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DEMAND PROJECTIONS FOR THE NORTHEAST CORRIDOR
Financial Analysis

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16. Abstract

This report describes the development and results of intercity travel demand projections by city-pair prepared for the Northeast Corridor financial analysis. In addition associated analyses of projected passenger volumes by station and of selected alternative station sites are included.

The report first presents the methodology used both to develop projections of total travel by all modes for each city-pair and to assess the rail share of the total. Next, the development of the travel and socioeconomic data base is discussed. The assumptions and sources used for calibration and projection data sets are given, including travel patterns, travel impedances, and population and income information for each city-pair.

Two basic rail alternatives were analyzed: rail service would remain unchanged for 1974 service levels; and the Northeast Corridor Development Program would be implemented by 1982.

The results of each of the scenarios and sensitivity analyses performed for each alternative are described. Detailed annual rail passenger volume estimates were prepared for the primary scenario, and station loading estimates for selected years were developed for high volume days and peak hours.

Finally, the potential benefits of additional service to new or additional suburban station sites north of Philadelphia and New York City are examined.

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PREFACE

The Regional Rail Reorganization Act of 1973 directed the U.S. Secretary of Transportation to undertake engineering studies in preparation for implementation of the recommendations with respect to rail passenger service contained in the September 1971 Northeast Corridor Report. Included in the study requirements was the need for detailed DEMAND projections for high speed rail service.

Planning for the service has been conducted by the Office of Northeast Corridor Development (ONECD) in the Federal Railroad Administration. The Transportation Systems Center (TSC) provided assistance to ONECD in the areas of demand forecasting and financial analysis. The work described in this document was done under contract to TSC.

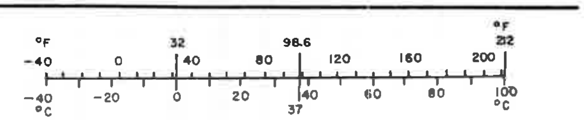
METRIC CONVERSION FACTORS

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

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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I. INTRODUCTION

This report presents the methodology, analysis, and results of projections of rail travel demand in the Northeast Corridor. These projections were prepared for the Transportation Systems Center (TSC) for use by the Office of Northeast Corridor Development (ONECD) of the Federal Railroad Administration (FRA). The purpose of the program is to carry out the mandate by Congress in the Rail Reorganization Act of 1973 to implement the recommendations of the Northeast Corridor Project to develop a high-speed rail service in the corridor. To assist with the financial analysis, demand projections were prepared to examine the revenue implications of different policy options and to assess the nature of the system loading to estimate operating requirements.

THE PROBLEM

The U.S. Department of Transportation's (DOT) report on improved rail service in the Northeast Corridor[1] made specific recommendations concerning the nature and level of improvement in Northeast Corridor rail service. Because the report was based on research conducted before the recent energy shortages and before the severe inflation of recent years, the validity of the recommendations could not be considered without question. It was, thus, desirable to examine again a wide range of possible demographic, economic, and rail service scenarios in order to assess the most appropriate plan for development. Demand projections and financial analyses accordingly had to be prepared to reflect the various scenarios and to include the most recently available cost data from the ongoing engineering studies now being conducted for the Northeast Corridor Development Program.

OBJECTIVE OF THE STUDY

The primary objective of the study was to prepare reliable rail patronage projections for use as revenue and system loading inputs to the financial analysis. A variety of population and economic conditions and other modes of service were also to be examined. Two secondary objectives directed the analysis: the necessity of using existing techniques, and the necessity of updating base and projection data to reflect the most recent developments and thinking.

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[1] Improved High-Speed Rail for the Northeast Corridor. U.S. Department of Transportation. January 1973.

To meet the first objective, the study team selected intercity demand and modal split models developed during the Northeast Corridor Transportation Project and other DOT studies. Based on an existing comparison of available models,[1] the CN27 calibration of the cross-elasticity model (McLynn) and a demand growth model (PMM&Co.)[2] were chosen. A computer program that incorporated the models was used to prepare rail demand projections by city pair for each projection year studied. A list of the city pairs used in the analysis is shown in Table I.1. Eleven possible city pairs were specifically not used, either because they did not allow their separation from other city pairs, or because of the availability of competitive commuter service for their travelers. All of the excluded city pairs are short distance, and should be relatively insignificant for corridor service.

The second objective was met by reviewing all the travel and impedance data sources and updating input data to the models. Travel data were updated to the most recent available volumes; impedances were reviewed to include new highway speed limits and new toll and fare increases. Several sources of population and economic projections were reviewed, and the most appropriate series was chosen for use in the analysis.

Three additional demand-related analyses were conducted to assist FRA in the design of the Northeast rail passenger service. These were development of time series demand estimates for station loading purposes, nalysis of alternative station locations in selected areas, and analysismof time-of-day travel patterns. The station loading (i.e., passenger on and off volume) was prepared for station designs to provide estimates of potential pedestrian volumes consistent with the official FRA demand projections. Selected stations were examined in the northern Philadelphia and the New York-to-New Haven areas to determine the potential for additional demand. Finally, a time-of-day travel pattern analysis was performed to assist in analyzing the potential patterns of rail demand during the projection period.

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[1] Peat, Marwick, Mitchell & Co. Analysis of Intercity Modal Split Models. U.S. Department of Transportation. July 1973.

[2] Peat, Marwick, Mitchell & Co. Variations in Travel Forecasts for Improved High-Speed Rail Services in Northeast Corridor. U.S. Department of Transportation. July 1973.

STRUCTURE OF THIS REPORT

This report first presents the modeling techniques used in preparing the projections. Next the revisions to the base data are described, and the various population and income data sources are noted. Finally, results of projections for each of the analyses are presented, along with the basic assumptions used in each.

TABLE I. 1

CITY-PAIRS USED IN THE ANALYSIS

Washington, D. C.

- Baltimore
- Wilmington
- Philadelphia
- Trenton
- Northeast New Jersey
- New York City
- Long Island
- North New York
- Bridgeport
- New Haven
- New London
- Providence
- Boston

Baltimore

- Wilmington
- Philadelphia
- Trenton
- Northeast New Jersey
- New York City
- Long Island
- North New York
- Bridgeport
- New Haven
- New London
- Providence
- Boston

Wilmington

- Philadelphia
- Trenton
- Northeast New Jersey
- New York City
- Long Island
- North New York
- Bridgeport
- New Haven
- New London
- Providence
- Boston

Philadelphia

- Northeast New Jersey
- New York City
- Long Island
- North New York
- Bridgeport
- New Haven
- New London
- Providence
- Boston

Trenton

- New York City
- Bridgeport
- New Haven
- New London
- Providence
- Boston

Northeast New Jersey

- New London
- Providence
- Boston

New York City

- New Haven
- New London
- Providence
- Boston

Long Island

- New London
- Providence
- Boston

North New York

- New London
- Providence
- Boston

Bridgeport

- New London
- Providence
- Boston

New Haven

- New London
- Providence
- Boston

New London

- Providence
- Boston

Providence

- Boston

II. METHODOLOGY FOR PROJECTING RAIL TRAVEL DEMAND

Patronage and revenue estimates for each projection year for the improved high-speed rail service in the Northeast Corridor were developed in a two-phase analysis process:

- total travel by all modes in each of the major markets was projected; and then

- the share of travelers using rail in each market was projected as a function of the attributes of rail and the competing intercity transportation services.

The models used in each phase of the analysis are described in this section. A previously developed computer program was modified to automatically iterate through each year of the projected period varying the travel, population, and income characteristics according to the scenario being tested. For each scenario tested, the program could project patronage and revenue for each city pair, rail link, mode, and year.

PROJECTIONS OF TOTAL DEMANDS

The projection of total travel in each market for each projection year was based on three factors relating to:

- changes in local and national population;

- changes in local real per capita income; and

- changes in average trip length.

Using 1974 travel demand as a base, the three factors were combined as shown in the following equation to estimate total travel in each projection year:

$$D_F = D_B \left[\frac{P_{aF} P_{bF} P_{nB}}{P_{aB} P_{bB} P_{nF}}\right] \left[\frac{1.77\ (I)_F - 203}{1.77\ (I)_B - 203}\right]$$

where:

D_F, D_B	=	the demand between the two cities for the projection years and the base year, respectively;
P_a, P_b	=	the metropolitan area populations of city a and city b for the respective years;
P_n	=	the national population for the respective years; and
I	=	the per capita income of the two cities, a and b, weighted by their populations for the respective years.

Per capita income projections by Standard Metropolitan Statistical Area (SMSA) to 2020 were obtained from "1972 OBERS Projections - Regional Economic Activity in the U.S.," U.S. Water Resources Council, Washington, D.C., April 1974. These projections are expressed in constant 1967 dollars and assume a national population growth based on the U.S. Bureau of the Census Series E forecasts. Table II.1 shows total demand and annual growth for typical city pairs using this approach for estimating growth.

ESTIMATION OF RAIL SHARES

The model used for projecting the rail share of the total travel in each market is an adaptation of the stratified abstract mode cross-elasticity model developed by McLynn. The particular version of the cross-elasticity model used for this project is based on the CN27 calibration, which has been used in several previous studies, including some of those in the second NEC report.[1] This calibration proved to be the most accurate of eight models tested by PMM&Co.[2] for both rail shares and modal shares. The application described here should improve further upon the accuracy as previously tested. The model is stratified into two trip purpose models, one for business and one for nonbusiness trips; the primary difference between the two is sensitivity to trip time and trip cost. Business travelers are assumed to have much higher sensitivity to trip time than nonbusiness, while nonbusiness travelers are more sensitive to cost.

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[1] Recommendations for Northeast Corridor Transportation. U.S. Department of Transportation. September 1971.

Analysis of Intercity Modal Split Models, op. cit.

TABLE II.1

GROWTH IN TOTAL TRAVEL DEMAND
FOR SELECTED CITY-PAIRS

City-Pairs	1974 (000)	Annual % Growth	1982 (000)	Annual % Growth	1990 (000)
Washington - Boston	803.1	5.11	1,196.1	4.95	1,760.4
Washington - New York*	6,065.0	4.72	8,772.0	4.66	12,625.7
Washington - Philadelphia	3,367.1	4.90	4,935.2	4.64	7,096.1
New York - Philadelphia	13,200.4	3.57	17,479.8	3.09	22,293.0
Bridgeport - Boston	429.9	4.17	596.2	3.68	796.3
Total Corridor	71,256.0	4.02	97,665.0	3.70	130,632.0

*New York includes Northeast New Jersey, New York, Long Island and North New York.

In the cross-elasticity model, the modal share is determined as the ratio of a measure of a given mode's combined attributes to the sum of the attribute measures for all modes. That is, the share of the intercity travel market between any two points by mode i, S_i, is given by the fraction:

$$S_i = \frac{w_i}{\sum_i w_i}$$

where:

w = the combined measure of the attributes for mode i.

The cross-elasticity model combines the modal attributes of travel time, price, and frequency in a function of the form:

$$w_i = a_0 t^{a_1} c^{a_2} f'^{a_3}$$

where:

a_0, a_1, a_2, a_3 = calibrated parameters of the models;

t = travel time;

c = travel price; and

f' = a measure of service frequency.

Since an increase in travel time and price for a given mode implies that the mode has become relatively less attractive (if all other modes do not change), the sign of the calibrated coefficients a_1 and a_2 must be negative to ensure that increases in travel time and price for the mode decrease that mode's share. If f', the measure of service frequency for non-automobile modes, is a transformation that increases with increasing frequency, then an increase in frequency implies an improvement in a mode's competitive position and the sign of the exponent a_3 must be positive. Conversely, if f' decreases with increasing frequency, then the sign of a_3 must be negative. The values of the calibrated coefficients also imply certain values for modal share elasticities and imply a "value-of-time" or, more accurately, the trade-off between time and price. The coefficient a_0 acts essentially as a scaling factor in the modal split model because it is applied in a multiplicative fashion and because it has relatively little effect on the sensitivity of modal split to changes in system attributes. A definition and the calibrated parameters for the model used in this study are described in Figure II. 1.

Description: Stratified, abstract mode, cross-elasticity model - 1971

Specification:

$$S_i = \frac{w_i}{\sum_i w_i} \qquad w_i = a_0 t^{a_1} c^{a_2} f'^{a_3}$$

$$f' = 1 - e^{-kf}$$

Calibrated Parameters:

		a_0	a_1	a_2	a_3	k
business	air	1.1232	-3.384	-0.483	2.279	0.12
	rail	1.4813	-3.384	-0.483	2.279	0.12
	bus	0.3767	-3.384	-0.483	0	0
	automobile	1.0	-3.384	-0.483	0	0
non-business	air	0.7767	-1.5821	-1.5821	2.0462	0.18
	rail	1.9881	-1.5821	-1.5821	2.0462	0.18
	bus	1.3872	-1.5821	-1.5821	0	0
	automobile	1.0	-1.5821	-1.5821	0	0

Variable Definition:

t = total average one-way door-to-door travel time in hours

c = total average one-way door-to-door travel price in dollars

automobile per person trip cost: business--2.3¢/mile; non-business--1.0¢/mile

f = average number of one-way trips in one direction

FIGURE II.1: DESCRIPTION OF MODEL: CN27

The modal split model was used to predict traveler response to alternative transportation services with a "pivot point" procedure. With this approach, the parameter a_0 is adjusted for each city-pair such that the model exactly reproduces the modal shares for the existing condition. Under normal circumstances, a calibrated model will replicate aggregate travel patterns but will normally exhibit some error for each particular forecasting situation (city-pair). The adjustment of the scaling factor or mode-specific constant a_0 assures that the model will reproduce the base condition for every city-pair and will therefore provide a better measure of incremental travel response due to changes in transportation service for each city-pair.

The constants, a_0, are adjusted such that $\sum_i w_i = 1$ and such that the model replicates base-year modal split for each mode. If w'_i is the observed base-year modal split for mode i, this condition implies:

$$w'_i = a'_{0i}\, t_i^{a_1 i}\, c_i^{a_2 i}\, f'^{a_3 i}$$

where $a'_0 i$ is the adjusted value of $a_0 i$. Thus:

$$a'_{0i} = \frac{w_i}{t_i^{a_1 i}\, c_i^{a_2 i}\, f'^{a_3 i}}$$

or:

$$a'_{0i} = a_{0i} \frac{w'_i}{w_i}$$

The advantage of utilizing a pivot point analysis is that those aspects of an intercity travel market that may not be reflected in the travel time, travel cost, and frequency variables can be incorporated in the modal split model to reflect the existing pattern of base year patronage. The application of the pivot point analysis results in different travel markets exhibiting the same responsiveness to changes in travel time, cost, or frequency. Using the pivot point analysis, models with identical elasticities but different modal constants become, in effect, the same model.

III. BASE AND PROJECTION DATA

Two data files were developed for operation of the model:

- the base period data file for calibrating the models; and
- the projection period data file for establishing projection conditions.

The base data file consists of three sets of data:

- historical travel patterns by mode;
- historical travel impedances by mode; and
- population and income information.

The projection data file consists of projection estimates for the latter two:

- projected travel impedances by mode; and
- projected population and income information.

This section briefly describes the components and sources of these data files. The reader should refer to the source documents if more detailed descriptions of the items or values used are desired.

HISTORICAL TRAVEL PATTERN DATA

Historical travel patterns for the base year were developed essentially by updating modal travel data developed previously by Peat, Marwick, Mitchell & Co. and documented in two reports prepared for the Federal Railroad Administration.[1,2] Based on the available information to update travel estimates, a base year of the 12 months ending

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[1] Analysis of Intercity Modal Split Models, op. cit.

[2] Variations in Travel Forecasts, op. cit.

June 1974 was chosen. Therefore, the major efforts were directed toward either obtaining 12-month estimates for the base period or developing appropriate adjustment factors to the 1969-1970 data so that the patterns prevalent then could be used to represent the June 1974 base year.

Automobile Travel

Because highway surveys have not been performed throughout the Northeast Corridor in the past few years, traffic counts were obtained from other sources. Data on key intercity highway links were obtained from the Federal Highway Administration, the New Jersey Turnpike Authority, and the Massachusetts Turnpike Authority for fiscal years 1970 and 1974. Growth factors were developed using those data. The percentage change in volumes on a link or the average of the change in volumes on more than one link was applied to the appropriate city pairs using those links. Table III. 1 lists the highway links with their respective volumes and growth factors.

Bus Travel

Because no available origin-destination data exist, growth factors were developed using Interstate Commerce Commission (ICC) carrier statistics of patronage for fiscal years 1970 and 1974. Weighted average factors based on the number of scheduled runs of each carrier between a given city pair were used to update the original volumes. The four carriers operating in the Northeast Corridor and for which data were obtained are:

- Trailways of New England;
- Bonanza (formerly Shortline);
- Safeway Trails; and
- Greyhound.

Air Travel

The Civil Aeronautics Board (CAB) 10-percent ticket sample survey is the only origin-destination data source available for both time periods. But, the CAB 10-percent ticket sample only provides an estimate of terminal-to-terminal origin-destination (rather than a city-to-city origin-destination). Therefore, the original air travel volumes

TABLE III. 1

AVERAGE DAILY AUTOMOBILE TRAVEL VOLUMES AND FACTORS FOR KEY INTERCITY HIGHWAY LINKS

LINK	AVERAGE DAILY TRAVEL VOLUMES		FACTOR
	1970	1974	
Maryland:			
U.S. 40 at Susquehanna River Toll Bridge	15,513	14,873	.959
I-95 at JFK Memorial Highway Toll Gate	27,782	29,948	1.078
New Jersey:			
N.J. Turnpike north of junction with Pennsylvania Turnpike	56,498	44,020	.868
Connecticut:			
State Route 15 at Wilbur Cross Parkway	28,297	29,765	1.052
I-95 at Housatonic River	50,562	53,192	1.052
I-95 east of New Haven at Madison	20,474	22,958	1.121
Connecticut Turnpike between New London and Providence at Monteville	7,073	8,968	1.268
Rhode Island:			
Noozeneck Expressway (I-95) west of Providence	15,317	14,251	.930
Massachusetts:			
Massachusetts Turnpike (I-90) at Sturbridge	17,639	22,655	1.284

SOURCES: Federal Highway Administration
New Jersey Turnpike Authority
Massachusetts turnpike Authority

were developed as a combination of both the CAB 10-percent survey and the Northeast Corridor Intercity Travel Survey (conducted in 1969). (See Variations in Travel Forecasts, PMM&Co., 1973.)

For city pairs having an estimated amount of air travel and not having direct or indirect flights between the respective airports serving the city pair, the NEC estimate was added to the CAB estimate. When the NEC survey sampled travel between a city pair and the estimate was considerably greater than the CAB's, the possibility existed that air travelers were using alternate airports as well as the direct airport, and the NEC estimate was used. When partial estimates were obtained for a city pair because of multi-legged flights or connecting passengers, the CAB estimate was used.

To update these data, growth factors were developed using the CAB 10-percent survey for the 12 months ending March 31, 1970, and March 31, 1974, since the June 30, 1974, data were not available at the time. These factors were then applied to the original volumes, except where new or significantly revised service was introduced. When major service changes occurred, primarily between small city pairs, the 1974 CAB volumes were used directly; i.e., service to and from New Haven and Bridgeport airports did not exist in all of the years.

The CAB's slightly inflated volumes for the larger terminals indicate that many travelers from small cities drive to nearby large cities where there is better air service. Because this was found to be the case for travelers between other NEC cities and Trenton, northeast New Jersey, Long Island, northern New York, and Bridgeport, the growth factor developed for New York City was applied to these cities. Volumes for Long Island were developed as a combination of updated volumes, using the New York City factor and the 1974 CAB count of patronage at the Islip Airport. The original data excluded patronage at Islip because of its low volume. This volume has increased substantially between 1970 and 1974. The same growth factor developed for Philadelphia was applied to Wilmington because most NEC travel to and from Wilmington by air is through the Philadelphia airport.

Rail Travel

As in the case of the CAB 10-percent survey, the continuing on-board rail passenger count conducted by the FRA, the Data Tag Program, provides only a station-to-station estimate of rail travelers, rather than a true origin-destination count. Therefore, the total passenger count for the 1969-1970 period was developed from both the Data Tag Program and the NEC survey.

To update these original data, growth factors were developed using the average patronage obtained from the Data Tag Program for routes between New York and points south, and routes between New York and points north, for the 12 months ending June 1970 and June 1974. Sample months in 1974 of trains going through New York were expanded to yearly totals and used directly for the appropriate city pairs. All rail volumes include patronage on conventional, metroliner, and turbo trains.

Because New York City, northeast New Jersey, Long Island, and northern New York are essentially one metropolitan area, one factor was developed combining New York and northeast New Jersey patronage and then applied to all four areas.

Both Bridgeport and Stamford are in Fairfield County; they can also be considered part of the same metropolitan area. Because this study is evaluating the use of only one station, 1974 patronage data on trips to and from Stamford and Bridgeport (obtained from the Data Tag Program) were combined and used directly.

MODAL IMPEDANCES FOR CALIBRATION PURPOSES

Access Impedances

The basic assumptions and development of original access impedances are described in an earlier report by Peat, Marwick, Livingston & Co.[1] The actual access impedances used are based on an update of the original impedances to 1971 values.[2] Only the changes in assumption and the impacts of recent developments on the assumptions are discussed here.

Access Times

It was assumed that access times for all modes have remained constant since 1971. It was assumed that most access is by automobile, and new speed limits do not have a significant effect on urban traffic flow.

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[1] Peat, Marwick, Livingston & Co. Access and Demand Data Used in the Development and Calibration of the Northeast Corridor Transportation Models.

[2] Variations in Travel Forecasts, op. cit.

Access Cost

Access costs for all modes were revised to reflect the increase in the consumer price index of gasoline, both regular and premium, and the decrease in average miles traveled per gallon of fuel consumed.[1] These 1974 costs were deflated to 1973 dollars by using the consumer price index for the Northeast Region.

Line Haul Impedances

Line haul impedances were developed as noted below either from the 1971 data[2] or from more recent information when major changes in service occurred.

Line Haul Times

It was assumed that air travel times have not changed significantly since 1971. Bus travel times were increased by 9 percent to reflect the 55-mph speed limit which was in effect during the first half of 1974. Nine percent was derived from both FHWA statistics and changes in bus run times between 1970 and 1974, as shown in Russell's Official National Motor Coach Guide.

Rail travel times were derived from schedules that were in effect during the first quarter of 1974. An average time was developed by weighting metroliner and conventional train times by the number of each type of train between each city pair.

Auto travel times were left at the 1971 values because the 55-mph speed limit did not appear to be enforced or at least adhered to for a long enough period of time to show a significant change in travel time.

Line Haul Costs

Costs for all modes are those which were in effect during the first quarter of 1974. These costs were then deflated to 1973 dollars for the analysis. Bus fares were obtained from the Interstate Commerce Commission; air fares were obtained from the Official Airline Guide (OAG); and rail fares were obtained from Amtrak and were based on a

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[1] Highway Statistics published annually by the Federal Highway Administration.

[2] Variations in Travel Forecasts, op. cit.

weighted average of the number of metroliner coach and conventional coach trains between each city pair. Auto costs are a combination of tolls, gasoline (at $0.60/gallon, estimated price during calibration period), and the cost of oil and tires.[1]

Frequencies

Air and bus frequencies were updated to the summer of 1974 using the OAG and Russell's Official National Motor Coach Guide, respectively. Rail frequencies were obtained from Amtrak and are those which were in effect during January 1974.

MODAL IMPEDANCES FOR PROJECTION PURPOSES

The modal impedances used in the base projections are described below. The alternatives discussed in the next section which involve varying impedances are described in terms of variations from these base values.

Access Times and Costs

The same access times and costs for all modes used for calibration purposes were used for projection purposes.

Line Haul Times

Auto, bus, and air travel times were the same as those used for calibration purposes. Rail travel times were determined using preliminary unpublished data from ONECD engineering consultants. They assume a run time of 2 1/2 hours between Washington and New York, 3 hours between New York and Boston, and 1 hour between New York and Philadelphia. Run times for other city pairs were interpolated using the ratio of present scheduled run times to proposed run times and applying the ratio to station stops for the given city pair segments. At the time these projections were prepared, proposed intermediate station running times were not available from the engineering consultants.

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[1] Cost of Operating an Automobile. Federal Highway Administration. April 1972.

Line Haul Cost

As in the calibration data set, all fares were deflated to 1973 dollars. The bus fares obtained from ICC were those in effect during the summer of 1974, and air fares from the OAG were in effect during the fall of 1974. Rail fares were calculated at $1.50 + 0.075/mile in 1973 dollars and, thus, were not deflated. Auto costs were developed in the same way as for calibration purposes, except gasoline was specified by Transportation Systems Center to be $0.55/gallon.

Frequencies

Air and bus frequencies were the same as those used for calibration purposes. Rail frequencies were based on estimates by ONECD of two trains every hour between major cities[1] and one train per hour between a major city and a minor city. It was assumed that service between two minor cities would be approximately one train every two hours.

DEMOGRAPHIC AND ECONOMIC PROJECTIONS

Three sources of population and income projections were reviewed for demand analysis purposes. These are:

- 1972 OBERS Projections - Economic Activity in the U.S., by U.S. Water Resources Council, Washington, D.C., and Bureau of Economic Analysis (BEA), Department of Commerce;

- Metropolitan Demographic Projections, 1960-1985, National Planning Association (NPA) Regional Economic Projection Series, 1974; and

- Travel Demand Forecast, Robert Winestone, Office of the Secretary, U.S. Department of Transportation.

All three sources base their population projections on the Bureau of Census' Series "E" population projections which assume 2.10 births per female. It should be noted that recently there has been a lower rate of births per female. It is not known what impact a continuation

[1] Major cities are defined as: Washington, Baltimore, Philadelphia, New York, New Haven, Providence, and Boston. All other cities being analyzed in this study are considered minor cities.

of this trend would have on travel demand over the next several decades. For base projection purposes, the OBERS Projections were used because, of the three projections, they are intermediate. While population projections for all three are similar, income projections are quite different. NPA's projections are viewed as optimistic and Winestone's as conservative.

Table III. 2, a comparison of per capita income, is a sample of the three viewpoints. Population and income projections were obtained for each metropolitan area. Tables III. 3 and III. 4 compare the population and income projections, respectively, of the three sources for selected metropolitan areas.

A constant annual growth rate was assumed during the 1970 to 1980 decade to adjust the projected population to 1974:

$$P_{1974} = P_{1970} \left(\frac{P_{1980}}{P_{1970}} \right)^{0.4}$$

where:

P = the metropolitan area population.

Population and income statements were interpolated similarly for forecast years, except for Winestone income data, where a linear interpolation was used. Numerous variations were tested to determine the sensitivity of demand to the projection assumptions. These variations and the basic projections are discussed in the next section.

TABLE III. 2

PER CAPITA INCOME
(1967 constant dollars)

YEAR	SOURCE		
	NPA	BEA - OBERS	Winestone (linear)
1970	3,476	3,476	3,156
1975	4,183	*	3,425
1980	5,077	4,700	3,694
1985	6,126	5,400	3,962
1990	*	6,100	4,231
2000	*	8,100	4,769
2020	*	13,200	5,844

* Projections not given for these years.

TABLE III. 3

POPULATION FORECASTS FOR SELECTED METROPOLITAN AREAS* (000)

SMSA	YEAR									
	1970		1980		1985		1990		2000	2020
Boston										
BEA	3,715.0	(1.02)	4,113.2	(1.05)	4,334.5	(1.05)	4,567.6	(.90)	4,995.5	5,819.1
NPA	2,910.5	(.89)	3,180.5	(1.19)	3,374.1					
Winestone	3,709.2	(.67)	3,966.1	(.64)	4,094.6	(.62)	4,223.0	(.59)	4,479.9	
Providence										
BEA	770.8	(.77)	832.2	(.68)	861.0	(.68)	890.7	(.60)	945.5	1,046.6
NPA	910.2	(.80)	985.8	(.84)	1,027.8					
Winestone	768.0	(1.04)	851.6	(.97)	893.7	(.93)	935.9	(.86)	1,019.4	
New London										
BEA	231.2	(.66)	247.0	(.92)	258.6	(.93)	270.8	(.73)	291.3	335.1
NPA	244.3	(1.48)	283.1	(1.43)	303.9					
Winestone	230.4	(1.26)	261.1	(1.15)	276.4	(1.09)	291.8	(1.00)	322.4	
New York										
BEA	11,587.6	(.56)	12,258.2	(.84)	12,781.1	(.84)	13,326.2	(.72)	4,323.2	16,202.3
NPA	12,540.5	(.51)	13,195.9	(.70)	13,666.7					
Winestone	11,580.0	(.71)	12,430.8	(.68)	12,856.2	(.65)	13,281.7	(.62)	4,132.6	
Philadelphia										
BEA	4,853.2	(.84)	5,277.8	(.73)	5,474.5	(.73)	5,678.5	(.58)	6,015.8	6,670.2
NPA	4,835.8	(.53)	5,098.2	(.62)	5,258.2					
Winestone	4,823.8	(.33)	4,985.3	(.32)	5,065.9	(.32)	5,146.9	(.31)	5,308.4	
Washington, D. C.										
BEA	2,865.9	(1.94)	3,474.3	(2.35)	3,902.3	(2.35)	4,383.1	(1.70)	5,189.6	6,894.1
NPA	2,918.5	(2.63)	3,785.0	(2.40)	4,260.7					
Winestone	2,857.8	(1.22)	3,225.0	(1.11)	3,408.7	(1.05)	3,591.9	(.98)	3,959.0	

* Numbers in parentheses indicate annual growth rate in percent between years.

TABLE III. 4

PER CAPITA INCOME FORECASTS FOR SELECTED METROPOLITAN AREAS*
(1967 constant dollars)

SMSA	YEAR					
	1970	1980	1985	1990	2000	2020
Boston						
BEA	4,050	(3.11) 5,500	(2.42) 6,200	(2.46) 7,000	9,200	14,500
NPA	3,839	(3.70) 5,519	(3.71) 6,622			
Winestone†	3,181	(1.93) 3,850	(1.68) 4,184	(1.55) 4,519	5,188	
Providence						
BEA	3,513	(3.38) 4,900	(2.34) 5,500	(2.75) 6,300	8,300	13,300
NPA	3,463	(4.39) 5,320	(4.04) 6,486			
Winestone†	2,938	(1.80) 3,511	(1.58) 3,797	(1.47) 4,084	4,657	
New London						
BEA	3,538	(3.10) 4,800	(2.76) 5,500	(2.42) 6,200	8,200	13,300
NPA	4,258	(3.51) 6.013	(3.81) 7,250			
Winestone†	3,582	(1.76) 4,266	(1.55) 4,608	(1.45) 4,951	5,635	
New York						
BEA	4,722	(2,93) 6,300	(2.42) 7,100	(2.16) 7,900	10,200	15,500
NPA	4,182	(4.18) 6,296	(4.01) 7,662			
Winestone†	3,502	(1.83) 4,198	(1,61) 4,547	(1.49) 4,895	5,592	
Philadelphia						
BEA	3,798	(2.99) 5,100	(2.61) 5,800	(2.31) 6,500	8,600	13,900
NPA	3,595	(3.94) 5,291	(3.77) 6,365			
Winestone†	2,985	(1.78) 3,560	(1.56) 3,847	(1.44) 4,133	4,707	
Washington, D. C.						
BEA	4,392	(2.82) 5,800	(2.31) 6,500	(2.35) 7,300	9,500	15,000
NPA	3,884	(3.96) 5,729	(3.42) 6,779			
Winestone†	3,157	(1.92) 3,818	(1.68) 4,149	(1.55) 4,480	5,142	

* Numbers in parentheses indicate annual growth rates in percent between years.

† Winestone figures are in 1970 dollars disposable per capita income.

IV. RESULTS

The analysis focused on two major base cases which could be in effect in 1982:

- rail service (as well as all other modes) could remain unchanged, i.e., existing service as of March 1974; and
- the Northeast Corridor Development Program is implemented while other modes remain unchanged.

For the first base case rail impedances were the same as for calibration. The improvements to rail travel time, frequency, and fares used for the second base case are described in Section III. Combinations of the following sets of attributes were examined for each alternative:

- simultaneous increased costs for auto and air;
- simultaneous increased travel time for auto and bus;
- decreased fares for rail; and
- increased travel time for rail.

An exponential growth rate of the Bureau of Economic Analysis population location and income projections was used as the basic condition in scenarios for both alternatives with the exception of four cases which examined alternative or adjusted populaton and income growth rates. Table IV. 1 describes all of the final alternatives tested in this task and lists them in chronological order of their analysis.

1974 RAIL SERVICE LEVELS

Six analyses of the first alternative, which assumed that the existing conditions would continue for all modes, were conducted and are summarized in Table IV. 2.

Scenario 1 assumed no changes in attributes for any mode, which resulted in an increase of 3. 3 million rail passengers by 1982 due to the growth in the total market; rail volume in 1974 was 9. 1 million.

Scenario 2 assumed continuing energy shortages and corresponding increases in the price of fuel. The increased cost of fuel would divert

TABLE IV. 1

NORTHEAST CORRIDOR PATRONAGE ANALYSIS

DATE	POPULATION AND INCOME GROWTH *	RAIL PATRONAGE (000)		RAIL REVENUE (000, 000)		ASSUMPTIONS				TYPE OF SUMMARY	OUTPUT DETAIL	YEARS@
		1982	1990	1982	1990	COST PARAMETERS	TIME PARAMETERS	OTHER PARAMETRIC CHANGES IN RAIL	BASE VOLUME			
2/20/75	BEA/Exp	17,229	22,808	195	261	All Factors x 1.0	All Factors x 1.0		9,142	X	X	1982-2015 1982-1990
2/20/75	BEA/Exp	23,351	30,925	259	347	Auto x 1.42; Air x 1.10	Auto x 1.10; Bus x 1.10		9,142	X		1982-2015
2/20/75	Winestone Income/Lin BEA Pop./Exp.	20,984	24,944	232	276	Auto x 1.42; Air x 1.10	Auto x 1.10; Bus x 1.10		9,142	X		1982-2015
2/21/75	BEA/Exp	12,426		102		All Factors x 1.0	All Factors x 1.0	Existing 1974 Impedances	9,142	X	X	1974-1982
2/21/75	Winestone Income/Lin BEA Pop./Exp.	11,142		91		All Factors x 1.0	All Factors x 1.0		9,142	X		1974-1982
3/3/75	BEA/Exp	17,705	23,455	143	191	Auto x 1.42; Air x 1.10	Auto x 1.10; Bus x 1.10	Existing 1974 Impedances	9,142	X	X	1982-2015 1990
3/13/75	BEA Income Growth of 1 Percent	14,883		169		All Factors x 1.0	All Factors x 1.0		9,142	X		1982
3/13/75	BEA Income Growth of 2 Percent	16,131		183		All Factors x 1.0	All Factors x 1.0		9,142 9,142	X X		1982 1982-1990
3/10/75	BEA/Exp	18,285	24,217	187	251	Rail x .90; Rest x 1.0			9,142	X		1982-1990
3/10/75	BEA/Exp	19,513	25,855	178	239	Rail x .80; Rest x 1.0			9,142	X		1982-1990
3/10/75	BEA/Exp	20,957	27,783	168	226	Rail x .70; Rest x 1.0			9,142	X		1982-1990
3/10/75	BEA/Exp	22,677	30,082	157	210	Rail x .60; Rest x 1.0			9,142	X		1982-1990
3/10/75	BEA/Exp	15,932	21,074	179	239	All Factors x 1.0	Rail x 1.10		9,142	X		1982-1990
3/10/75	BEA/Exp	14,762	19,512	164	218	All Factors x 1.0	Rail x 1.20		9,142	X		1982-1990
3/10/75	BEA/Exp	13,707	18,104	150	201	All Factors x 1.0	Rail x 1.30		9,142	X		1982-1990
3/10/75	BEA/Exp	12,753	16,834	139	185	All Factors x 1.0	Rail x 1.40		9,142	X		1982-1990
3/10/75	BEA/Exp	16,860	22,306	151	202	Rail x .80; Rest x 1.0	Rail x 1.20		9,142	X		1982-1990
4/2/75	BEA/Exp	13,290	17,604	99	132	Rail x .90; Rest x 1.0		Existing 1974 Impedances	9,142	X		1982-1990
4/2/75	BEA/Exp	14,295	18,946	95	127	Rail x .80; Rest x 1.0		Existing 1974 Impedances	9,142	X		1982-1990
4/2/75	BEA/Exp	15,478	20,527	90	121	Rail x .70; Rest x 1.0		Existing 1974 Impedances	9,142	X		1982-1990
4/2/75	BEA/Exp	16,888	22,415	85	114	Rail x .60; Rest x 1.0		Existing 1974 Impedances	9,142	X		1982 -1990
4/7/75	BEA/Exp	15,374		171		All Factors x 1.0			9,142	X		1982
4/7/75	BEA/Exp		28,003		309	Auto x 1.42; Air x 1.0	Auto x 1.10; Bus x 1.10	Increased Rail Forecast: NY-DC; 2hr. 50 min.	9,142	X		1990
4/24/75	BEA/Exp		33,770		376	Auto x 1.67; Air x 1.16	Auto x 1.10; Bus x 1.10	NY-Boston; 3hr. 30 min.	9,142	X		1990

* The following abbreviations are used in this table:

BEA - Bureau of Economic Analysis Income and population forecasts;
Winestone - Winestone income and population forecasts;
EXP - Exponential method of calculating growth rates;
LIN - Linear method of calculating growth rates; and
POP - Population.

\# Type of output is either a link summary or a city-pair detail; x indicates which type of output was run.

@ Years - Year of output data.

TABLE IV. 2

CONVENTIONAL RAIL SCENARIOS TESTED*

Scenario Number	Cost Parameters	Time Parameters	Rail Patronage (000)	
			1982	1990
1	Same as base assumptions	Same as base assumptions	12,426	--
2	Auto x 1.42; Air x 1.10	Auto x 1.10; Bus x 1.10	17,705	23,455
3	Rail x .90		13,290	17,604
4	Rail x .80		14,295	18,964
5	Rail x .70		15,478	20,527
6	Rail x .60		16,888	22,415

*The exponential method of calculating growth rates was applied to the Bureau of Economic Analysis' population and income forecasts for all six scenarios.

travelers from auto and short-haul air to other modes, especially rail. An increase in the line-haul times for auto and bus due to slower speeds on intercity highways was a related assumption. Without any improvements to rail service but with a continuing increase in energy cost, rail patronage was projected to increase by an additional 5 million over Scenario 1 by 1982.

Scenarios 3 through 6 examine the effect of decreases in the present rail fares while all other services remain constant. The effects range from an increase of less than a million passengers over Scenario 1, with a 10-percent reduction in fare, to an increase of 4.4 million, with a 40-percent reduction in fare.

IMPROVED RAIL SERVICE

Fifteen analyses of the second alternative, which assumed an improvement in rail service while other modes remain unchanged, were conducted and are summarized in Table IV.3.

Scenario 1 in Table IV.3 projects that if all attributes remain constant except for the initial improvements to rail, there would be an increase of 8.1 million rail passengers by 1982 and an additional 5.6 million by 1990.

Future rail patronage, using the attributes in Scenario 3 came closest to matching the estimates made by the Federal Railroad Administration of 30.0 passengers in 1990. Again, this scenario projects an increase in energy costs and a continuation of slower highway speeds.

A combination of BEA's exponential population growth rates and Winestone's linear income growth rates is so conservative an outlook that the rail volume of 11.1 million in 1982 is 1.3 million passengers less than the results obtained if all modal services, including rail, remain unchanged from their existing conditions.

Scenarios 7 through 10 were examinations of varying rail fare levels. With every 10-percent reduction in fare is an incremental increase in volume. At the same time, however, revenues continue to decrease, from 187 million dollars with a 10-percent fare reduction to 157 million dollars with a 40-percent fare reduction in 1982. The initial fare in all these cases $1.50 + $0.075 per mile.

Scenarios 11 through 14 examined the effects of increased rail travel time, assuming that all other modal attributes remained the

TABLE IV. 3

IMPROVED RAIL SERVICE SCENARIOS TESTED*

Scenario Number	Cost Parameters	Time Parameters	Rail Patronage (000)	
			1982	1990
1	Same as base assumptions	Same as base assumptions	17,229	22,808
2	Same as base assumptions	Same as base assumptions	11,142	---
3	Auto x 1.42; Air x 1.10	Auto x 1.10; Bus x 1.10	23,351	30,925
4	Auto x 1.42; Air x 1.10	Auto x 1.10; Bus x 1.10	20,984	24,944
5	Same as base assumptions	Same as base assumptions	14,883	---
6	Same as base assumptions	Same as base assumptions	16,131	---
7	Rail x .90	Same as base assumptions	18,285	24,217
8	Rail x .80	Same as base assumptions	19,513	25,855
9	Rail x .70	Same as base assumptions	20,957	27,783
10	Rail x .60	Same as base assumptions	22,677	30,082
11	Same as base assumptions	Rail x 1.10	15,932	21,074
12	Same as base assumptions	Rail x 1.20	14,762	19,512
13	Same as base assumptions	Rail x 1.30	13,707	18,104
14	Same as base assumptions	Rail x 1.40	12,753	16,834
15	Rail x .80	Rail x 1.20	16,860	22,306

*The exponential method of calculating growth rates was applied to the Bureau of Economic Analysis' population and income forecasts for all scenarios except:

- Scenarios 2 and 4 which assume a linear growth rate applied to Winestone's income forecasts and exponential growth rate applied to BEA population forecasts;
- Scenario 5 which assumes a BEA income growth of 1%; and
- Scenario 6 which assumes a BEA income growth of 2%.

same. The results show an approximate reduction in rail patronage of one million with each 10-percent increase in travel time in 1982.

If rail fares were reduced by 20 percent and travel time were increased by 20 percent, the 1982 patronage would be 16.9 million. This is approximately midway between the 20-percent reduction in fare and 20-percent increase in travel time and indicates an approximate equal weight to the two alternatives.

Scenario 3 of the Improved Rail Service Case matched closely the projections prepared by FRA. Because it presented a realistic future, Scenario 3 was chosen as the basic projection for most additional analyses. Table IV.4 shows the detailed modal shares for selected city pairs and for the total corridor (i.e., those city pairs analyzed). It should be noted that those city pairs analyzed constitute perhaps half of all intercity trips within the full Northeast Corridor geographic area.

TABLE IV. 4

MODAL SHARES FOR SELECTED CITY-PAIRS

City-Pair	FRA Alternative Patronage (thousands)		Modal Share (percent)			
	Total	Rail	Auto	Bus	Air	Rail
Washington-Boston						
1974	803.1	21.5	23.9	1.2	72.2	2.7
1982	1,196.1	106.9	23.2	1.2	66.8	8.9
1990	1,760.4	187.3	15.2	1.3	72.9	10.6
Washington-New York						
1974	6,065.0	985.2	45.4	8.8	29.6	16.2
1982	8,772.0	1,864.2	44.4	8.3	26.0	21.3
1990	12,625.7	3,361.6	33.4	10.3	29.7	26.6
Washington-Philadelphia						
1974	3,367.1	616.1	72.1	4.1	5.5	18.3
1982	4,935.2	1,034.9	70.0	4.0	5.0	21.0
1990	7,096.1	2,168.4	57.3	5.7	6.4	30.6
New York-Philadelphia						
1974	13,200.4	3,107.3	73.3	2.6	0.6	23.5
1982	17,479.8	4,894.3	69.2	2.4	0.4	28.0
1990	22,293.0	8,356.5	58.5	3.4	0.6	37.5
Bridgeport-Boston						
1974	429.9	52.8	79.9	1.5	6.3	12.3
1982	596.2	402.8	29.9	0.6	1.9	67.6
1990	796.3	628.3	18.4	0.7	2.0	78.9
Total Corridor*						
1974	71,256.0	9,141.0	75.5	3.8	7.9	12.8
1982	97,665.0	17,228.0	72.4	3.6	6.4	17.6
1990	130,632.0	30,924.0	63.4	5.2	7.8	23.7

*City pairs which can be served by CorridorRail.

V. DETAILED ANNUAL AND STATION LOADING FORECASTS

To convert demand projections to passenger counts usable in station design, Peat, Marwick, Mitchell & Co. was requested first to develop a scenario to replicate the Federal Railroad Administration's estimated total travel for each year and then to distribute these volumes among the stations. In this analysis of the Northeast Corridor, the model used by PMM&Co. was the only model currently used by ONECD which can project demand for all city pairs of interest. Like other models, the PMM&Co. model is a steady state model. That is, it projects travel patterns, after travelers have fully adjusted to changes in service. For an essentially new service, such as the one being analyzed, this adjustment may take several years. While FRA's annual projections recognize this lag in traveler response, it is necessary to simulate this response in the model rather than model it directly. This section describes this simulation process and the assumptions which were used to develop peaking factor estimates for high day and peak hour volumes for each station in the proposed service.

RECONCILIATION WITH FRA PROJECTIONS

The PMM&Co. demand projections were prepared primarily for steady state 1990 conditions. The conditions in 1990 which most closely approximate the 30-million patron projection for CorridorRail prepared by FRA are:

- a 40-percent increase in real (constant dollar) energy cost component of driving and flying over 1974 cost; and
- a strictly enforced 55-mph highway speed limit or an increase in traffic congestion which would result in a 10-percent increase in highway travel times over mid-1974 times.

To replicate the gradual buildup in travel from 1982 (when new service would first be introduced) to 1987 (when it is estimated that travel patterns would essentially stabilize), it was necessary to artificially adjust the anticipated energy cost and highway trip times.

Table V.1 shows the assumptions used in developing travel impedances to reconcile the demand model projections with the FRA forecasts. The 1982 analysis shows that under steady state conditions, the

TABLE V.1

IMPEDANCE ASSUMPTIONS USED TO DEVELOP

FRA COMPATIBLE DEMAND

Year	Assumptions Relative to 1974 (percent increase)		Demand (millions of annual trips)	
	Energy Cost	Auto, Bus Time	FRA	Estimated
1982	Same as 1974	Same as 1974	17.0	17.2
1983	3	10	20.1	20.1
1984	15	10	22.2	22.1
1985	30	10	24.2	24.3
1986	40	10	26.1	27.4
1987	45	10	27.4	27.4
1988	45	10	28.4	28.4
1989	45	10	29.2	29.4
1990	40	10	30.0	29.9
1995	30	10	34.8	35.0
2000	21	10	40.3	40.3
2005	19	10	46.7	46.7
2010	17	10	54.2	54.2
2015	15	10	62.8	62.8

FRA demand estimate of 17 million passengers could be exceeded slightly if 1974 energy costs and highway travel times were in affect. Since energy costs are already higher than in 1974 and are likely to be still higher by 1982 (in real dollars), the FRA number seems reasonable, considering the time lag in traveler response to new services. For 1983, highway travel times were arbitrarily increased 10 percent and energy cost 3 percent to replicate the FRA projection. From 1984 to 1987 real energy costs were assumed to increase at up to 12 percent per year. During the period from 1987 to 1989, the FRA projection would appear to have reached steady state, with rail travel increasing just as fast as total travel.

After 1989, the FRA projection of rail travel grows at a slower rate than the model projection of travel for all modes. This implies that the rail share of total travel would gradually drop from 1990 on. To replicate the gradual drop in rail share, real energy costs were assumed to decrease slightly. In fact, this is not likely. It might be more reasonable to assume that the BEA income projections that were used to estimate growth in total travel are overly optimistic; and that energy cost and the rail share of total travel might stabilize around 1990. Thus, the 3-percent growth in rail travel after 1990 does not appear overly optimistic even in light of a lower growth rate in the real per capita income than the BEA projections. Real per capita income would only have to rise at about 2 percent per year to bring about the FRA projected growth.

ESTIMATION OF STATION LOADINGS

Station loadings (total passengers boarding and alighting from trains at a station) have been tabulated in Tables V. 2 through V. 5 for the years 1974, 1982, 1990, and 2015 based on FRA projection totals. The high day is the design day used by Bechtel in their analysis,[1] which was defined as: 0. 38x annual. As such, it represents a higher than average day, probably a typical Friday. The peak day (see the analysis in Appendix B) might be as much as twice the volume of the high day, depending upon the type of service offered. If a no-reservation service were offered, peaks would likely be higher than if reservations were required. Stations listed in the tables are those included in initial studies undertaken by FRA.

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[1]Bechtel, Inc. Northeast Corridor High-Speed Rail Passenger Service Improvement Project: Task 1 - Demand Analysis. Federal Rail Administration, U. S. Department of Transportation. April 1975.

TABLE V.2

PASSENGER ON-OFF VOLUMES AT NORTHEAST CORRIDOR STATIONS

ESTIMATED FOR 1974

City	Number of Passengers On-Off			Station	Alternate Station Splits							
					Low Suburban				High Suburban			
	Annual	High Day	Peak Hour		Percent Split	Annual	High Day	Peak Hour	Percent Split	Annual	High Day	Peak Hour
Washington, D.C.	1,949,563	7,221	1,083	Union	85	1,657,129	6,138	921	70	1,364,694	5,054	758
				Beltway	15	292,434	1,083	162	30	584,869	2,167	325
Baltimore	894,352	3,312	497									
Wilmington	513,332	1,901	285									
Philadelphia	4,159,712	15,406	2,311									
Trenton	1,406,968	5,211	782									
N.E. New Jersey	754,825	2,796	419	Metropark	10	75,482	280	42	20	150,965	559	84
				Newark	90	679,343	2,516	377	80	603,860	2,237	335
New York City	6,383,119	23,641	3,546									
Stamford	233,371	864	130									
New Haven	436,744	1,618	243									
New London	253,135	938	141									
Providence	365,692	1,354	203									
Boston	933,121	3,456	518	South Station	85	793,153	2,938	441	70	653,185	2,419	363
				Route 128	15	139,968	518	77	30	279,936	1,037	155

TABLE V.3

PASSENGER ON-OFF VOLUMES AT NORTHEAST CORRIDOR STATIONS

ESTIMATED FOR 1982

City	Number of Passengers On-Off			Station	Alternate Station Splits							
					Low Suburban				High Suburban			
	Annual	High Day	Peak Hour		Percent Split	Annual	High Day	Peak Hour	Percent Split	Annual	High Day	Peak Hour
Washington, D. C.	3,783,334	14,012	2,102	Union Beltway	85 15	3,215,834 567,500	11,910 2,102	1,787 315	70 30	2,648,334 1,135,000	9,809 4,203	1,471 631
Baltimore	1,483,971	5,496	824									
Wilmington	741,276	2,745	412									
Philadelphia	6,755,620	25,021	3,753									
Trenton	2,070,929	7,670	1,151									
N.E. New Jersey	1,443,972	5,348	802	Metropark Newark	10 90	144,397 1,299,575	535 4,813	80 722	20 80	288,794 1,155,178	1,070 4,278	160 642
New York City	11,072,359	41,009	6,151									
Stamford	1,186,473	4,396	659									
New Haven	1,114,579	4,128	619									
New London	582,050	2,156	323									
Providence	1,108,603	4,106	616									
Boston	3,128,274	11,586	1,738	South Station Route 128	85 15	2,659,033 469,241	9,848 1,738	1,477 261	70 30	2,189,792 938,482	8,110 3,476	1,217 412

TABLE V.4

PASSENGER ON-OFF VOLUMES AT NORTHEAST CORRIDOR STATIONS ESTIMATED FOR 1990

City	Number of Passengers On-Off			Station	Alternate Station Splits							
					Low Suburban				High Suburban			
	Annual	High Day	Peak Hour		Percent Split	Annual	High Day	Peak Hour	Percent Split	Annual	High Day	Peak Hour
Washington, D. C.	7,156,935	26,507	3,976	Union Beltway	85 15	6,083,395 1,073,540	22,531 3,976	3,380 596	70 30	5,009,855 2,147,080	18,555 7,952	2,783 1,193
Baltimore	2,790,073	10,334	1,550									
Wilmington	1,423,909	5,274	791									
Philadelphia	11,742,831	43,492	6,524									
Trenton	3,419,549	12,665	1,900									
N. E. New Jersey	2,838,915	10,515	1,577	Metropark Newark	10 90	283,891 2,555,024	1,051 9,463	158 1,419	20 80	567,783 2,271,132	2,103 8,412	315 1,262
New York City	17,908,031	66,326	9,949									
Stamford	2,020,328	7,483	1,122									
New Haven	2,009,898	7,444	1,117									
New London	1,095,037	4,056	608									
Providence	2,017,048	7,471	1,120									
Boston	5,374,638	19,906	2,986	South Station Route 128	85 15	4,568,442 806,196	16,920 2,986	2,538 448	70 30	3,762,247 1,612,391	13,934 5,972	2,090 896

TABLE V.5

PASSENGER ON-OFF VOLUMES AT NORTHEAST CORRIDOR STATIONS ESTIMATED FOR 2010

City	Number of Passengers On-Off			Station	Alternate Station Splits							
					Low Suburban				High Suburban			
	Annual	High Day	Peak Hour		Percent Split	Annual	High Day	Peak Hour	Percent Split	Annual	High Day	Peak Hour
Washington, D.C.	14,735,763	54,577	8,187	Union Beltway	85 15	12,525,399 2,210,364	46,390 8,187	6,959 1,228	70 30	10,315,034 4,420,729	38,204 16,373	5,731 2,456
Baltimore	4,748,822	17,588	2,638									
Wilmington	2,573,228	9,530	1,430									
Philadelphia	20,535,231	76,056	11,408									
Trenton	6,377,508	23,620	3,543									
N.E. New Jersey	5,057,819	18,733	2,810	Metropark Newark	10 90	505,782 4,552,037	1,874 16,859	281 2,529	20 80	1,011,564 4,046,255	3,747 14,986	562 2,248
New York City	32,067,296	118,768	17,815									
Stamford	2,796,101	10,356	1,553									
New Haven	3,470,353	12,853	1,928									
New London	1,866,217	6,912	1,037									
Providence	3,482,537	12,898	1,935									
Boston	9,679,329	35,849	5,377	South Station Route 128	85 15	8,227,430 1,451,899	30,472 5,377	4,571 806	70 30	6,775,530 2,903,799	25,095 10,754	3,764 1,613

Peak hour is defined in this analysis as 15 percent of the high-day volume. In fact, while 15 percent is a typical peak hour factor for average days, peak-day volumes tend to be somewhat more dispersed than more typical days, and an estimate of 10 percent of peak-day is appropriate. Thus, the estimate given here would be appropriate if peak-day traffic were twice average day ($365/270 \times .15 \approx 2 \times .10$). A significant imbalance could occur during a peak hour. Thus, the peak hour for boardings, the more space demanding operation at a station, should be estimated as 60 percent of the numbers given.

High and low estimates have been prepared for the traffic split betwen stations in metropolitan areas having more than one station. In Boston, which has two downtown stations and one at Route 128 current patronage percentages show about 18 percent using Route 128; in Washington, a relatively inaccessible and parking-constrained Capital Beltway draws about 15 percent; the Metropark share at the northeastern New Jersey traffic is between 10 and 20 percent.

VI. IMPACT ON PATRONAGE OF SELECTED ADDITIONAL STATIONS

The stations shown below were initially chosen by FRA as the primary focal points of service in the corridor. The number of stops of any one train, however, were limited to five intermediate stations between Boston and New York, and five between New York and Washington, in order to maintain the overall planned schedule. Major stations (i. e., those noted with an asterisk) would receive service from every train. The planned station stops are:

* Boston (South Station)
Route 128
* Providence
New London
* New Haven
Stamford
* New York (Penn Station)
Newark
Metropark
Trenton
* Philadelphia (30th Street Station)
Wilmington
* Baltimore
(Capital Beltway)
New Carrollton
* Washington

Since there are only five intermediate stations north of New York, every one would receive service from every train under the base case. Service would be rotated among the five secondary stations south of New York.

North of New York, the base service plan allows possibilities for expansion of service to more stations if the frequency of service to others is reduced. South of New York, the planned additional service between Philadelphia and New York would allow for more stops, particularly north of Philadelphia. In examining the locations of proposed station stops relative to population distribution, one notes that the two largest SMSA's in the corridor, New York and Philadelphia, have only one station each, and that they are particularly lacking nearby stations on the north sides of the metropolitan areas. For example, Trenton is 32 miles north of Philadelphia and relatively inaccessible by direct expressway route from the northern suburbs of Philadelphia; Stamford is 36 miles north of Penn Station, although somewhat more accessible to northern New York suburbs. Therefore, FRA decided to examine both the potential for additional service locations between 30th Street Station Philadelphia and Trenton, and the extent of service requirements in the entire area between New York and New Haven.

APPROACH TO ESTIMATING

Models

To conduct these tasks, PMM&Co. used a terminal accessibility model (UNIM)[1] that was developed for the Northeast Corridor Project, to revise access time estimates for input to the modal split model described in Section II. The access model develops estimates of average access impedance from an area to one or more terminals using general arterial travel speeds and specific expressway links. The basic system used in the model to represent areas consisted of districts (usually coded as counties) and subdistricts (geometric subareas of the districts). Trip generation rates were based on population density for the subdistricts. Access impedances were based upon analytical and empirical estimates of access characteristics from the small subdistricts to each terminal. District-level impedances were estimated by weighting subdistrict impedances according to their populations. Different levels of service to terminals can be represented by incorporating service frequencies in a terminal choice portion of the model. Detailed information on the operation of the model and input requirements are included in the above referenced reports.

Input Data

Both the Philadelphia area and the northern New York (the northern suburbs of New York City)/Fairfield County area had previously been coded for the access model. It was felt that the coding of the Philadelphia area was adequate for this study; however, the northern New York/Fairfield County areas needed to be coded at a finer level of detail, since the previous coding was focused primarily upon New York City. New population distribution curves and arterial speed curves were prepared for Westchester and Rockland Counties, and Fairfield County was divided into three separate districts focusing on Stamford, Bridgeport, and Danbury. New population distributions and speed curves were developed for each district.

[1] Peat, Marwick, Livingston & Co. Access Characteristics Estimation System: Vol. I and II. U. S. Department of Transportation Office of High-Speed Ground Transportation. December 1969.

ANALYSIS

Philadelphia Area

Access impedances were examined for all eight districts (counties) comprising the Philadelphia SMSA. Four potential sites of a new high-speed-rail-service station (Figure VI. 1) were examined for their impacts on access and, hence, on demand. The four potential terminal combinations and the districts that they would serve are:

Terminal Sites		Districts
Penn Central Station (30th St.)		Philadelphia, Pa.
and		Delaware Cty., Pa.
North Philadelphia, (existing) or	Serve	Chester Cty., Pa.
Bridesburg, or		Montgomery Cty., Pa.
Cornwells Heights - Andalusia, or		Bucks Cty., Pa.
Bristol		Glocester Cty., Pa.
		Burlington Cty., Pa.
		Camden Cty., Pa.

It was assumed that a new station would have about the same effective frequency (that which is most useful to the traveler) as Penn Central Station. Since it is suburban, it would be operated much as the Capital Beltway or Metropark stations are today. More trains would stop during the morning peak hours to carry passengers to downtown areas such as New York and Washington; during the evening hours, trains would return passengers from the downtown stations. Fewer stops would be made during the day. In this way, effective frequency is maintained at a high level, while actual frequency is somewhat lower. Thus, passengers generally have the option to travel to whichever station is closer. Further, passengers traveling north would save several additional minutes since northbound trains would stop at the new station after they stop at Penn Central Station. Southbound passengers using the new station would see an increase in line-haul travel time.

Specific sites were not chosen as part of this task since accessibility does not change rapidly as terminal locations are moved within an area. Wherever it was located the station was assumed to have relatively easy access from nearby expressways and arterials and no substantial parking problems which would increase impedances. (These were not major considerations at Penn Central Station, since it is relatively accessible from commuter lines and the Schuylkill Expressway. Most travelers use public transportation to reach this station.)

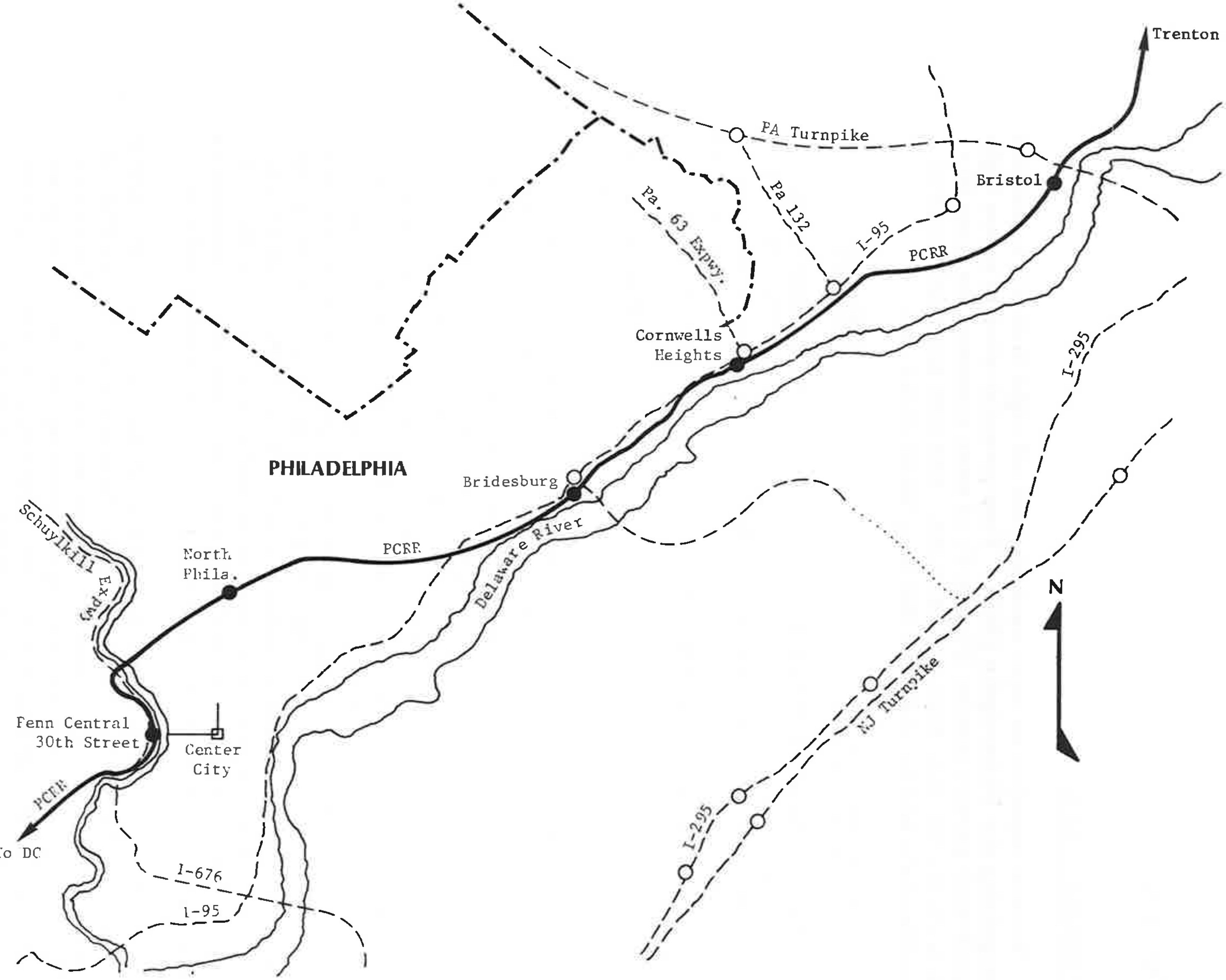


FIGURE VI-1: NORTHERN PHILADELPHIA - SUBURBAN TERMINAL LOCATIONS TESTED

Northern New York - Fairfield County

The accessibility of stations from five counties north of New York City, and the three districts of Fairfield County, were examined. Five existing sites in these two areas, plus Penn Station and New Haven, were tested. The study area is shown in Figure VI-2. The seven potential sites and the counties and districts that they would serve are:

Terminals		Districts
Penn Station		Westchester County
New Rochelle		Rockland County
Rye		Dutchers County
Stamford	Serve	Putnam County
Norwalk		Orange County
Bridgeport		Stamford district
New Haven		Bridgeport district
		Danbury district

The problems analyzed were the locations and the number of stations to be served. Since the base plan included Stamford and only four other stops, a potential for additional service in this area exists if service is reduced to Stamford, New London, and Route 128. At the service levels projected for the Northeast Corridor Service, demand from these cities is relatively insensitive and thus should not be significantly affected.

Two types of service were examined--simultaneous and competing. Simultaneous service is service where each train that serves the area stops at each station in the area. Competing service is where trains stop at alternate stations (i.e., one train stops at Station A, the next train at Station B, etc.). With simultaneous service, patrons were assumed to use the station closest to their true origin or destination. With competing service, patrons were distributed to stations based on the access time to the station and the level of service at the station, using the terminal choice portion of the model. Generally, districts were not assigned to terminals which would have patrons bypassing an intermediate terminal (i.e., Westchester patrons were not given the choice between Bridgeport and Stamford, if alternating service were offered. However, partrons might choose between Rye and Stamford if alternating service were being offered.)

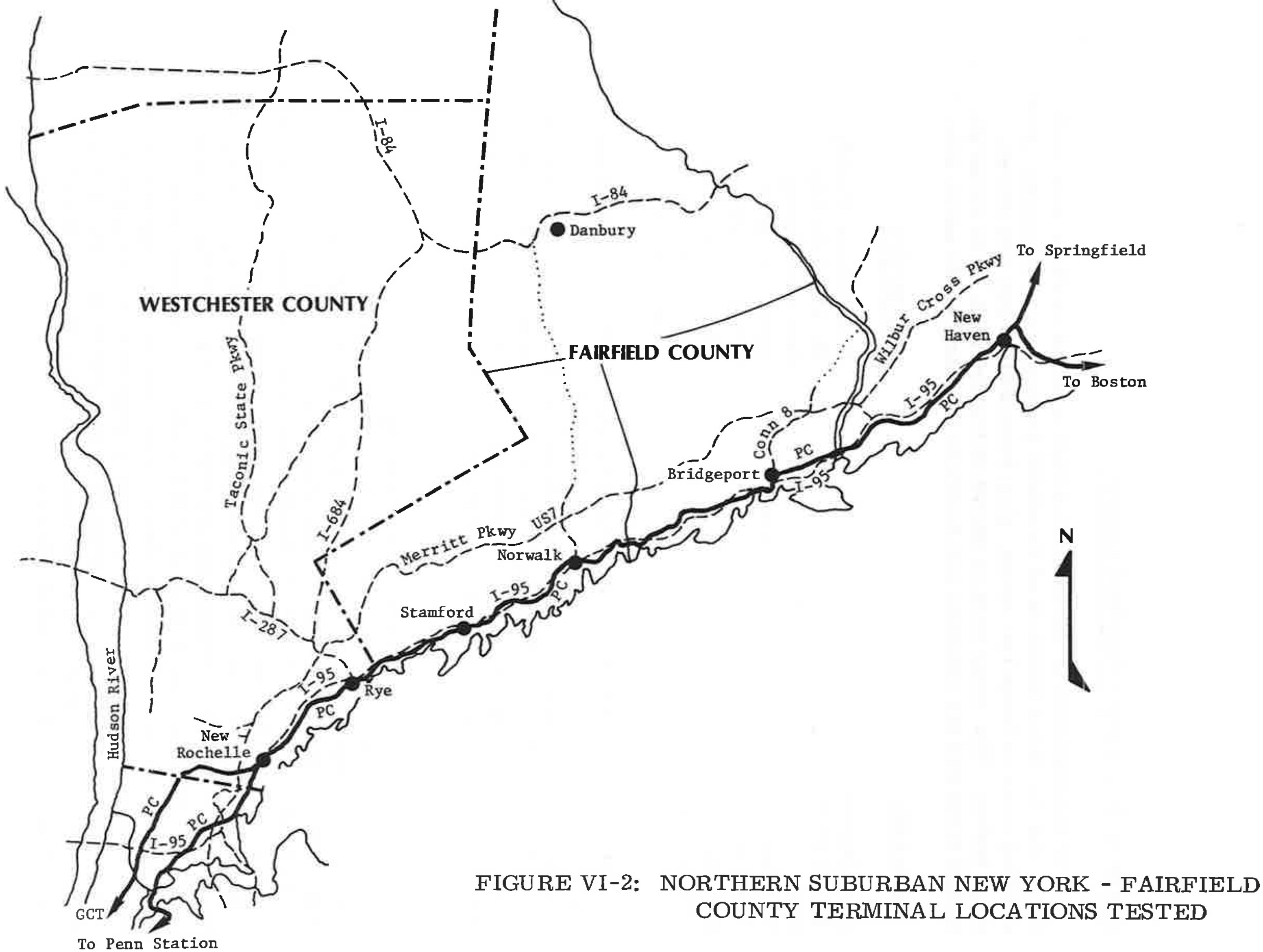


FIGURE VI-2: NORTHERN SUBURBAN NEW YORK - FAIRFIELD COUNTY TERMINAL LOCATIONS TESTED

RESULTS

Philadelphia Area

Table VI. 1 shows the average access time (including terminal time) for the five alternative station combinations tested and the overall impact on travel demand in the corridor. Cornwells Heights has slightly better accessibility than Bristol and Bridesburg and is a substantial improvement over North Philadelphia. It should be emphasized that the values obtained are overall times for the entire metropolitan area. Since only about 20 percent of the Philadelphia travelers would use Cornwells Heights, the savings are much more significant for those who do use it. Further, northbound travelers using Cornwells Heights would save about 10 minutes in line-haul time as well. Service to Cornwells Heights would increase total travel in 1990 from the Philadelphia area by rail from 11. 74 million annually to 12. 31 million (i. e., an increase of 570, 000 passengers a year). Station loadings, using the same assumptions as in Section V, are shown in Table VI. 2. As shown in the table, total revenue would increase about $9 million per year in 1990, with the addition of Cornwells Heights.

Northern Suburban New York/Fairfield County

Two problems were addressed in this area. First, what would be the impact of adding a station for the northern suburbs of New York? Second, how many stations should be served in the New York-New Haven area? Two sites were considered for a station that would serve northern New York, Rye, and New Rochelle. New Rochelle was generally less accessible to all areas of the five northern New York districts except extreme southern Westchester County. The operation of a station at Rye would result in substantial savings of access time compared to Penn Station or Stamford and an increase of travel in 1990 from northern New York from 1. 28 million passengers per year to 1. 57 million (i. e., an increase of 290, 000 passengers per year). Station loadings would change as shown in Table VI. 3. Total revenue would increase about $5 million per year by 1990, with the addition of Rye.

Table VI. 4 shows the average access time (including terminal time) by direction of travel for seven alternative station combinations examined for Fairfield County, and the overall impact on travel demand in the county. The access time was used in conjunction with line-haul times from the respective stations to determine the resulting passenger demand.

TABLE VI. 1

PHILADELPHIA METROPOLITAN
AREA AVERAGE ACCESS TIMES

Terminal	Average Access Time (minutes)	Total Corridor Demand (millions of passengers)
Penn Central Station Only	40.5	30.9
Penn Central and North Philadelphia	37.4	31.2
Penn Central and Bridesburg	37.0	31.2
Penn Central and Cornwells Heights	36.7	31.5
Penn Central and Bristol	37.0	31.4

TABLE VI. 2

CHANGES IN STATION LOADINGS FOR
PHILADELPHIA METROPOLITAN AREA
(thousands of passengers)

Station	Annual	High Day	Peak Hour
Penn Central (30th St. only)	11,739	43.5	6.5
Penn Central and Cornwells Heights			
Penn Central	9,874	36.6	5.5
Cornwells Heights	2,438	9.0	1.4
Total	12,312	45.6	6.9

TABLE VI. 3

CHANGES IN STATION LOADINGS
FOR NORTHERN NEW YORK
(thousands of passengers)

Station	Annual	High Day	Peak Hour
Penn Station only	17,908	66.3	9.9
Penn Station and Rye			
Rye	1,575	5.8	1.0
Penn Station	16,626	61.6	9.2
Total	18,201	67.4	10.2

TABLE VI. 4

FAIRFIELD COUNTY AVERAGE ACCESS TIMES

Terminal	Average Access Times (minutes)		Total Fairfield County Demand (thousands of passengers)
	Southbound	Northbound	
Penn Station - Stamford - New Haven (base case)	41.8	39.2	1,512
Penn Station - Rye - New Haven	51.4	54.2	1,504
Penn Station - Norwalk - New Haven	36.9	39.5	1,516
Penn Station - Bridgeport - New Haven	37.3	37.2	1,498
Penn Station - Rye - Norwalk - New Haven	40.3	39.5	1,520
Penn Station - Rye - Stamford - New Haven	41.8	39.2	1,514
Penn Station - Rye - Stamford - Bridgeport - New Haven	30.2	37.2	1,528

The addition of any two stations (which would include Rye as one stop) would result in a marginal increase in travel in Fairfield County. The best combination--New York, Rye, Norwalk, New Haven--would increase travel in Fairfield County in 1990 by 8,000 passengers per year, from 1,512 thousand to 1,520 thousand. The impact that Rye would have on total corridor travel is approximately the same whether the other station location is Stamford or Norwalk. In either case, the increase in total corridor travel in 1990 would be marginal. Station loadings for the two best alternatives with two stations is shown in Table VI. 5.

Although Bridgeport alone showed better average access times than Stamford for both southbound and northbound travel, the net effect on demand was a decrease in patronage. This is because while access times for travelers from the Bridgeport district to the Bridgeport station are better than access times from other districts to their respective stations, the numbers in Table VI. 4 do not reflect the greater line-haul time from Bridgeport for the more numerous southbound travelers.

Serving Fairfield County with only Bridgeport or Rye between New York and New Haven was least effective in attracting patronage from the County. Neither location is close enough to the center of the County to allow for good accessibility from all three districts.

CONCLUSIONS

Construction of a station in the vicinity of Cornwells Heights appears to be warranted under almost any circumstances by the potential incremental patronage and revenue. Full service at Rye in addition to Stamford would also be warranted. The incremental patronage does not appear to warrant service at a third station between New York and New Haven. Skip-stop alternating station service alternatives had higher effective (adjusted for frequency of service) access times than any alternative shown in Table VI. 4, and thus appears to be detrimental to the overall service level in this area. With one stop in addition to Rye, the analysis indicates little difference in patronage whether the station is at Stamford or Norwalk, and a definite loss of patronage if the additional station is at Bridgeport.

The analysis only examined the patronage impacts of operating additional stations and assumed that there would be no net degradation of existing service. If reasonable service (hourly) cannot be provided to the additional stations without some increase in running times on at least some trains, patronage should be revised downward slightly for

TABLE VI. 5

CHANGES IN STATION LOADINGS FOR FAIRFIELD COUNTY
(thousands of passengers)

Station	Annual	High Day	Peak Hour
Base Case			
Penn Station - New York	18,392	68.1	10.2
Stamford	1,665	6.2	1.0
New Haven	2,689	10.0	1.5
Total	22,746	84.3	12.7
Penn Station	17,680	65.5	9.8
Rye	1,806	6.7	1.0
Norwalk	730	2.7	0.4
New Haven	2,689	10.0	1.5
Total	22,905	84.9	12.7
Penn Station	17,680	65.5	9.8
Rye	1,617	6.0	0.9
Stamford	914	3.4	0.5
New Haven	2,689	10.0	1.5
Total	22,900	84.9	12.7

through travel. These analyses do not consider the cost of building or improving the station sites or operating the stations, or the incremental cost of operating (stopping and starting) trains at these stations. These costs should be at least partially offset by savings at the Penn Station and 30th Street Station, which are projected to have substantial volumes of travelers by 1990.

APPENDIX A

DEMAND MODEL DEVELOPMENT

RELATIONSHIP BETWEEN TOTAL TRAVEL AND METROPOLITAN AREA POPULATIONS

A relationship between population growth and travel growth between cities which fulfills several requirements not met by other formulations was developed. The growth rate of travel between two cities should be proportional to the growths of each city, all other factors being equal, since the total number of persons available to travel increases in proportion to the population. An additive form such as:

$$\frac{D_{abF}}{D_{abB}} = \frac{P_{aF} + P_{bF}}{P_{aB} + P_{bB}}$$

is satisfactory if both cities are about the same size. For example, if for cities a and b, for years 1 and 2:

$$P_{a_1} = P_{b_1} = 10, \text{ and}$$

$$P_{a_2} = P_{b_2} = 15, \text{ then}$$

$$\frac{D_{ab_2}}{D_{ab_1}} = \frac{P_{a_2} + P_{b_2}}{P_{a_1} + P_{b_1}} = \frac{15 + 15}{10 + 10} = 1.5$$

or, travel growth is equal to the population growth. An additive form, however, tends to emphasize the growth of the larger city, if the two cities are significantly different in size. If, for example, a very large city, a, does not grow, while a small city, b, doubles its population, a significant increase (although not necessarily a doubling) in travel between the two cities would be expected. The additive formulation, however, results in only a relatively small increase in travel:

$$P_{a_1} = P_{a_2} = 10, \text{ and}$$

$$P_{b_1} = 1, \; P_{b_2} = 2, \text{ then}$$

$$\frac{D_{ab_2}}{D_{ab_1}} = \frac{10 + 2}{10 + 1} \quad \frac{12}{11} = 1.09$$

A multiplicative formulation corrects one problem of the additive formulation but, if other factors are constant and total travel is proportional to total population, an unconstrained multiplicative function will tend to overestimate total travel growth. Using the previous example, if two cities of approximately equal size each double in population, then total travel between them could be expected to double, but with the multiplicative form:

$$P_{a_1} = P_{b_1} = 10. \text{ and}$$

$$P_{a_2} = P_{b_2} = 20, \text{ then}$$

$$\frac{D_{ab_2}}{D_{ab_1}} = \frac{P_{a_2} P_{b_2}}{P_{a_1} P_{b_1}} = \frac{20 \cdot 20}{10 \cdot 10} = 4$$

Some form of control total or normalization is required if a multiplicative function is used. The normalization factor used in this study was the national population growth rate. Thus, projected travel demand between cities a and b is proportional to the product of the population growths of the two cities divided by the national population growth, or:

$$\frac{D_{abF}}{D_{abB}} = \frac{P_{aF} P_{bF} P_{nB}}{P_{aB} P_{bB} P_{nF}}$$

For the above two cases, if both equal sized cities double their populations, and the national population also doubles, then

$$\frac{D_{ab_2}}{D_{ab_1}} = \frac{P_{a_2} P_{b_2} P_{n_1}}{P_{a_1} P_{b_1} P_{n_2}} = \frac{20 \cdot 20 \cdot 1}{10 \cdot 10 \cdot 2} = 2$$

For the two cities with significantly different population sizes, if national population doubles, then

$$\frac{D_{ab_2}}{D_{ab_1}} = \frac{P_{a_2} P_{b_2} P_{n_1}}{P_{a_1} P_{b_1} P_{n_2}} = \frac{10 \cdot 2 \cdot 1}{10 \cdot 1 \cdot 2} = 1$$

With this formulation, the growth between two cities is inversely proportional to the growth of all other cities. In this second example, city a becomes less attractive to travelers from city b as compared to other cities. If no national growth occurred, city b becomes more attractive and a relatively larger travel generator than other cities and:

$$\frac{D_{ab_2}}{D_{ab_1}} = \frac{10 \cdot 2 \cdot 1}{10 \cdot 1 \cdot 1} = 2$$

RELATIONSHIP BETWEEN PER CAPITA PASSENGER MILES OF TRAVEL AND PER CAPITA INCOME

The second factor in the equation to project total travel considers the relationship between per capita intercity passenger miles of travel and per capita personal incomes. A graph of historical national per capita intercity travel and per capita income in constant dollars is shown in Exhibit A.1. A least squares fit of the data yields the relationship:

$$Y = 1.77\ I - 203$$

where:

Y = per capita passenger miles of intercity travel; and

I = per capita personal income.

The coefficient of determination (R^2) for this equation is 0.97; the standard error of estimate is 226.

The correlation of these two variables appears quite strong. Much of the remaining variance may possibly be explained with a variable describing the state of the economy. Because of the difficulty in predicting the timing and severity of future cycles, no attempt was made to incorporate a business cycle variable in the forecasting model.

The passenger-mile travel growth factor, as related to income growth, was determined as

$$FI_F = \frac{1.77\ I_F - 203}{1.77\ I_B - 203}$$

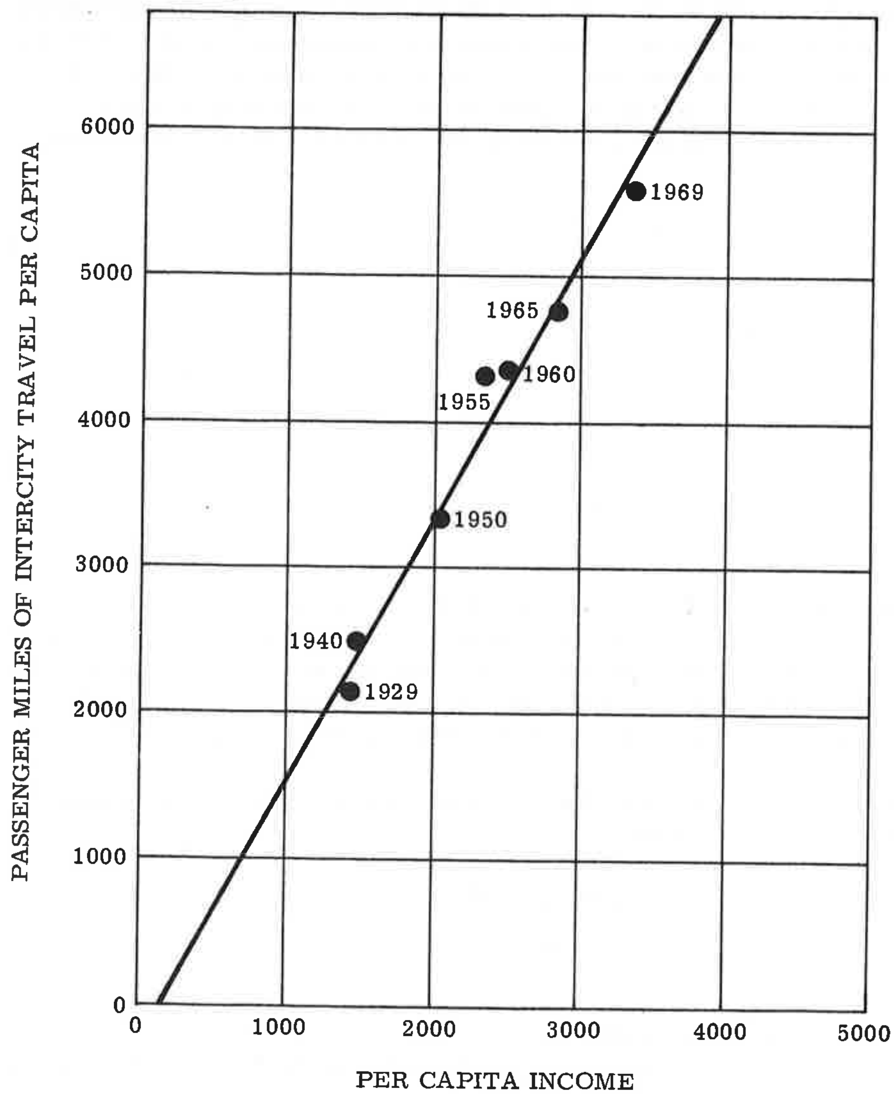
where:

I = per capita personal income; and
FI = per capita passenger-mile travel growth factor estimated for forecast year.

EXHIBIT A.1

PER CAPITA INCOME AND TRAVEL BY YEAR

Year	Per Capita Income (constant 1967$)	Per Capita Intercity Travel (miles)
1929	1,458	2,140
1940	1,483	2,500
1950	2,065	3,336
1955	2,350	4,320
1960	2,500	4,345
1965	2,820	4,750
1969	3,360	5,570



APPENDIX B

PEAKING CHARACTERISTICS AND TIME PATTERNS

As part of the financial analysis, fleet size was projected based on the peaking patterns of travel. Since diversion of travelers to rail might not follow the same patterns as existing rail travel, a stratification of total travel patterns was prepared from available survey data.

Based on the Northeast Corridor Intercity Travel Survey by A. M. Voorhees & Associates, Inc. for the Office of the Secretary of the Department of Transportation, daily and weekly peaking patterns were developed. Patterns were stratified by distance between cities (0 to 150 miles, 150 to 250 miles, 250 or more miles), purpose (business or nonbusiness), group size (one, two, three or more persons), and income level (low, medium, high). Yearly peaking patterns of rail volumes in the New York-Washington and New York-Boston corridors were developed and compared to peaking patterns on major Northeast Corridor expressways.

PEAKING CHARACTERISTICS

Figure B.1 compares typical peaking characteristics of several major Northeast Corridor expressways to peaking characteristics of rail travel in the New York-Washington and New York-Boston corridors. The horizontal axis represents the days of the year ordered by descending volumes, and the vertical axis represents the ratios of the volume of each day to that of the average day.

As is common throughout the corridor, traffic volumes on the urban facilities - Baltimore Harbor tunnel and the Garden State Highway - although heavier are less peaked than those on other facilities. Traffic peaks most on rural intercity routes. For example, a peak day on the Delaware Memorial Bridge is characterized by about 2.3 times as much traffic as that of the average day, while peak traffic on the JFK Highway (I-95) in Maryland is almost three times the average daily traffic). Semi-rural highways, such as the Wilbur Cross Parkway and the Connecticut Turnpike, have peaking characteristics which fall between those of the rural and urban facilities. In general, about 20 percent of all intercity travel occurs during the peak 10 percent of the days of the year.

Rail travel volumes between New York and Washington show slightly lower peaking characteristics than urban facilities (i.e., constantly near capacity traffic and suppressed demand). Rail volumes between New York and Boston have peaking patterns more like those of semirural highways (i.e., more pronounced peaking and lower volumes).

TIME PATTERNS

Variations in travel also occur within the days of the week and during the hours of the day. The Northeast Corridor Intercity Travel Survey also developed hourly and daily peaking patterns for all modes combined. Patterns were stratified by distance between two cities (0 to 150 miles, 150 to 250 miles, 250 or more miles), trip purpose (business, nonbusiness), group size (one, two, three or more persons) and income level (low, medium, high). Figures 2 through 13 illustrate peaking patterns within each distance group; business and nonbusiness trips were stratified either by group size or income level.

As expected, single-person business trips peak during midweek. (Wednesday is the peak day of travel.) Two- and three-person trips show similar patterns, with less pronounced peaking and far fewer trips (Figures B.2, B.6, and B.10). Nonbusiness trips tend to peak near the weekend, with larger group sizes having more significant impacts on travel patterns (Figures B.3, B.7, and B.11). Single-person business trips of less than 150 miles have their peak travel in the mornings, except on Thursday and Friday afternoons when there is a substantial travel between 12 and 4 p.m. Longer trips (over 150 miles) show midweek peaks later in the day.

Nonbusiness trips of less than 250 miles have their peaks on Friday afternoons and Saturday mornings and then again on Sunday afternoons. Three or more person groups dominate these travel patterns. This is as expected, reflecting nonbusiness weekend travel (Figures B.3 and B.7).

Longer nonbusiness trips (over 250 miles) show somewhat different travel patterns--group size is smaller and there is less peaking occurring one or two days of the week. Travel begins to increase substantially on Thursday, drops off Saturday afternoon and Sunday morning, reaches its highest peak Sunday evenings, and then begins to taper off through Tuesday (Figure B.11).

Income level has a significant impact on the travel behavior of both business and nonbusiness travel. Regardless of trip distance, people in the low income group (i.e., those earning less than $7,500) make too few business trips to reveal any peaking patterns. Business travel under 150 miles is dominated by people earning from $7,500 to $20,000 (medium income), while trips over 150 miles are made predominantly by people earning over $20,000 (higher income groups).

The daily and hourly travel patterns for both high and medium income business travelers is parallel (Figures B.4, B.8, and B.12). Shorter business trips peak on Tuesday and Wednesday mornings; longer trips (greater than 150 miles) show less distinct peaking patterns and seem to fluctuate throughout the week.

Short (less than 150 miles) trips are made predominantly by middle income travelers, peaking on Friday and Saturday mornings and again, but less pronounced, on Sunday evenings. Medium-income level people dominate the travel on longer trips also. Travel is more scattered on longer trips, but still peaks around the weekend (Figures B.12 and B.13).

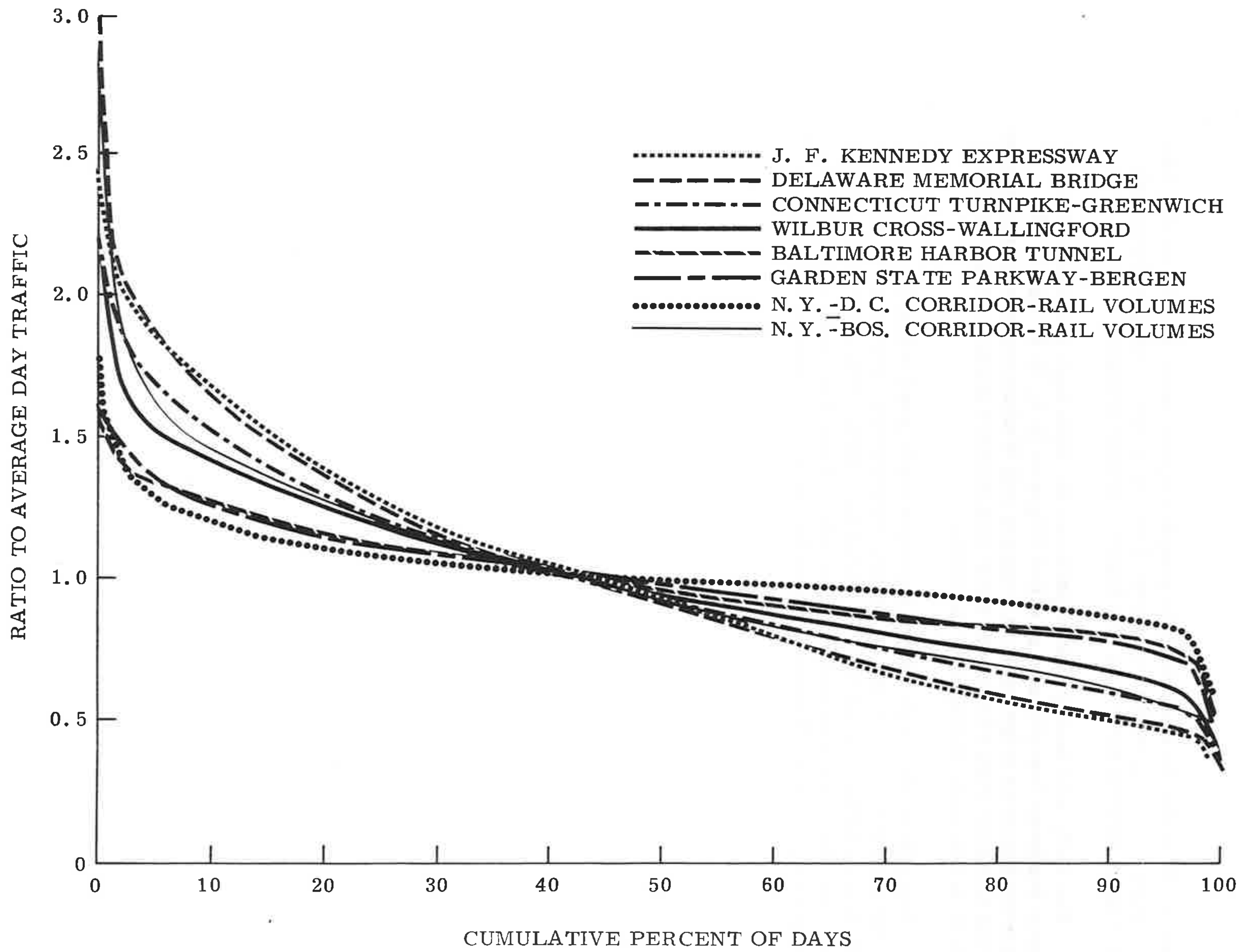


FIGURE B. 1: TYPICAL PEAKING CHARACTERISTICS OF CORRIDOR EXPRESSWAYS

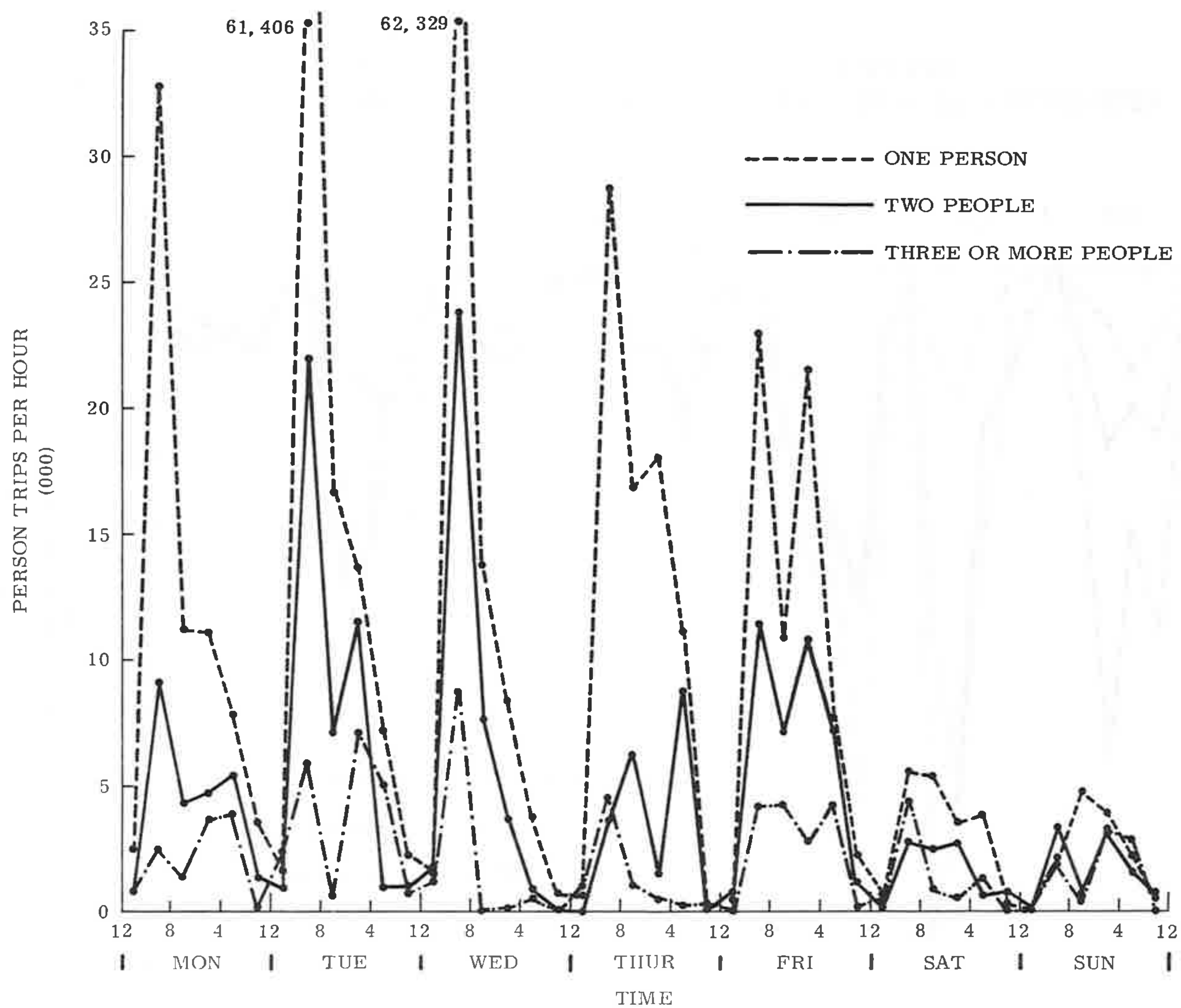


FIGURE B. 2: TIME PATTERNS OF BUSINESS TRIPS BY GROUP SIZE BETWEEN CITIES 0 TO 150 MILES APART

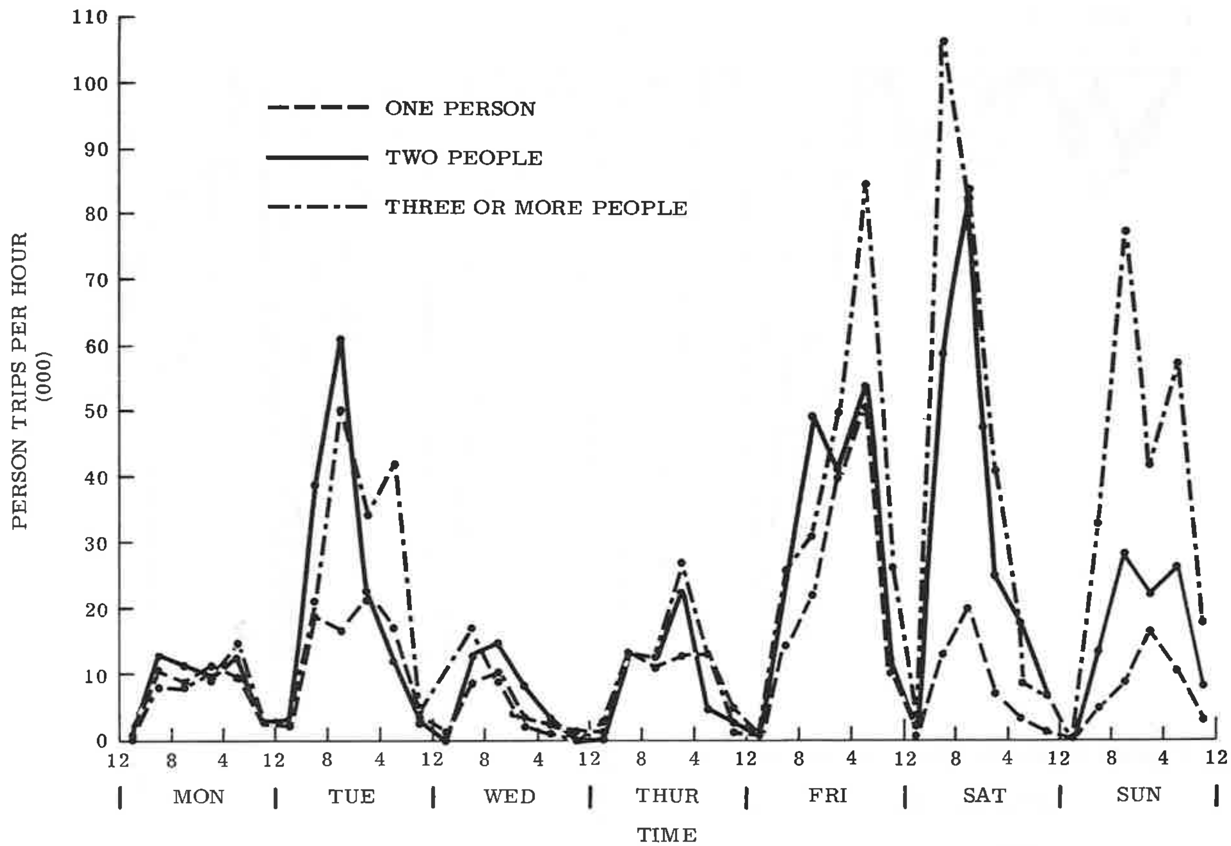


FIGURE B. 3: TIME PATTERNS OF NONBUSINESS TRIPS BY GROUP SIZE BETWEEN CITIES 0 TO 150 MILES APART

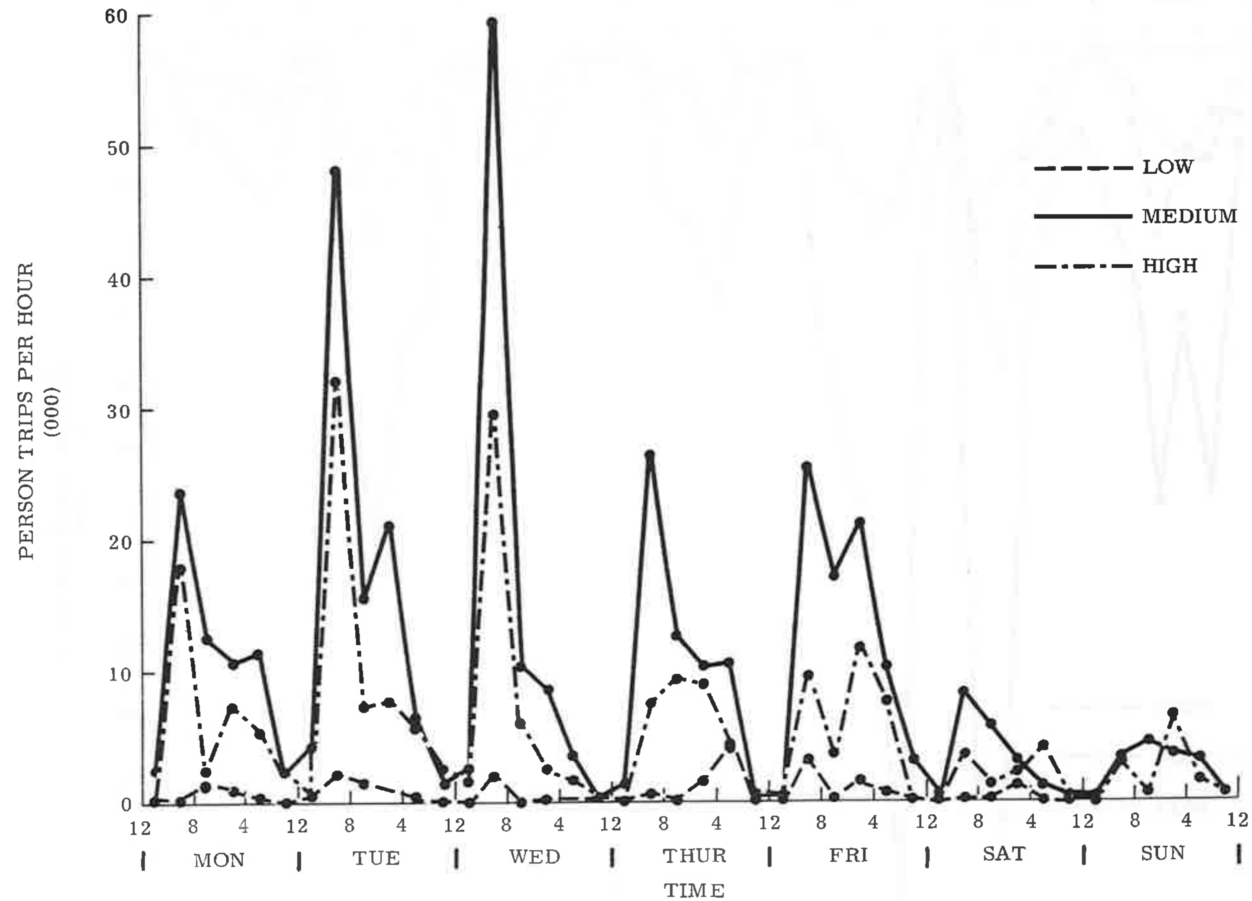


FIGURE B.4: TIME PATTERNS OF BUSINESS TRIPS BY INCOME CATEGORY BETWEEN CITIES 0 TO 150 MILES APART

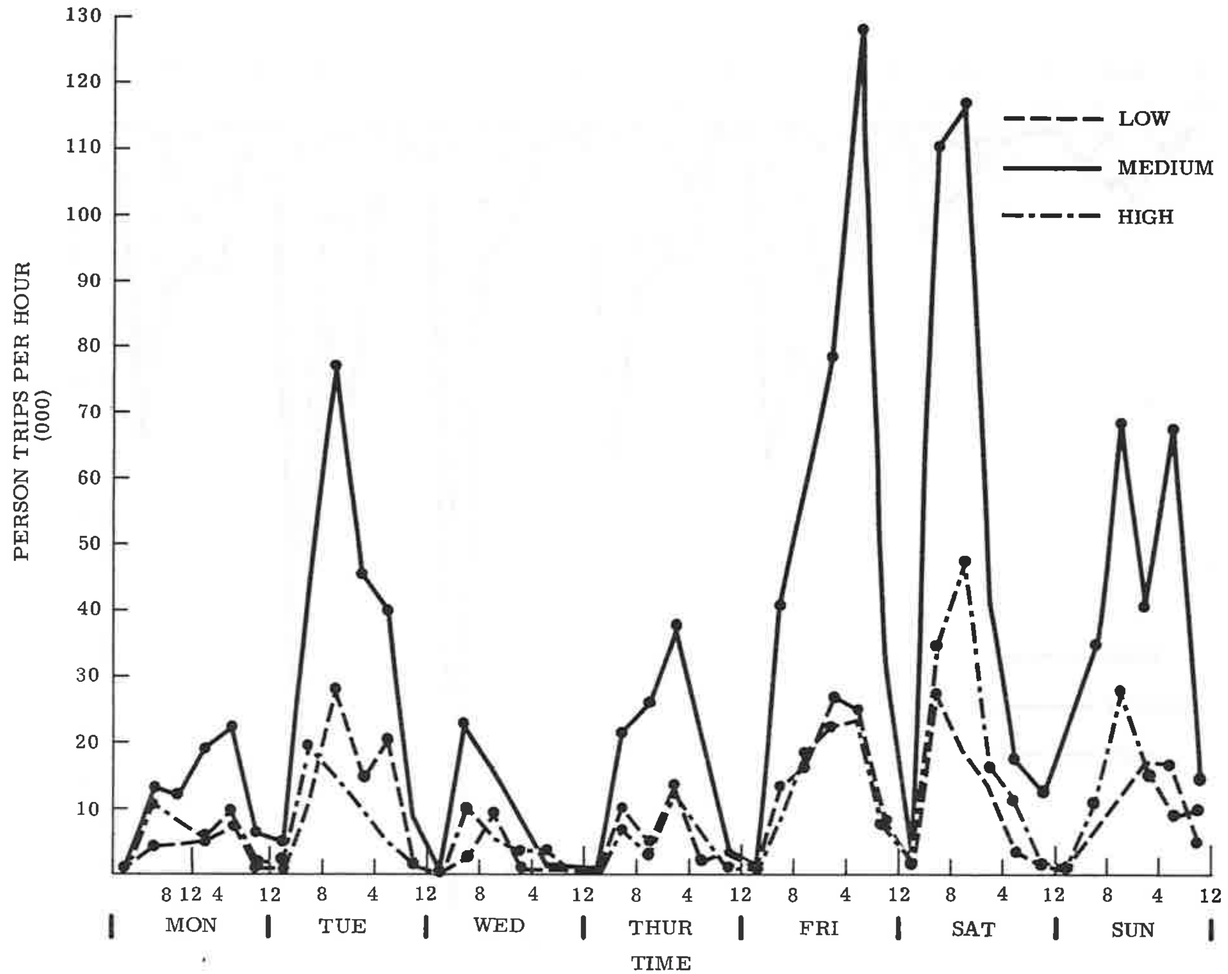


FIGURE B. 5: TIME PATTERNS OF NONBUSINESS TRIPS BY INCOME CATEGORY BETWEEN CITIES 0 TO 150 MILES APART

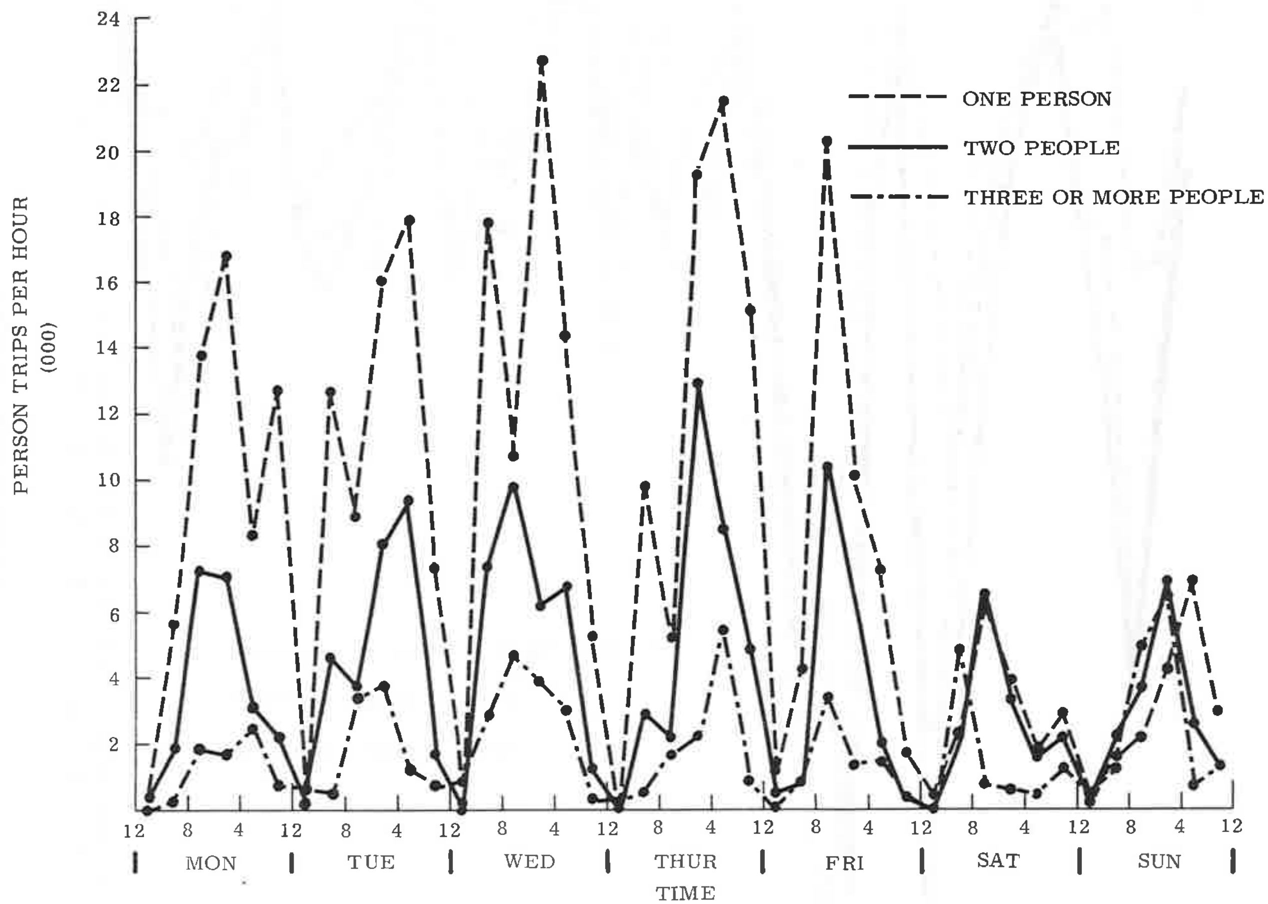


FIGURE B. 6: TIME PATTERNS OF BUSINESS TRIPS BY GROUP SIZE BETWEEN CITIES 150 TO 250 MILES APART

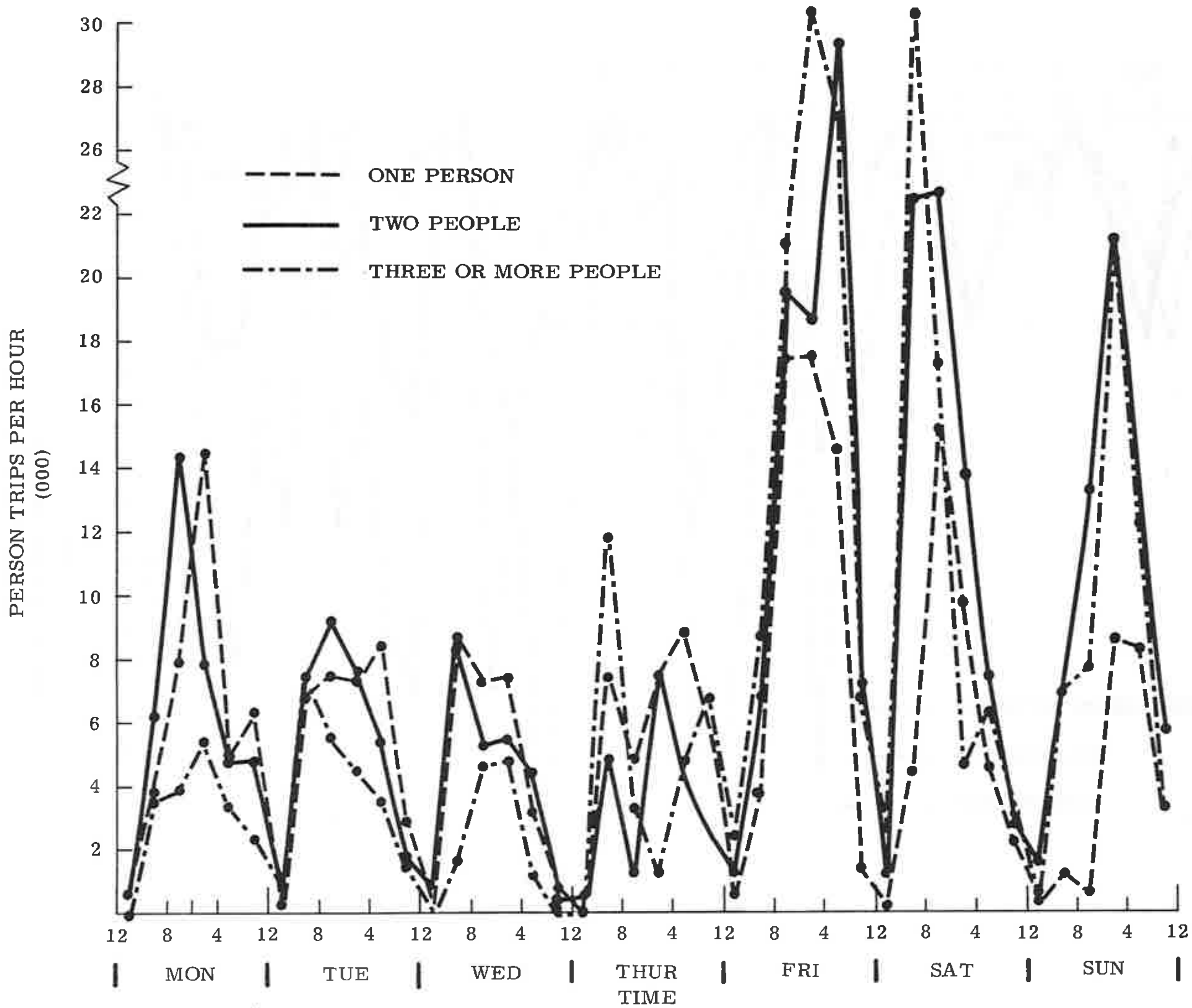


FIGURE B. 7: TIME PATTERNS OF NONBUSINESS TRIPS BY GROUP SIZE BETWEEN CITIES 150 TO 250 MILES APART

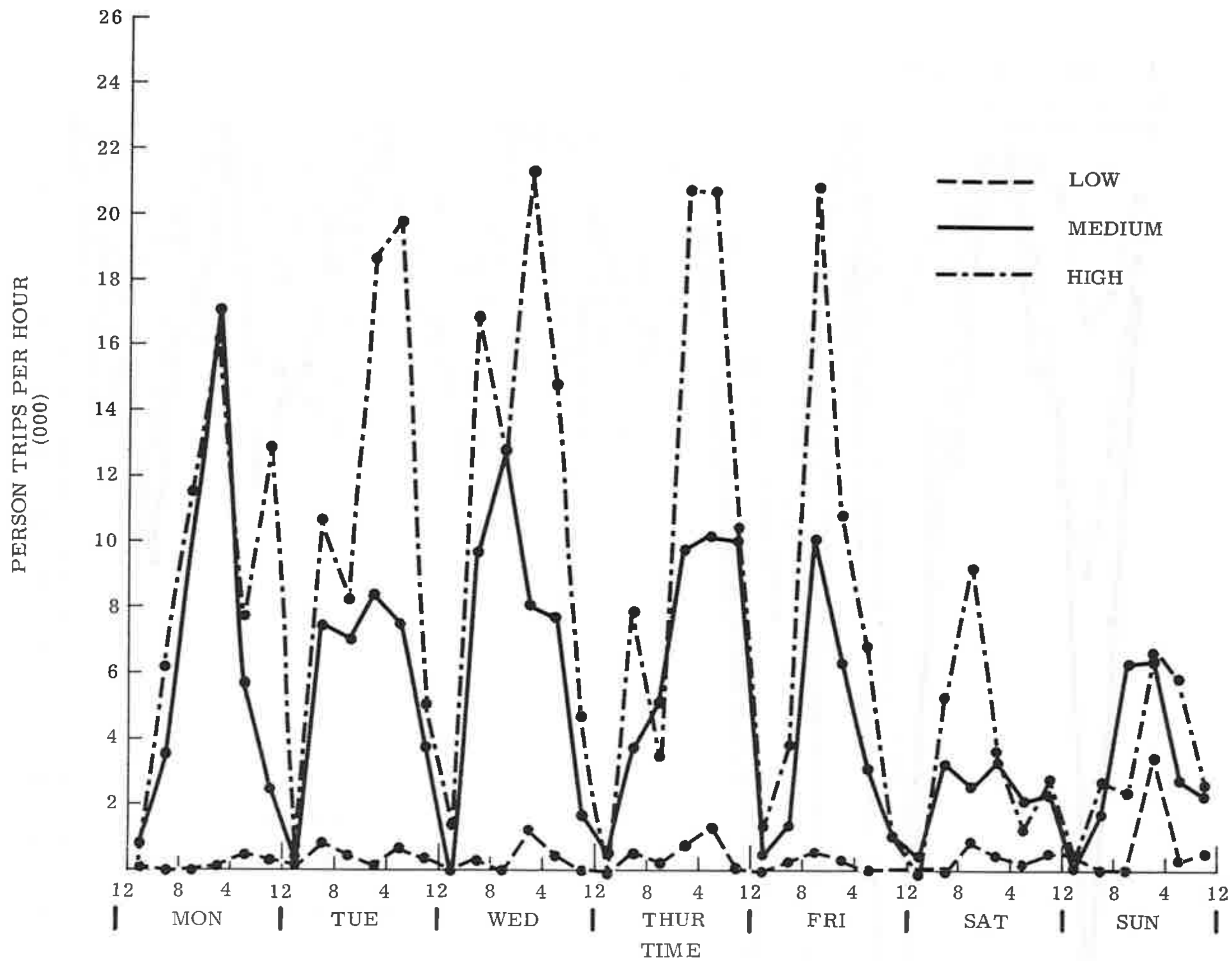


FIGURE B. 8: TIME PATTERNS OF BUSINESS TRIPS BY INCOME CATEGORY BETWEEN CITIES 150 TO 250 MILES APART

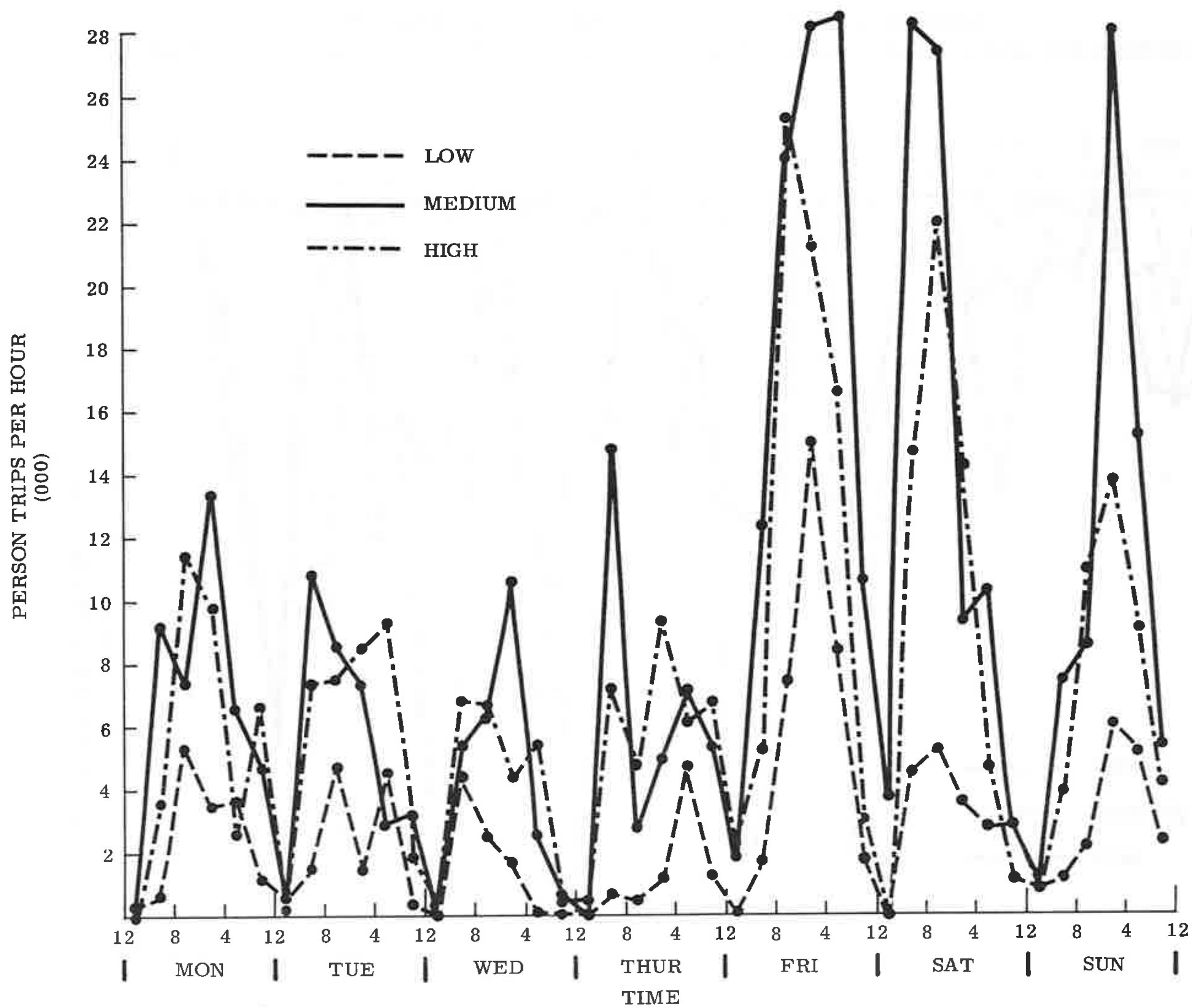


FIGURE B. 9: TIME PATTERNS OF NONBUSINESS TRIPS BY INCOME CATEGORY BETWEEN CITIES 150 TO 250 MILES APART

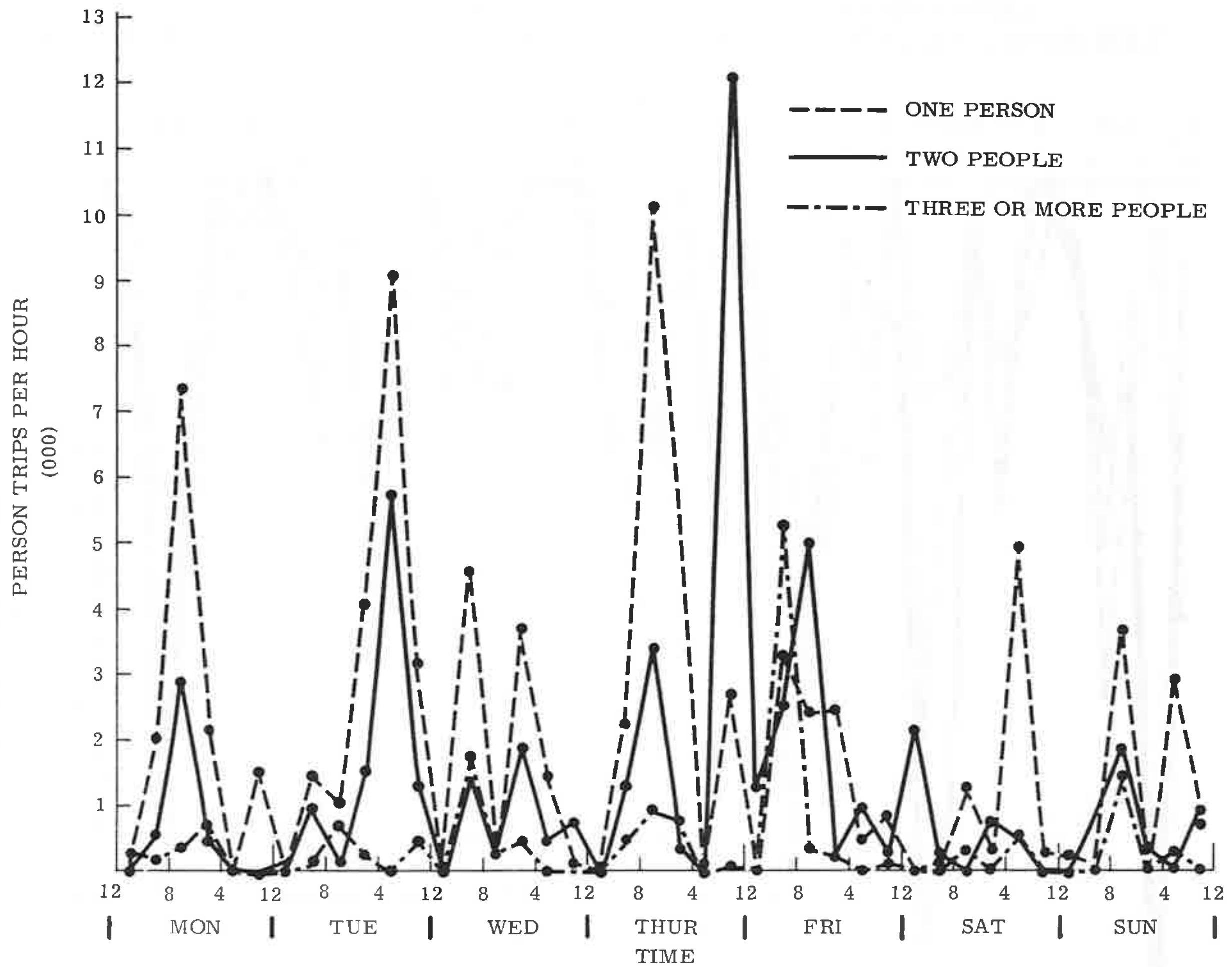


FIGURE B. 10: TIME PATTERNS OF BUSINESS TRIPS BY GROUP SIZE BETWEEN CITIES 250 AND MORE MILES APART

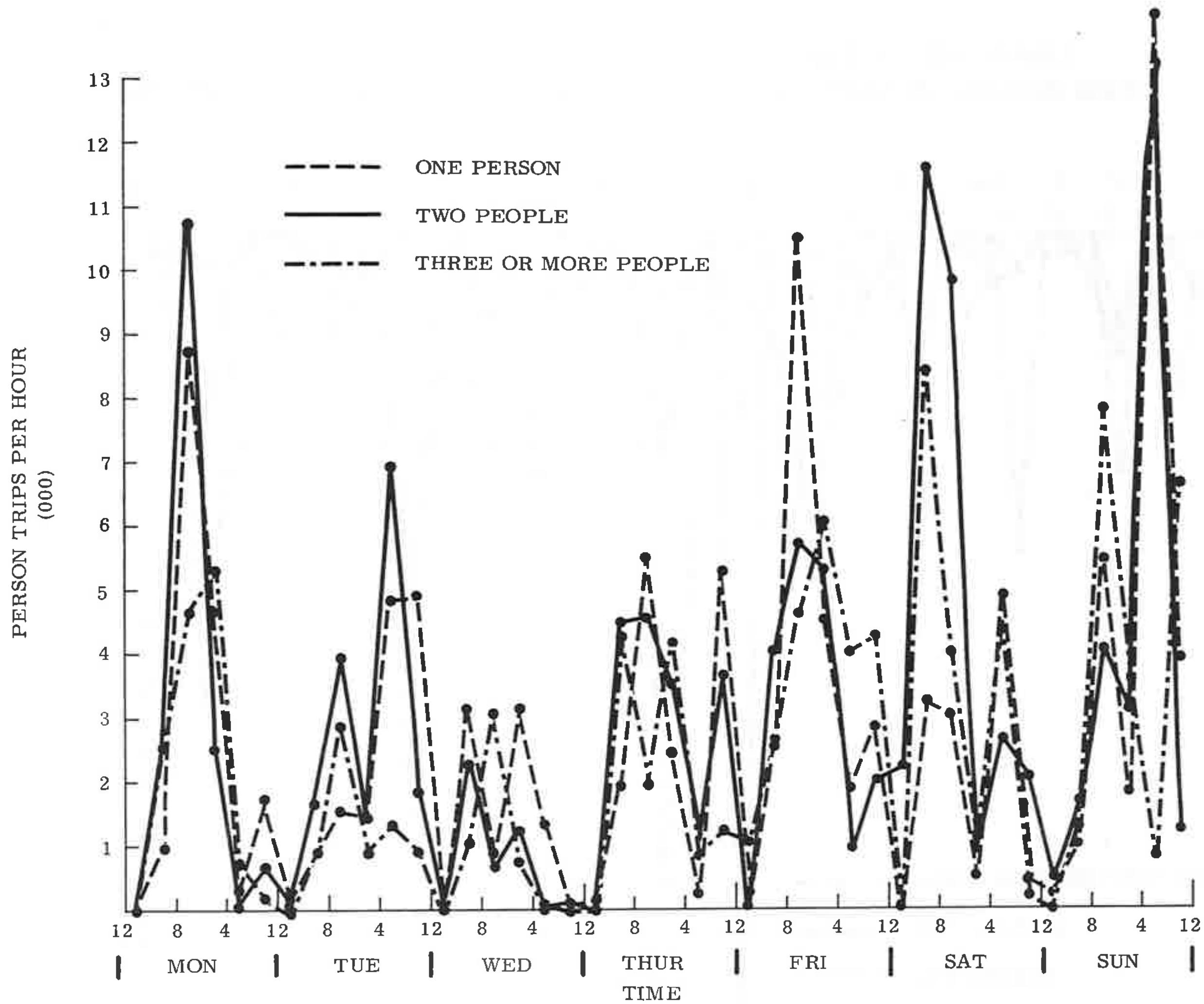


FIGURE B. 11: TIME PATTERNS OF NONBUSINESS TRIPS BY GROUP SIZE BETWEEN CITIES 250 AND MORE MILES APART

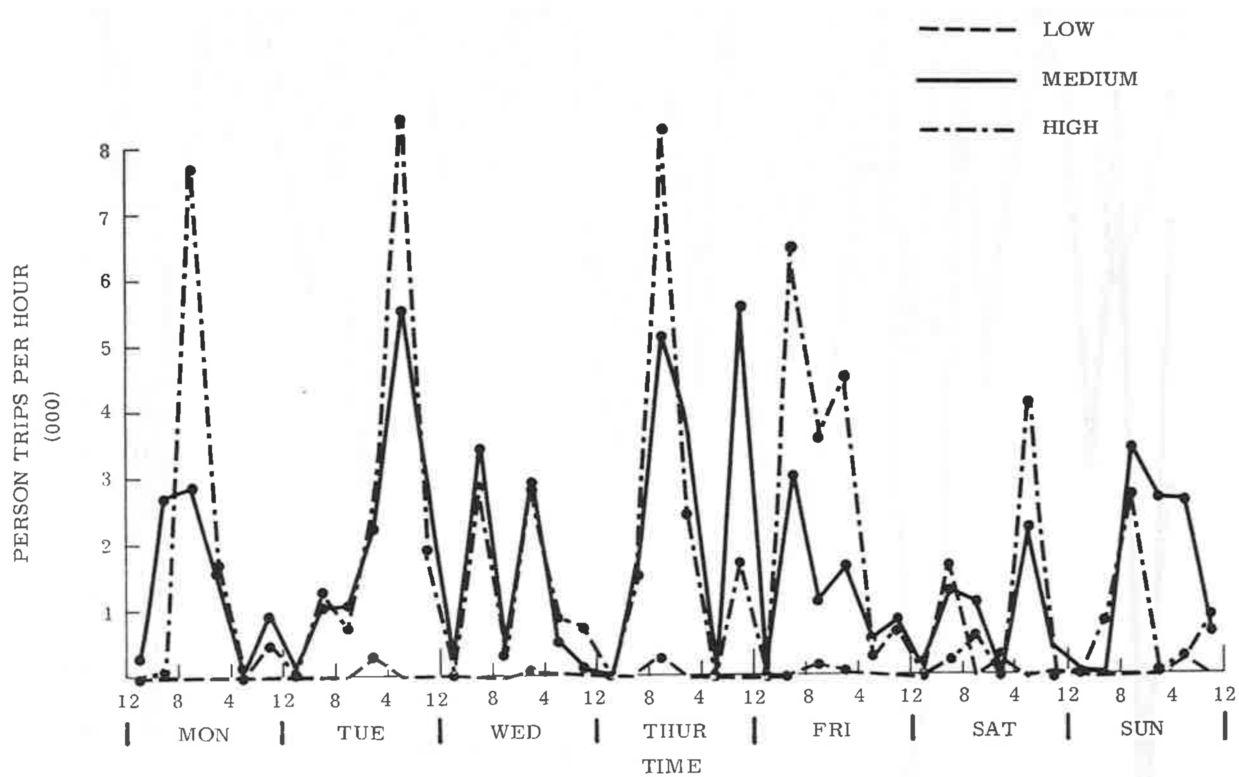


FIGURE B. 12: TIME PATTERNS OF BUSINESS TRIPS BY INCOME CATEGORY BETWEEN CITIES 250 AND MORE MILES APART

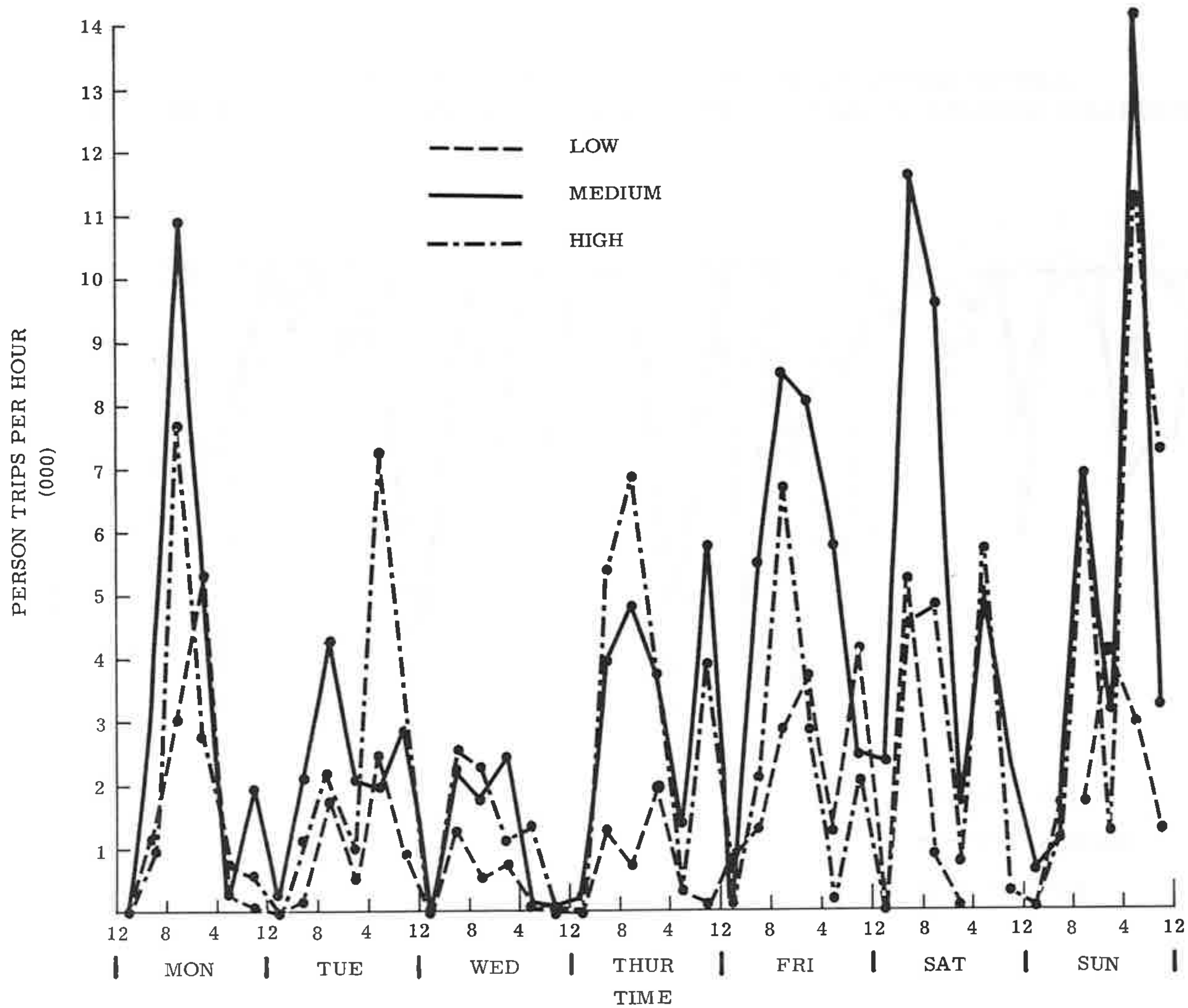


FIGURE B.13: TIME PATTERNS OF NONBUSINESS TRIPS BY INCOME CATEGORY BETWEEN CITIES 250 AND MORE MILES APART

APPENDIX C

REPORT OF INVENTIONS

After a diligent review of the work performed under this phase of the contract it was determined that no innovation, discovery, improvement or invention has been made. The work involved updating the data base to be used with existing demand and modal split models, so no innovative improvements or discoveries were expected.