are, by their nature, not precise. Any prediction of events which have not yet occurred can only be accurate within a range dependent upon the precision of the data and methodologies employed. As noted in the initial discussion of the methodologies (see, for example, the Introductory chapter of Volume 3), each number appearing in the impact-incidence tables should be thought of as one value in a range of possible values; i.e., the mean or expected value of some distribution. In this appendix, we attempt to place values on those ranges. Specifically, this "sensitivity analysis" attempts to determine the sensitivity of the various outputs appearing in the impact-incidence tables to imprecisions, or errors, in the parameters.

4.1 Methodology

The development of the impacts used a large number of data items, as evidenced by the example in the previous appendix. Some of these data were output from various models (e.g. FORCAST), and thus, themselves dependent upon certain input values. Other inputs (e.g. average auto trip length) were developed based on some site specific or general data. (In the above example, average auto trip length was based on area size and data available from various cities). For the sensitivity analysis, it is assumed that the descriptions of settings and scenarios are precisè and accurate. Although prediction of the population and characteristics of urban areas for the future cannot be exact, the fact that the representative settings are not meant to be specific sites allows them to be considered as the actual setting, having no prediction error associated with their descriptions. The remainder of the inputs, however, are presumed to be imprecise.

For each of the inputs to the impact-incidence tables, an estimate has been made of the possible error of the estimate. These errors were developed in a variety of ways. For example, as noted in Appendix 1, validations of the FORCAST model have shown the model to be accurate within 0 to ±30%. We have used 30% as the (upper bound) estimate of the possible error in the ridership projection. For inputs developed from a set of data (e.g. percent of passengers diverted from a given mode; market share achievable by vanpool), we have computed the standard deviation of the distribution of available data. We have used this value to provide an upper and lower bound, or confidence interval, about the "mean" value which was used in the analysis.[1] Finally, for inputs which were approximated based on single data points, (e.g. percent of auto trips which are driver trips), we have made reasonable assumptions about the standard deviation of the underlying distribution. For example, an estimate of a factor such as "the number of TH in the service area" was assumed to have a much tighter confidence interval than an estimate of the "percent of passengers diverted from social service agencies" based on a priori assumption regarding the sources of variations for these values.

Detailed sensitivity analysis was performed for one scenario only: Setting 1, IP Scenario A, the scenario detailed in the 'example' in Appendix 3. The inputs to the impact-incidence table of this scenario, an estimate of the possible "error" (standard deviation expressed as a percent of the mean value used) for each input, and the source of these estimates, are presented in Table 4.1.

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[1]Note that, for a normal distribution, approximately 70% of all values fall within 1 standard deviation of the mean.

Table 4.1

Data Inputs and Associated Standard Deviation

Parameter	Standard Deviation as Pct. of Mean	Source
1. Ridership	±30%	Model Validation
2. % Ridership elderly	±65%	Model Validation
3. % Ridership 0_auto	±45%	Model Validation
4. % Ridership both elderly and 0-auto	±60%	Model Validation
5. % Ridership work, non-work	±10%	Model Validation
6. Change in auto ownership	±80%	Estimate
7. % Ridership formerly bus rides	±50%	Modal Diversion Data
8. % Ridership formerly auto	±40%	Modal Diversion Data
9. % Ridership formerly taxi rides	±50%	Modal Diversion Data
10. % Ridership induced	±50%	Modal Diversion Data
11. % Induced trips by special markets	±60%	Modal Diversion Data
12. Average auto trip length	±20%	Estimate
13. Average length of diverted auto trips	±15%	Estimate
14. Average trips/HH/year	±35%	Estimate
15. Persons using transit per daily work trip	±20%	Survey results, Rochester, N.Y.
16. Persons using transit per daily non-work trip	±15%	Survey results, Rochester, N.Y.
17. % diverted auto formerly drivers	±25%	Estimate
18. Vanpool market share	±40%	Vanpool data
19. Vanpool trip distance	±20%	Estimate
20. % of vanpool riders diverted from auto	± 5%	Vanpool user data
21. Annual taxi passengers per taxi	±25%	CDC-Wells data on taxis
22. Taxi trip length	±30%	CDC-Wells data on taxis

Table 4.1 (Cont.)

Parameter	Standard Deviation as Pct. of Mean	Source
23. Passengers/taxi trip	±10%	CDC-Wells data on taxis
24. Annual miles/taxi	±30%	CDC-Wells data on taxis
25. Taxi profit margin	±30%	Estimate
26. % taxi cost variable	±10%	Estimate
27. Drivers/taxi	±25%	Estimate
28. % former auto trips to CBD	±40%	Estimate
29. % of 28, work, non-work	±50%	Estimate
30. Average parking duration, non-work	±15%	Estimate
31. Average hourly parking rates	±15%	Estimate
32. Average monthly parking rates	±20%	Estimate
33. % Riders diverted from social service agencies	±75%	Estimate
34. Number of TH in service area	±30%	Estimate
35. Trip rate of TH	±60%	Estimate
36. Fuel consumption rates	±15%	Estimate
37. Emission factors	±15%	Estimate
38. VMT reduction per auto eliminated	±20%	Estimate
39. % auto trips chauffeur trips	±20%	Estimate

Two different approaches towards sensitivity analyses were followed. In the first, a range, or confidence interval around the mean predicted value of each impact was developed. In effect, the standard deviations of the input values, as shown in Table 4.1, were used to develop standard deviations of the output values. In these calculations, each input destribution was assumed to be normally distributed, with errors independent of <u>most</u> other input variable errors.[1] The standard deviation of each <u>output</u> distribution was computed in one of several ways. In cases where inputs were added, the standard deviation of the output distribution could be readily calculated, since the variance of the distribution resulting from the addition of two, independent distributions is equal to the square root of the sum of the squares of the variances of the two distributions. In cases where two distributions were multiplied or combined in some other way, a Monte Carlo simulation was used instead of a relatively complex direct computation. Under this technique, 100 points in each of the input distributions were drawn randomly from the distribution (given the mean and standard deviation). The corresponding points were then multiplied (or exercised in whatever way the distributions were combined). The standard deviation of the resulting distribution was then estimated from the 100 "output" points. This technique should result in reasonably accurate estimates of standard deviation, given the assumptions about the underlying distributions.

In the case of consumer surplus, the "confidence interval" was calculated assuming that the uncertainty in the ridership predictions resulted from an incomplete specification of the paratransit utility function. This assumption implies that the level of service coefficients are specified correctly, but that the "bias" constant term in the utility factor for the mode are inaccurate. Other assumptions are possible in determining the possible error in consumer surplus (e.g., it might have been assumed that

---

[1]Exceptions to the independence assumption were: ridership and autos foregone; auto trips diverted and autos foregone; VMT reduction, autos foregone, chauffeur trips diverted, and auto trips diverted. In these cases, the distributions were assumed to be 100% covariant, which effectively allowed the standard deviations to be added in cases where the distributions are added to obtain an output.

level of service was predicted incorrectly); different assumptions would produce different confidence intervals. It is important to note, however, that the impact on total consumer surplus error should not change significantly, although individual market segment confidence intervals could be quite different under different assumptions.

The second approach involved the analyses of four specific "cases" where only a few of the important variables were varied. In these cases, the variable independence assumption was essentially dropped to allow an investigation of interrelationships between (uncertain) inputs which compound the error in the outputs. For example, one case illustrates how lower demand for IP services, along with a greater percent of transit dependent potions, can impact the net cost. Table 4.2 indicates the amount each variable was varied for each case. The principal input variables which were altered include ridership levels, percent of each market segment, the modal diversion statistics, diverted trip distance, and the number of autos forgone.

It should be noted that the variations used in this analyses were not necessarily as extreme as those indicated in Table 4.1. It was not always possible to vary a combination of variables to their extreme values without violating a physical constraint. In the first sensitivity analysis scenario, for example, had the diversion from auto been placed at its highest value while diversion from taxi remained constant, the two values would have summed to more than 100%.

4.2 Results

The ranges around the mean value of the prinicpal outputs of IP Scenario A, "Southern Belle", developed using the first sensitivity methodology, are presented in Table 4.3. The mean values presented in this table are the same as that presented in the description of the scenario results (Volume 3).

One general conclusion that can be drawn is that the potential error in some impacts is greater than the error of most inputs. For example, consumer surplus is shown to have a possible error

Table 4.2

Second Approach To Sensitivity Analysis

Cases Considered: Variation (from mean)

	1	2	3	4
Ridership	+30%	+30%	-30%	-30%
% E&H	-65%	+65%	+75%	-65%
% O-AUTO	-45%	+45%	+45%	-45%
$ E&H and O-AUTO	-60%	+60%	+60%	-60%
Mode Shift				
Bus	-20%	+25%	+85%	+100%
Auto	+10%	-25%	-25%	-20%
Walk	+20%	+25%	+23%	+33%
Induced	-33%	+25%	+23%	+33%
Taxi	-33%	+87%	+85%	+33%
Diverted Trip Distance	-15%	-15%	0%	+15%
Autos Forgone	+80%	-80%	-80%	-80%

Table 4.3

Results of First Sensitivity Analysis: Setting 1; IP Scenario A

Impact	Lower Bound	Mean	Upper Bound
Change in Consumer Surplus ($000)			
All persons	439.6	734.8	1098.3
Elderly	-2.4	46.4	102.2
Ø Auto	55.7	150.2	193.5
New Transit Trips (000 trips)			
All persons	1127	1531	1935
Elderly	84	141	198
Transportation Handicapped	3.6	10.2	16.8
Ø Auto	117	218	318
Induced Transit Trips (000 trips)			
All persons	64	131	198
Elderly	12	42	72
Transportation Handicapped	0.5	3.1	6.7
Ø Auto	3	65	127
VMT Change (000 mi.)	-3591	-2498	-1405
CO Emissions Change (000 kg)	-130.6	-73.4	-16.18
HC Emissions Change (000 kg)	-16.3	-7.7	+0.9
NO_x Emissions Change (000 kg)	-9.3	-4.0	+1.3
Change in Employment			
Jobs	+62	+70	+78
Payroll ($000)	+511	+569	+626
Auto Expenditures ($000)	-596	-322	-48
Transit Operating Costs ($000)	915	934	953
New Transit Operating Cost ($000)	50	279	509
Net Transit Total Cost ($000)	330	559	788
Taxi Industry Revenue ($000)	-327.4	-241.0	-100.8
Taxi Industry Profits ($000)	-59.0	-38.3	-17.6

of 45.6%, as compared to an assumed ridership error of 30%. Note that, as should be expected, the potential error increases for the more disaggregate measures. For example, the possible error in the consumer surplus benefit received by elderly persons is 120%. Note also that the smallest errors were calculated for such factors as operating cost which is reasonably well determined by the system specification.

The obvious implication of Table 4.3 is that there are significant uncertainties associated with the results. These uncertainties tend to weaken some of the conclusions. On the other hand, it should be recognized that the analysis is somewhat conservative, since one would not expect all of the inputs to vary to the exteme used in this analysis.

At the (output) extremes in this example, the conclusion in the text that IP appears to be justified would probably be reversed. We applied the same percentage errors to the outputs of the "best" scenario in each of the other settings, and found that in 5 of the 7 cases the decision of whether or not the system appears justifiable would be reversed. In one of these cases, the switch from "justifiable" to "non-justifiable" was actually uncertain. Assuming that the "shift point" for this scenario was exactly at the point where all outputs were one standard deviation from the mean, and considering that 85% of all values (in a one-sided distribution) fall within one standard deviation, we could conclude that we can be 85% confident that the conclusion (of justifiability) is correct. In the other scenarios, the confidence would be somewhat lower. However, it should be recognized that, even if 5 of the 7 conclusions regarding justifiability were reversed, there would still be some justifiable systems and some non. Thus, the general conclusion that IP may or may not be justified remains valid. Furthermore, there would appear to be no reason to expect that the error in the results is biased in any particular direction. Thus, while ridership might be lower in one case and costs higher, the reverse might be the reverse in another. Thus, again, while the conclusions for a particular scenario may be uncertain, the overall conclusion should be reasonable. Finally, it should be pointed out that many of the other results reached in the study are based on comparisons between scenarios (e.g., whether checkpoint service is superior to doorstep). Since there is no reason to expect the error to differ significantly in the two scenarios, these conclusions remain valid.

An analysis of the sources of the major errors which may result in altering conclusions indicates that the primary source of variation occurs in the prediction of change in auto expenditures. In general, the auto expenditure impacts represents a major economic benefit. Unfortunately, this value is largely based on the number of automobiles forgone by residents of the service area, and the methodology employed to estimate this number can only be expected to produce a "ball park" figure. With an error of up to 80% for this value, there is a strong need to improve the estimation of this impact, and thus a need to develop better forecasting tools.

Table 4.4 presents the results of the second sensitivity methodology. These results indicate that, for most major outputs. the input errors do not significantly compound to produce errors greater than those in Table 4.3. Major exceptions to this general result include the impacts to taxi operators and the employment impacts. In these cases, errors in ridership and diversion from taxi combine to form significantly greater variations from mean predicted outputs. All other variables appear to be impacted in an intuitively predictable manner, and to a magnitude similar to that projected in Table 4.3.

In summary, the sensitivity analysis has indicated that there are uncertainties regarding the absolute levels of all of the outputs, as there must be in any study which involves forecasts of behavior and costs. While the uncertainty limits the confidence once can place on some of the individual results, the overall conclusions appear reasonable. IP systems may, in some instances, be beneficial, and there is the need for further research, experimentation, and demonstrations.

Table 4.4

Results of Second Sensitivity Analysis: Setting 1; IP Scenario A

Impact	Case 1	Case 2	Case 3	Case 4
New Transit Trips (000 trips)				
All persons	1922	1907	1166	1128
Elderly	67	298	165	35
Transportation Handicapped	10.2	10.2	10.2	10.2
Ø Auto	150	414	229	79
Induced Transit Trips (000 trips)				
All persons	131	212	112	122
Elderly	20	74	40	29
Transportation Handicapped	4.9	2.5	2.5	8.3
Ø Auto	72	103	56	64
VMT Change (000 mi.)	-3051	-3083	-1938	-1879
CO Emissions Change (000 kg)	-102.6	-120.7	-52.5	-44.6
HC Emissions Change (000 kg)	-11.7	-14.6	-5.0	-3.8
NO_x Emissions Change (000 kg)	-15.7	-6.7	-2.5	-2.1
Change in Employment				
Jobs	+64	+40	+64	+71.5
Payroll ($000)	+530	+384	+531	+577
Auto Expenditures ($000)	-580	-65	-65	-65
Transit Operating Costs ($000)	934	934	934	934
New Transit Operating Cost ($000)	81	81	478	478
Net Transit Total Cost ($000)	361	361	758	758
Taxi Industry Revenue ($000)	-278.6	-522.3	-277.3	-199.8
Taxi Industry Profits ($000)	-49.8	-93.5	-50.6	-35.8

Appendix 5

Aggregation of Impacts to National Levels

As an exercise, it was felt to be interesting to try to obtain ballpark estimates of the possible impacts of IP on a national level. A projection of the potential national impacts of IP is an extremely difficult task, certainly an impossible one to perform with any precision. First of all, there is the question of how to predict whether a particular urban area will implement an IP system; a variety of institutional factors will influence IP acceptance, and it is up to the local community to place relative importances on different IP impacts. In addition, some areas may wish to implement only portions of the types of IP systems developed in this report. In particular, systems that have been shown to be relatively ineffective may not be implemented at all or, if they are, discontinued after a few months or years. Furthermore, although the analysis was designed so that, on average, the impacts of IP would be similar for any setting in a given group, there is no guarantee that the impacts of a particular system implemented would be identical to the impacts of the system analyzed in the representative, prototypical city. Finally, recall that the systems analyzed need not have been "optimum."

The probability of implementation of IP, and the overall acceptability to the local community, is also highly dependent upon the availability of funding on both the local and Federal levels. It is perhaps in this area where the Federal government can have the greatest impact on IP implementation. It also becomes a slightly easier, although by no means easy, task to project national impacts of IP based on <u>different levels of Federal funding</u>.

It is not being suggested that the Federal government establish a separate funding source for paratransit service, since transit design decisions are probably best made on a local level. However, the Federal government can influence the extent to which IP or other expanded transit services are introduced, by the total amount of funding directed to a given area. The U.S. Department of Transportation already has planning requirements which must be met by an urban area in order to receive Federal funding; these include requirements for both short range, low capital intensive options, such as IP and for special plans for the elderly and handicapped. If increases in Federal funding (from one year to the next) to a given urban area for transit expansion were dependent upon a review of local short range transit improvements, the amount of funding made available will clearly impact the scope of the transit improvement, and vice versa.

This report is not the proper forum for an in-depth discussion of Federal funding programs and requirements, nor is it our intention to offer any recommendations in this area. Instead, the study has used the above, general funding "scenario" to help develop ballpark estimates of various IP impacts on a national scale. Specifically, three Federal funding scenarios have been considered:

1. Low level of funding: If Federal funds for service expansion are tight, it is likely that primarily the most "cost-effective" of IP systems will be approved and implemented. It is still not possible to predict with any certainty the number of IP systems to be implemented. However, as part of this scenario, we project that 50-60% of the "more effective" IP scenarios would be implemented, while 5-15% of the "less effective" ones would be. For this purpose, we define "more effective" as all of the IP scenarios which were categorized as having beneficial impacts which seem to offset the deficit, while the "less effective" systems are all others. Given the broad nature of this scenario, no attempt has been made to predict IP implementation rates on the city type level.

2. Medium level of Federal funding: At this level, all IP systems are more likely to be funded, but the probability of implementation of the less èffective systems grows faster than the probability of the more effective. As part of this scenario, it is assumed that 65% - 75% of the latter and 25% - 35% of the former systems are implemented.

3. High level of Federal funding: At this level, it is assumed that 80% - 90% of the more effective systems and 45% - 55% of the others are implemented.

Using these assumptions, a number of IP impacts have been aggregated to the national level. In general, those impacts found to be the most significant were projected, although, in cases of impacts of national interest, such as the change in VMT, even less significant impacts have been projected. Aggregation was performed by an impact value per capita rate for each setting considered, aggregating up to the cluster level by multiplying by total cluster (urban area) population, and summing across clusters. Separate aggregation factors were used for the elderly, TH, 0-car, and total population. For each setting and group, this involved developing the ratio of total group population (by market segment) to setting population; multiplying this factor by the setting impacts yields the group level impacts. The factors, shown in Table 5.1, were developed from the data base used in the city classification task. Note that this involved the use of 1970 census data, and thus effectively assumes that the population of the setting between 1970 and 1980 increases at the same rate as the population of the entire group. In lieu of 1980 population projections for every city, this was the only reasonable approach to take. The expansion ratio for the transportation handicapped (which cannot be derived from census data) was assumed to be midway between the ratios for the elderly and the general population; this was based on the fact that, in general, 50% of the TH are elderly and 50% are not. The impacts which are aggregated, and the factor used for each, are identified in Table 5.2.

The approach used was understood to contain a number of shortcomings, for example:

1 - Many impacts, such as transit operating cost, may not really be estimable on a "per capita" basis.

2 - Optimum IP systems were not developed for each setting; thus aggregation based on the scenarios considered may underestimate the overall "cost-effectiveness" of IP.

3 - There is no way of a priori determining how many IP systems will be implemented, or whether fixed route may be used instead in some locations.

Table 5.1

Aggregation Factors

Setting	1970 Setting Population (000)			1970 Group Population (000)			Aggregation Factors		
	elderly	0-auto (HH) [1]	total	elderly	0-auto (HH) [1]	total	elderly	0-auto (HH)	total
"Southern Belle"	10.7	28.8	149	714.9	1501.0	7853.3	66.81	52.12	52.71
"College Town"	8.6	17.9	179	194.0	324.0	2543.4	22.56	18.10	14.21
"Sun City"	18.4	30.6	297	520.5	892.5	7139.5	28.29	29.17	24.04
"Mid-American City"	33.5	44.8	353	2322.3	3431.0	27466.2	69.32	76.58	77.81
"Mill Town"	18.6	36.3	134	602.2	669.2	3666.2	32.38	18.44	27.36
"Large City"	182.3	343.0	1960	2209.2	4383.3	22005.1	12.12	12.78	11.23
"Metropolis"	304.7	657.2	2650	2807.9	6272.8	31170.0	9.22	9.54	11.76
TOTAL	576.8	1158.6	5722.0	9371.0	17473.8	101843.9	-	-	-

[1] This figure is the percent 0-car households times the population. This clearly overestimates 0-car population, since the average size of 0-car households is significantly smaller than the overall average. Since data on the total number of households or household size by auto ownership levels were not available, this value was used as a surrogate. Note that it is only being used to develop an aggregation factor and, as such is fairly reasonable.

Table 5.2

Impacts which are Aggregated

Impact	Aggregation Factor Used[1]	Impact	Aggregation Factor Used[1]
Federal Operating Subsidy:		Change in consumer surplus:[2] Elderly	E
Capital	GP	0-auto	Z
Operating	GP	total	GP
Local Operating Subsidy:		Change in VMT	GP
Capital	GP	Fuel Consumption	GP
Operating	GP	Emissions: CO	GP
		HC	GP
		NO_x	GP
New Transit[2] trips:			
elderly	E	Employment: Jobs	GP
TH	TH	Payroll	GP
0-auto	Z		
total	GP	Autos: Number foregone	GP
		Expenditures	GP
Induced elderly[2] trips:	E	Exclusive-ride	
TH	TH	Taxi passengers	GP
0-auto	Z		
total	GP		

[1]GP = general public or total, E = elderly, TH = transportation handicapped (computed as $\frac{GP + E}{2}$), Z = zero car household.

[2]Note that the use of different factors for different market segments under mobility and consumer surplus may yield national level results in which the components do not really add to the total value.

4 - Many of the scenarios considered utilized private operators, which keeps costs down. Institutional issues may prevent the private sector from being used in some places.

5 - IP systems implemented in different locations may be larger or smaller in scale than the one considered in the representative setting.

There are undoubtedly other problems with the approach as well. Other approaches may have avoided some of the problems. For example, because of the importance of population density to transit service type, it may have been preferable to factor up to the city group level separately for different density areas; i.e., it may be likely that a system implemented in a portion of a setting with density x would be implemented, and have similar impacts, in like-density areas in other cities in the group. Alternately, aggregation might have been performed on an IP module by module basis, with an analysis of each city in a group to determine how many similar modules might be implemented; this addresses the question of system scale in different cities of a group. Neither these nor other possible approaches, however, avoid the fact that a projection must be made of the total number of IP systems which will be implemented and maintained. The uncertainty involved in this assessment potentially results in greater errors than any of the other problems considered. For this reason, it was felt that the development of a more sophisticated aggregation approach was unwarranted.

The projections of national impacts, therefore, must be viewed as nothing more than a preliminary attempt to make ballpark estimates of the impacts of wide scale IP implementation, in order to help the U.S. Department of Transportation understand the magnitude of various impacts at various funding levels. The results of this procedure are shown in Table 5.3, and may be summarized as follows:

1. Total annual Federal funding for new IP services would amount to \$20.36 million to \$36.7 million at the "low level", \$51.7 million to \$68.05 million at the "medium level", and \$83.04 million to \$99.38 million at the high level of Federal funding.

2. At these levels of funding, the total number of new transit trips which would be generated would be 53.9 million - 76.30 million (low); 93.92 million - 117.29 million (medium); and 133.91 million - 156.32 million (high). This implies total Federal dollars per (new) transit trip of .38 - .48 in the low case, .55 - .56 in the medium, and .62 - .64 in the

Table 5.3

National Annual Impact of IP Under Different Federal Funding Levels

Impact		Low	Medium	High
Federal Subsidy (+$000,000)	Operating	10.17 - 21.14	31.59 - 42.57	53.02 - 63.99
	Capital	10.19 - 15.56	20.11 - 25.48	30.02 - 35.39
	Total	20.36 - 36.70	51.70 - 68.05	83.04 - 99.38
Local Subsidy (+$000,000)	Operating	10.17 - 21.14	31.59 - 42.57	53.02 - 63.99
	Capital	2.55 - 3.89	5.03 - 6.37	7.51 - 8.85
	Total	12.72 - 25.03	36.62 - 48.94	60.53 - 72.34
New Transit Trips (000,000)	By elderly	9.14 - 15.98	22.17 - 29.00	35.21 - 42.05
	By TH	1.13 - 2.52	3.86 - 5.24	6.58 - 7.97
	By 0-Auto	10.38 - 15.90	21.16 - 27.18	32.44 - 43.17
	Total	53.93 - 76.30	93.92 -117.29	133.91 -156.32
Induced Trips (000,000)	elderly	2.68 - 4.22	5.79 - 6.14	9.09 - 10.83
	TH	0.24 - 0.49	0.73 - 0.98	1.22 - 1.47
	0-Auto	2.75 - 4.39	5.81 - 7.53	8.88 - 10.51
	Total	6.00 - 9.47	12.46 - 15.93	18.92 - 22.39
Change in Consumer Surplus (+$000,000)	Elderly	4.28 - 5.89	8.17 - 8.37	12.98 - 14.50
	0-Auto	6.22 - 9.90	13.09 - 16.86	18.95 - 23.63
	Total	24.80 - 35.16	43.35 - 53.71	61.89 - 72.25
VMT (000,000 mi.)		-68.42 to -83.61	-92.04 to -107.24	-115.67 to -146.17
Fuel Consumption (000,000 gal.)		-1.04 to -.46	-.41 to +.85	+1.58 to +2.17
Emissions (000,000 kg)	CO	-0.81 to -0.006	+0.93 to +1.73	+2.67 to +3.47
	HC	-0.11 to -0.006	+0.11 to +0.21	+0.33 to +0.43
	NO_x	-0.10 to -0.08	-0.06 to -0.03	0.00 to +0.02
Employment: +Jobs		3026 - 4688	5508 - 7931	9416 - 1120
Payroll (+$000,000)		26.60 - 45.04	61.00 - 79.17	95.40 - 113.57
Automobile- autos		4855 - 7884	10,636 - 13,458	16,497 - 19,607
ownership:expend. (-$000,000)		19.87 - 32.84	44.33 - 55.98	67.09 - 83.40
Reduction in Exclusive-ride taxi patronage (-000,000 pass.)		5.87 - 9.09	11.63 - 14.67	17.20 - 20.24

high. Note that as more of the less productive systems are implemented, the cost per passenger increases somewhat.

3. A substantial portion of the new transit trips are made by the elderly. The Federal cost per elderly trip, interestingly, appears to remain essentially constant at approximately $2.35.

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16. Abstract

Integrated paratransit (IP) service is a concept which involves the integration of conventional fixed-route transit services with flexible, demand-responsive services in order to best serve emerging urban development patterns. To learn more about the capability of IP to meet the transit needs in the urban/suburban environment, the Urban Mass Transportation Administration sponsored a study to identify and define the benefits due to and the costs associated with the deployment of various hypothetical IP systems. This study systematically estimates potential impacts of a range of integrated transit/paratransit options and policies in a variety of settings and compares them with impacts of transportation alternatives. This study concludes that, in general, IP with fares closer to fixed-route transit than exclusive-ride taxi will result in net paratransit operating deficits. However, in some instances, the benefits of IP options in terms of improved service levels and mobility, reduced auto expenditures and other impacts appear to offset these operating deficits. Necessary factors for this include high paratransit productivities, possibly achieved by implementing hybrid, fixed-route/demand responsive service; and low operating costs, possibly achieved by contracting with private operators. IP was found to have a positive but insignificant impact in reducing automobile usage and ownership, but no measurable impact on vehicle miles traveled, fuel consumption, or emissions. Promising locations for paratransit implementation are those areas with population densities between 3,000 and 6,000 persons per square mile and limited transit service. The most promising paratransit concepts appear to be checkpoint many-to-many service, route deviation service, automated doorstop service with high vehicle densities, and vanpool service. The results of the study further suggest that paratransit service is sensitive to fare. Fare increases above $.25 were determined to be counterproductive, while free transfers from feeder services to line haul became an inducement to use paratransit. The study also concluded that digital communications and automated dispatching systems are potentially cost-effective technological innovations.
This last volume, Volume 6, includes five technical appendices which document the methodologies used in the benefit-cost analysis.

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