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Submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering from

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Preface

The Transportation Science Program at Princeton University has undertaken a broad study of transportation in a purely scientific manner with major emphasis on the problems of Megalopolis. Of particular interest is the evaluation of a high-speed rail system between Boston and Washington. The hypothesis of this part of the program is to locate a proposed route for such a system and analyze it from various aspects in order to ascertain its degree of practicability. This thesis will deal with just one of the many phases being studied--that of passenger traffic analyses.

The authors wish to thank especially the following who have contributed so much toward not only the successful completion of this thesis but the year of study it culminates:

The Bureau of Yards and Docks, Department of the Navy, for making this period possible.

Senator Claiborne Pell of Rhode Island who inspired this program.

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Above all, we wish to thank our wives for their encouragement and understanding.

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Potential of a High-Speed Rail System

Introduction

Interest in the need for new forms of transportation has been growing throughout the country since the close of World War II. Much has been written about the merits of Monorail, STOL, VTOL, electronic highways, and even personalized jet belts, but few such ideas can withstand critical evaluation of their ability to move large numbers of people rapidly, safely, efficiently, and economically.

New Modes of Transportation

Superhighways have given travelers a greatly increased flexibility of movement by auto along with a reasonable decrease in travel time. They are rapidly becoming overcrowded, however, as is evidenced in the recently rising accident rate and frequent delays due to traffic. To further increase the superhighway network is one way of attempting to solve the traffic problem, but the staggering commitment in money and land (versus capacity) is rapidly reaching the point of diminishing return. The travel time from city to city apparently cannot be reduced much below present without raising the speed limit, which might further increase the accident rate.

Although there is currently no STOL aircraft that can be utilized for mass passenger movement, a STOL system might do nothing more than increase the already overcrowded skyways. STOL equipment alone costs at least twice as much to operate, both per seat and per passenger mile, than do fixed-wing aircraft. Also, if travel time city-to-city is to be decreased, new airports must be built closer to the cities. This would not

only reverse the present trend of locating them farther from the cities, but would add a staggering financial load to the air traffic control systems.

The electronic highway, in theory, has merit but must also reduce auto flexibility and at a great increase in cost compared to a conventional highway--both to the taxpayer and to the auto owner. An interesting comparison is seen in estimating what an electronic highway can do that a high-speed railroad carrying autos (with the passengers in the autos, on special drive-on-drive-off flat cars) cannot do faster, cheaper, with much greater capacity, and with no loss in flexibility to the auto driver.

High-Speed Rail Service

High-speed (100 to 125 mph) rail service is not new in one sense. It has been used increasingly in France for the past few years. Another service for which extensive tests have already been run will open in Japan in the Fall of 1964. Both systems are practicable and proven from an engineering point of view. More importantly, such systems eliminate many of the objections of the so-called "new" modes of transportation. High-speed rail service would most certainly be safer than a highway (fatalities per 100,000,000 passenger-miles in 1960 were 2.2 for auto and 0.16 for rail)[1] and only slightly less flexible than intercity auto travel. It may actually be cheaper to build than future superhighways, when figured on a passenger-mile or ton-mile capacity basis, and is certainly as fast or faster than any mode now in use for relatively short distances, as is illustrated by the following example:

The present center to center travel times between New York and Washington are: 300 minutes by auto or express bus (100 per cent of the highway is limited access), 225 minutes by rail and 140 minutes by air. High-speed rail service would allow a person to make this trip in 120 minutes.

Scope of Thesis

The scope of this thesis will cover the traffic phase of a high-speed rail system between Boston and Washington to determine potential passenger patronage based on present travel data and future growth. Some general information on some of the more technical details that have already been completed--such as criteria, route location, car design, and scheduling--is included in the next chapter.

Chapter 2

A High-Speed Rail Concept for Megalopolis

Introduction

The most prominent metropolitan region in the United States extends 700 miles along the Atlantic Seaboard from north of Portland, Maine, to Richmond and Norfolk, Virginia, and considerably inland. It includes the large metropolitan areas of New York, Washington, Baltimore, Philadelphia, the Connecticut Valley (New Haven, Hartford and Springfield), Providence, and Boston, as well as the rapidly developing suburban areas in between. This region has been aptly named "Megalopolis," to denote the virtually continuous city extending from Boston to Washington.

Megalopolis contains more than one quarter of the United States population, is above average in National Income, and has always been a great influence on United States life and development. However, it also has the most serious transportation problem in the United States. What should be the most lucrative market in the country for passenger travel is in reality the most difficult. The railroads have lost over half their postwar passenger traffic; the airlines, with steadily increasing passenger traffic during the past decade, are mostly losing money or barely breaking even on the short intercity runs; and the bus companies are able to operate only through the additional revenues brought in by package express and charter service.

The through highways in Megalopolis are excellent; however, they are badly congested during the rush hours even though the majority are toll roads. The need in this region for a fast, safe, efficient means of mass transportation is obvious. It is for this reason that Megalopolis was

chosen as the type location for a study of the potential of a high-speed rail system.

Route and Station Location

After considerable thought it was decided that the proposed route and station locations for a high-speed rail transportation system within Megalopolis should be located according to the following criteria:

(1) Because most of the population in Megalopolis is situated within the narrow Boston-Washington corridor, the high-speed rail line should be located to connect these metropolitan areas.

(2) Provide direct rail connections at locations where the line passes close to limited access highways in suburban areas. This will provide suburban communities with easy access to the high-speed line.

(3) Provide direct rail interchanges at some major airports.

(4) Provide a bypass around New York to allow freight to be shipped directly from any point south of New York to the New England area. Presently freight being shipped by rail from south of New York to New England must travel one of the two following routes:

a) via car-float from New Jersey to Brooklyn and then north to New England;

b) via the circuitous Maybrook and New Haven Railroad route which crosses the Hudson River at Poughkeepsie.

Both of the above routes are inefficient and produce undue delays which result in much of the present freight being shipped by water or by truck.

(5) Provide direct rail connections for service to Cape Cod, Vermont, New Hampshire, and Maine to the north; and with the Southern Railroads for service south of Washington.

(6) Provide a direct rail service between the Connecticut Valley cities and the Boston-Providence area, a service which presently does not exist.

With the above criteria as a basis, the route location and station locations for this new high-speed rail transportation system were determined. (See Figures 1 through 6.) The new high-speed line is located on a rail right-of-way separate from the present Pennsylvania Railroad (between New York and Washington) and from the New Haven Railroad (between New York and Boston) for the following two very general reasons:

(1) Improvement of the existing Pennsylvania and New Haven rail line between Boston and Washington to handle high-speed rail traffic would seem to necessitate the following:

a) The straightening of four tracks instead of two.

b) The replacement of the present electrification system of 11,000 volts 25 cycles, which cannot be utilized effectively for 120 mph trains, to 25,000 volts 60 cycles. This would result in much of the present equipment becoming obsolete.

c) The replacement of the present automatic signaling system in order to accommodate high-speed trains. This change might severely impede freight traffic utilizing the line. Also, from a safety point of view, it is difficult to run slow-speed freight and high-speed passenger traffic simultaneously.

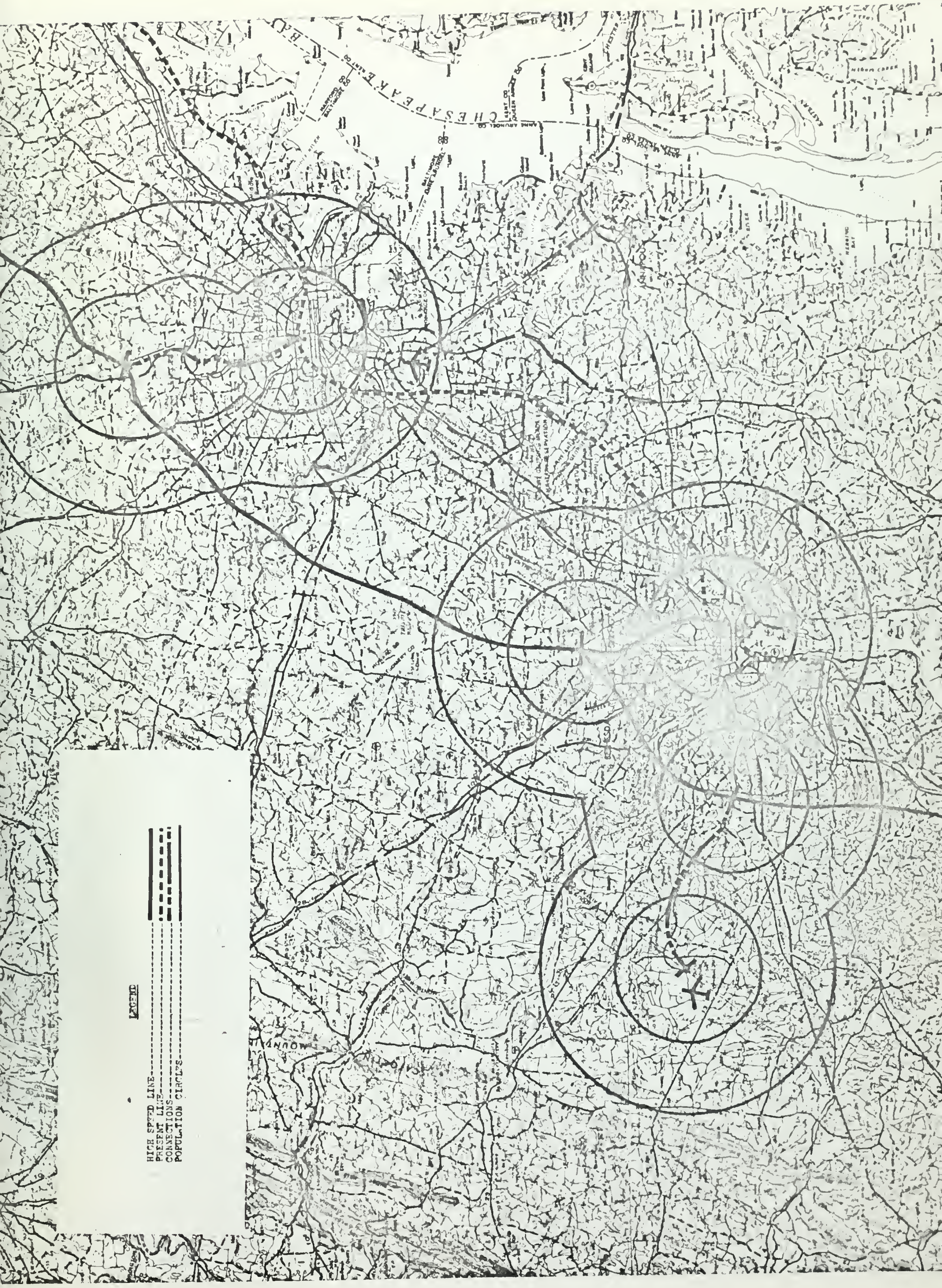

Fig. 1. Map of Washington Area

Fig. 2. Map of Philadelphia Area

Fig. 3. Map of New York Area

Fig. 4. Map of New Haven Area

Fig. 5. Map of Connecticut Valley Area

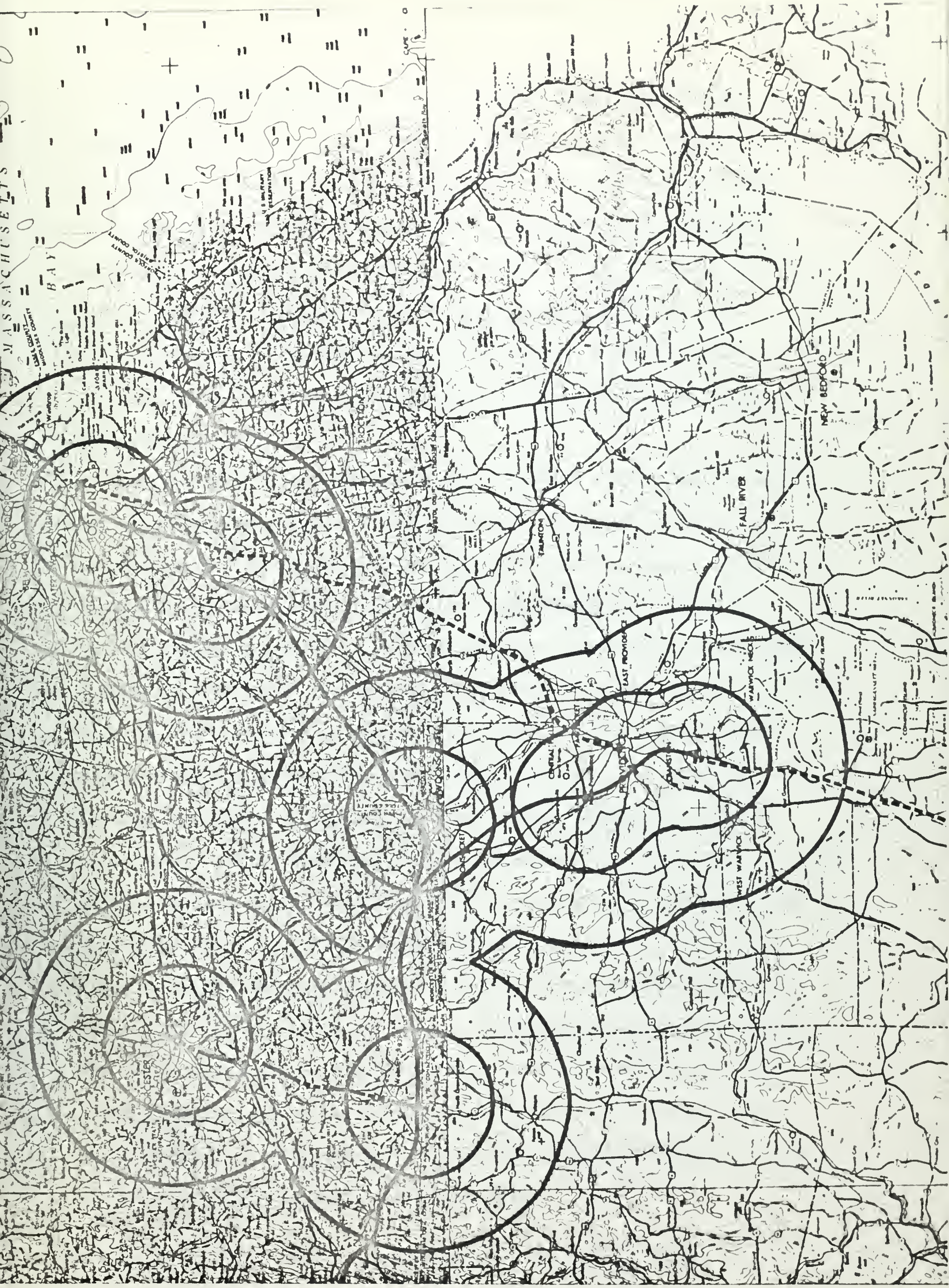

Fig. 6. Map of Boston Area

If the above improvements could be accomplished, the primary purpose of this existing rail line--to serve local industry--would be hindered, and yet the improved line would not meet the majority of the criteria previously listed for the establishment of a high-speed rail transportation system. As a final thought, all of the above improvements would have to be accomplished under the most adverse traffic conditions, as the existing line between Boston and Washington is one of the most heavily traveled rail routes in the United States.

(2) Constructing a high-speed rail line over a new route location and utilizing the existing and abandoned rail rights-of-way as much as possible would require only two tracks instead of four. The new line would be constructed similar to a superhighway by utilizing existing connecting rail lines into the major cities along the Boston-Washington corridor. This method would not only reduce construction costs and travel time, but would also provide a more scenic parkway type line through some of the best scenery the area has to offer. Locating the route of the new line through the Connecticut Valley will provide direct service for the population of one and a half million in that area to the other metropolitan areas along the Boston-Washington corridor. It is estimated that the cost of constructing this new high-speed rail system, including track, stations and equipment, would be only twice the cost of improving the present rail line. The end result would be a new rail line that could handle both high-speed passenger and by-pass freight traffic while the present line would continue to handle local and commuter passenger traffic as well as the bulk of the existing freight traffic.

In Figure 7 are listed the 40 existing and proposed station locations with the mileage between each station indicated. Within a ten-mile radius of each station there is a total population of 23,893,500 (no other U. S. railroad services this size market) which is broken down as follows:*

Boston to the New York-Newark area	5,782,700
New York-Newark area	10,765,200
Washington to the New York-Newark area	7,345,600

The total rail mileage between Boston and Washington, including existing links to Worcester, Holyoke, Hartford, New Haven, New York (Grand Central, Penn and Kennedy), Philadelphia (North Philadelphia and 30th St.), Towson and Baltimore, and Falls Church and Dulles is 678.8 miles. Of this 678.8 miles, 422.4 are existing rail rights of way, 63.1 are abandoned rail rights of way, and 193.3 are new rights of way. The main high-speed line between Boston and Washington will be separate single tracks from Boston and Providence to a point five miles west of Woonsocket where the two tracks converge and form a double track. The double track then extends to Wheaton, Maryland, at which point one single track continues to Washington and another single track continues to Dulles. The length of this main line is 507.9 miles (this does not include any existing link service). Of this 507.9 miles, 404.0 are double track and 103.9 are single track. The mileage from downtown Boston to Washington is 454.2 miles. The construction along this main high-speed line will require two major bridges, Hudson River and Susquehanna River, and two major tunnels, Fenton Mountain located between Webster and Springfield (2 miles) and at Redding, Connecticut (1/2 mile), between Stepney and Bedford.

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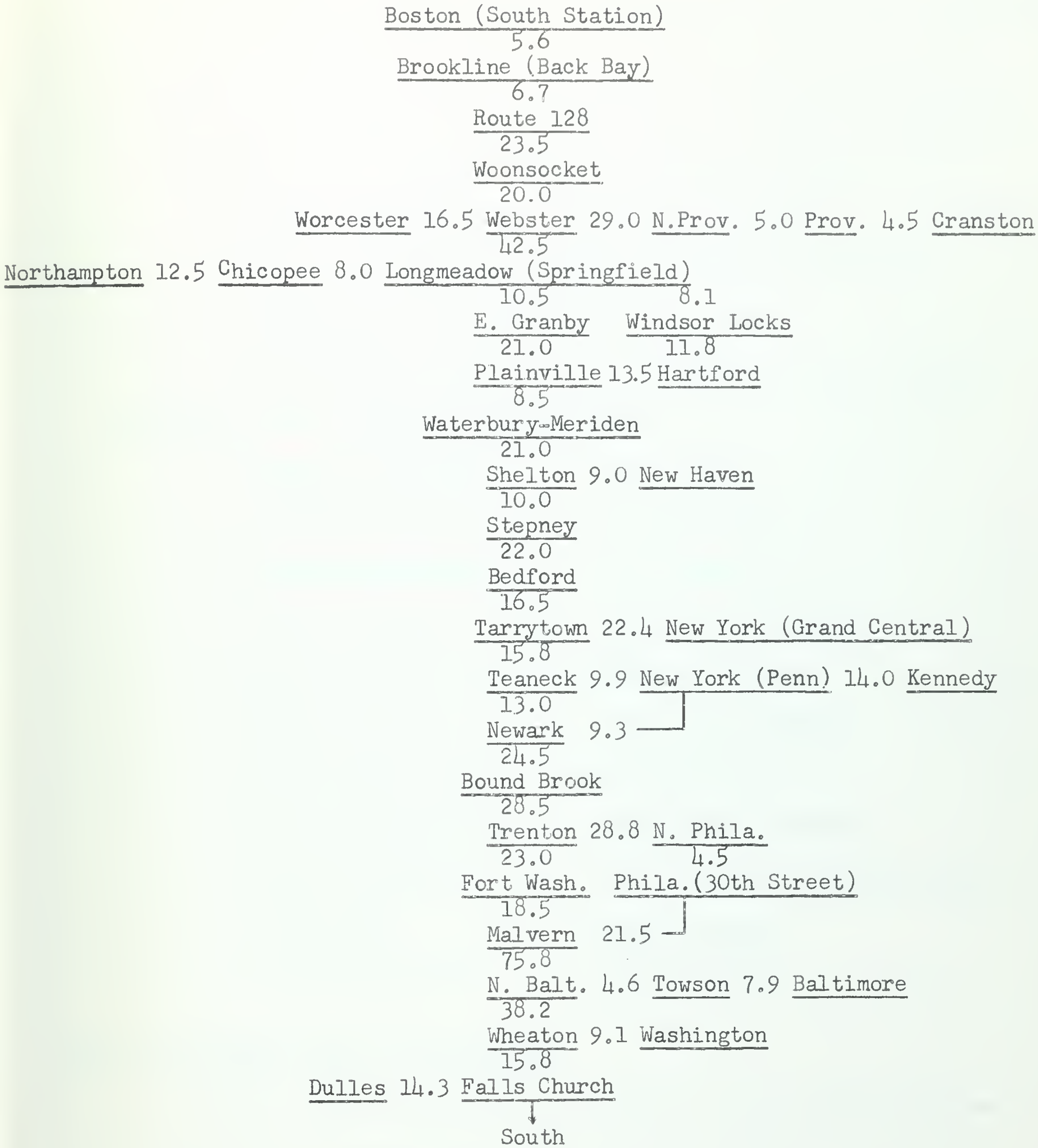
*Chapter 3 will explain how these populations were determined.



Total Mileage --678.8
Boston-N.Y.(Penn)--233.5
Wash.-N.Y.(Penn) --226.9
Boston-Washington--454.2

Fig. 7. Line Diagram of High-Speed Route Indicating Mileage Between Stations.

In accordance with the criteria established previously for determining the best route and station locations, this proposed high-speed rail line would provide the following detailed service (refer to Figures 1 through 6):

(1) Direct rail connection with the following airports:

a) Dulles and Friendship International Airports.

b) Kennedy International, Newark and LaGuardia Airports.

c) Bradley Field (Springfield-Hartford area).

(2) "Suburban" rail stations will be constructed at the following locations next to limited-access highways:

a) Route 128 (Boston)	Route 128
b) Longmeadow, Mass.	Interstate 91
c) Waterbury-Meriden, Conn.	Interstate 84
d) Shelton, Conn.	Wilbur Cross Parkway
e) Tarrytown, N. Y.	New York Thruway
f) Teaneck, N. J.	New Jersey Turnpike
g) Bound Brook, N. J.	Interstate 287
h) Fort Washington, Pa.	Pennsylvania Turnpike
i) North Baltimore	Baltimore-Harrisburg Expressway
j) Towson, Md.	Interstate 695
k) Falls Church, Va.	Interstate 495

Type of Passenger Train to be Utilized

The type of passenger train best suited for high-speed operations is a self-propelled, double-deck, three-car unit, commonly known as the JR-3. Both of the end cars would carry revenue seats only, whereas the middle car would contain the propulsion unit in the lower deck with the

upper deck available for passengers and a dining area. The average capacity of this three-car unit would be 320 passengers.

The type of propulsion required for this high-speed rail system would be 25,000 volts, 60 cycles; however, the propulsion unit design for the JR-3 will have the capability of running with any power in the United States. To accomplish this will require the following four different capabilities:

(1) 25,000 volts 60 cycles -- for the high-speed line

(2) 11,000 volts 25 cycles -- for the Penn and New Haven lines

(3) 3,000 volts D.C. -- for the Lackawanna lines, etc.

(4) 1,500 volts D.C. -- for the Illinois Central lines. etc.

The engineering design of a propulsion unit capable of the above four modes of operation is not a difficult problem. The French National Railways at the present time have an operational locomotive that operates on the following four common voltages in Europe that are very similar to the propulsion requirements specified above for the JR-3 unit:[3]

(1) 25,000 volts 50 cycles -- new lines

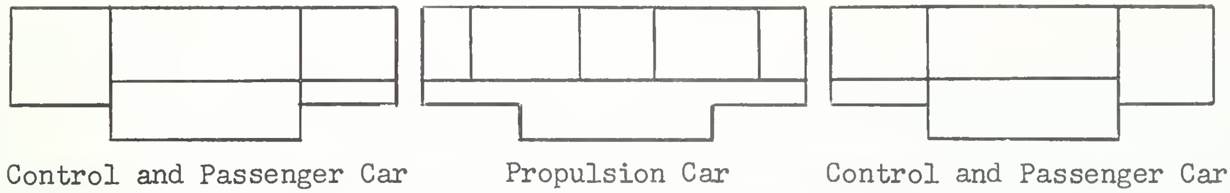
(2) 12,000 volts 16-2/3 cycles -- Switzerland

(3) 3,000 volts D.C. -- Italy

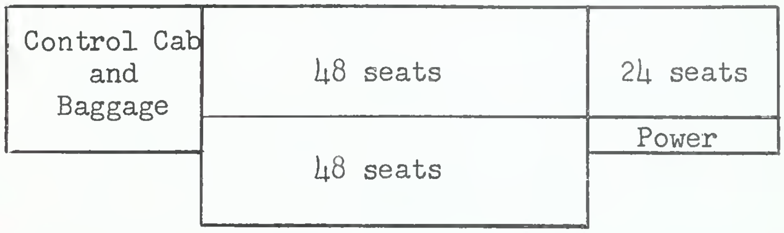
(4) 1,500 volts D.C. -- old French and Low Countries.

Figure 8 is a simplified sketch illustrating the type of three-car unit (JR-3) described above. Further study concerning the engineering design of this three-car unit is being conducted in other phases of the Transportation Science Program at Princeton University.

Three-Car JR-3 Unit

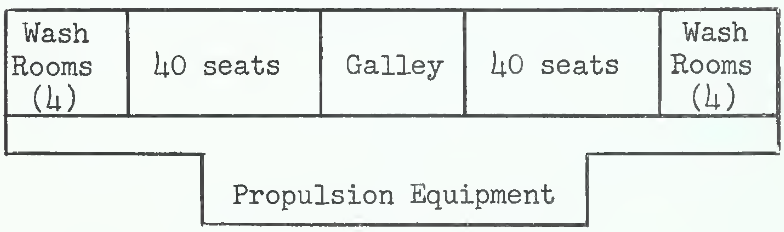


Control and Passenger Car



Weight: 60 tons
Capacity: 120 passengers (42" seat spacing)

Propulsion Car



Weight: 80 tons
Capacity: 80 passengers (booth seating)
Power: 1800 horsepower electric

Note: Each car has the same following dimensions:

Car length --82'6"
Drop center length --43'0"
End sections length--19'6"
Height --14'6"

Fig. 8. Schematic of Proposed JR-3 Unit for the High-Speed Line.

Scheduling

The intercity schedule for rail service for the high-speed line in order to be as efficient as possible has been established as follows: The first passenger trains of the day will depart at 6:00 A.M. and passenger service will continue until the last passenger train departs at 11:00 P.M. Shortly after midnight high-speed freight and Piggyback service will begin operating and will continue until 6:00 A.M. Because of the large population that this new high-speed line will serve, an average density of 56 passenger trains (each way) will be scheduled daily. This density will provide a minimum of hourly service for each of the 40 proposed stations. The details of the scheduling are included in Appendix A.

A typical example of a "one-stop" run from Boston and Providence to New York would be as follows:

> A three-car unit would depart from Boston (South Station) at 9:00 A.M. Another three-car unit would depart from Providence at 9:10 A.M. These two JR-3 units would then join together at the junction of the two single tracks five miles west of Woonsocket and travel as a single six-car unit (stopping at Hartford) to Tarrytown at which point the two JR-3 units would then separate. One JR-3 unit would proceed to Grand Central Station arriving at 11:15 A.M., while the other unit would proceed to Pennsylvania Station arriving at 11:00 A.M. This type of service would allow each passenger the choice of disembarking at either New York station by a walk-through transfer en route. Through similar inter-connected scheduling, the equivalent of hourly service can be maintained for most points.

Chapter 3

Passenger Potential

Introduction

There are several methods of determining passenger potential, each yielding various degrees of accuracy. For our purposes we chose to use the "gravity" formula, partly since it is the simplest to use when large numbers of city pairs are involved and can be easily programmed on a computer, and partly because none has yet proven more accurate.

Gravity Formula

The formula is basically quite simple and is based on the following factors: (1) Traffic volume will decrease as distance increases; (2) traffic volume will decrease as population decreases; (3) traffic volume will decrease as per capita wealth decreases. Distance, population and per capita wealth are the most important factors and account for at least 80 per cent of the potential influence. Other factors which influence the potential are: population concentration, the distance of the city from transportation centers and abnormal transient factors. Among the types of cities that produce abnormal transient factors are state capitals, small cities with military bases, small university towns, and seasonal resorts. The effective populations of these places should be increased by a factor of 50 to 100 per cent.

The number of passengers between any two cities can roughly be computed by the "gravity" formula:

$$T_p = \frac{(p_1 p_2)(w_1 w_2)}{D} \times \frac{1}{K}$$

where T_p yields the potential commercial carrier traffic in passengers per month; p_1 and p_2 are the populations of the two cities in thousands; w_1 and w_2 are the per capita wealth of the two cities; D is the distance between them; and K is an empherical constant determined to be .234. This formula is felt to be quite reliable for distances of 50 to 500 miles for estimating carrier potential.

The illustrations below show the effect population and distance have on traffic between two cities, A and B, as related by the formula.

City A	100 miles / 10,000 passengers	City B

If the distance in the case above were doubled, then the sketch below would result.

City A	200 miles / 5,000 passengers	City B

If City A's population were doubled and the distance remained the same as in the first case, the result would be:

City A	100 miles / 20,000 passengers	City B

The following is an example of how the formula applies between Chicago and the Twin Cities:

Data:		
	Average distance	--420 miles
	Population Chicago	--4,523.0 thousand
	Wealth Chicago	--1.29
	Population Twin Cities	--897.4 thousand
	Wealth Twin Cities	--1.28

Thus: $$T_p = \frac{(4,523.0 \times 897.4)(1.29 \times 1.28)}{420} \times \frac{1}{.234}$$

$$= 68,200 \text{ approximately}$$

Actual commercial traffic for a month when these figures were obtained was:

Intercity Bus	--	4,000
Rail Coach	--	34,500
Rail Sleeper	--	6,600
Airlines	--	8,000
Total		53,100

The actual number of passengers will rarely exceed the potential unless service by all three modes is considerably above average.

Population

The initial step in determining the passenger potential along the Boston-Washington corridor was to construct the proposed rail route on ten individual 1:250,000 scale topographic maps. Figures 1 through 6 illustrate the maps utilized. After selecting the route location, the suburban and downtown railroad stations were then located on the maps.

There are 40 proposed railroad stations served by the proposed line. In determining the population around each of these stations, circles of five- and ten-mile radii were constructed around them using the stations as the centers. These circles were then transferred to the census tract maps included in references 9 through 28 in order to obtain the most accurate population. However, of the 40 stations, only 17 were covered completely by the census tract maps. The remaining 23 stations were covered only partially. In order to determine the population served by these stations, the census tract maps were used in conjunction with the population maps of

the entire state involved (see references 29 through 33).

Figure 9 is the census tract map of the Boston area which illustrates how the population for the three stations there was determined. The populations of the remaining stations along the route which were included in census tract maps were determined in much the same manner. Table 1 lists the stations and the source of the population data for each one.

The populations listed in Table 2 were utilized in the formula as follows: For distances less than 100 miles the adjusted 5-mile population was used. For distances greater than 100 miles the adjusted populations of the 10-mile circles were used. For Boston and Washington, since these cities are at each end of the route, it was felt that when the distance was greater than 150 miles it could safely be assumed that people as far out as 15 miles from their stations could be considered as potential passengers.

The "purchasing power" of the people living within the circles around each proposed station was obtained from "Survey of Buying Power" (reference 8). The quality index utilized is defined as "a measure of the purchasing ability of each county and city as compared to the nation. The average of the United States is 100."

A transient factor of 50 per cent was added to the actual populations of Providence, R. I., Hartford, Conn., and Washington, D. C., since these three cities generate more travel than an ordinary city of comparable population. This increase in travel is mainly due to the fact that each of the above cities is a capital.

Fig. 9. Census Tracts in the Boston SMSA and Adjacent Area

Table 1

Source of Station Population

Station:		Population Determined by:
1.	Boston (South Station)	Census Tract (Ref. 10)
2.	Brookline (Back Bay)	Census Tract (Ref. 10)
3.	Route 128	Census Tract and State Map (Ref. 10 & 31)
4.	Woonsocket	Census Tract and State Map (Ref. 21 & 31)
5.	Cranston (S. Prov.)	Census Tract and State Map (Ref. 21 & 31)
6.	Providence	Census Tract and State Map (Ref. 21 & 31)
7.	North Providence	Census Tract and State Map (Ref. 21 & 31)
8.	Webster	Census Tract and State Map (Ref. 28 & 31)
9.	Worcester	Census Tract (Ref. 28)
10.	Northampton	Census Tract and State Map (Ref. 23 & 31)
11.	Chicopee	Census Tract and State Map (Ref. 23 & 31)
12.	Longmeadow (Springfield)	Census Tract and State Map (Ref. 23,29,&31)
13.	East Granby	Census Tract and State Map (Ref. 12 & 29)
14.	Windsor Locks	Census Tract and State Map (Ref. 12 & 29)
15.	Hartford	Census Tract (Ref. 12)
16.	Plainville	Census Tract and State Map (Ref. 12 & 29)
17.	Waterbury-Meriden	Census Tract and State Map (Ref. 27 & 29)
18.	New Haven	Census Tract and State Map (Ref. 16 & 29)
19.	Shelton	Census Tract and State Map (Ref. 11,16,&29)
20.	Stepney (Bridgeport)	Census Tract and State Map (Ref. 11 & 29)
21.	Bedford (Stamford)	Census Tract and State Map (Ref. 17,24,&29)
22.	Tarrytown	Census Tract (Ref. 17)
23.	Teaneck	Census Tract (Ref. 19)
24.	New York (Penn Station)	Census Tract (Ref. 13 & 17)
25.	New York (Grand Central)	Census Tract (Ref. 17)
26.	Kennedy	Census Tract (Ref. 17)
27.	Newark	Census Tract (Ref. 13 & 18)
28.	Bound Brook	Census Tract (Ref. 14,18,&22)
29.	Trenton	Census Tract and State Map (Ref. 20,25,&32)
30.	Fort Washington	Census Tract (Ref. 20)
31.	North Philadelphia	Census Tract (Ref. 20)
32.	Philadelphia (30th Street)	Census Tract (Ref. 20)
33.	Malvern	Census Tract (Ref. 20)
34.	North Baltimore	Census Tract and State Map (Ref. 9 & 30)
35.	Towson	Census Tract and State Map (Ref. 9 & 30)
36.	Baltimore	Census Tract (Ref. 9)
37.	Wheaton	Census Tract and State Map (Ref. 26 & 30)
38.	Washington	Census Tract (Ref. 26)
39.	Falls Church	Census Tract and State Map (Ref. 26 & 33)
40.	Dulles	Census Tract and State Map (Ref. 26 & 33)

Table 2

Station Populations and Related Factors

Station	Population 5 mi.	Population 10 mi.	Quality Index	Transient Factor	Adjusted Population 5 mi.	Adjusted Population 10 mi.
Boston	1008.4	1632.9				
Brookline			119	1.0	1304.2	2229.3
Route 128	87.6	240.5				(2839.1)*
Woonsocket	75.7	123.2	101	1.0	76.4	124.4
Cranston	90.0	207.5				
Providence	152.9	164.1	102	1.5	678.9	918.7
N. Providence	200.9	228.9				
Webster	26.4	70.4	106	1.0	250.6	362.9
Worcester	210	272				
Northampton	39.6	69.4				
Chicopee	117	186.7	108	1.0	340.0	488.2
Springfield	158.3	196				
East Granby	14.4	37.3	117	1.0	58.6	137.9
Windsor Locks	35.7	80.6				
Hartford	269.6	391.8	120	1.5	740.2	1016.2
Plainville	141.7	172.8				
Waterbury-Meriden	91.5	239.6	111	1.0	101.5	265.9
New Haven	246.4	301	100	1.0	309.0	485.6
Shelton	62.6	184.6				
Stepney	17.5	240.9	107	1.0	18.7	257.7
Bedford	50.0	209.6	145	1.0	72.5	303.9
Tarrytown	167.1	532.9	149	1.0	248.9	794.0
Teaneck	498.4	1099.2	117	1.0	583.1	1286.0
Penn. Station	3163.4	6238.2	118	1.0	3732.8	7361.0
Grand Central						
Kennedy Airport	636.8	1836.8	125	1.0	796.0	2296.0
Newark	900.7	1591.0	122	1.0	1098.8	1941.0
Bound Brook	92.6	287.0	132	1.0	122.2	378.8
Trenton	96.8	223.3	115	1.0	111.3	256.7
N. Philadelphia	1747.0	2699.4				
30th Street			115	1.0	2384.0	4149.6
Ft. Washington	236.0	663.3				
Malvern	90.1	245.7				
North Baltimore	194.6	280.7				
Towson			102	1.0	1062.2	1448.1
Baltimore	846.8	1139.1				
Wheaton	194.0	423.5				
Dulles	46.5	129.8	127	1.5	2047.3	3442.5
Falls Church						(3659.5)*
Washington	834.3	1253.8				

*15-mile adjusted population.

Potential

In order to reduce the number of "gravity" computations (p_1p_2/D) for the 40 proposed stations, several stations were grouped together, thus arriving at 21 separate locations. To further reduce the number of computations any combination of these 21 locations which resulted in a trip less than 50 miles was omitted except for the following city pairs:

(1) Hartford-New Haven

(2) Washington-Baltimore

(3) Philadelphia-Trenton

Table 3 indicates the daily potential between any city pair along the proposed rail route. Figure 10 shows the daily density along the route with passenger-miles above the line and passengers below the line.

In order to both simplify and clarify the data (or lack of data) in the next chapter, discussion and figures are limited to the nine major cities in Megalopolis. Table 4 lists these nine cities and what per cent of the total potential traffic is generated by each.

Table 5 shows what per cent of each of the nine cities' total traffic potential within Megalopolis goes to the other eight.

Table 6 is similar in format to the tables used to list actual travel data and is made up so that the data (or lack of data) in these tables can be put in proper perspective. It lists the passenger potential between the cities and how this potential compares percentagewise with the total potential of the leading cities. Example:

> Springfield accounts for only 2.33 per cent of the total potential of the route (Table 4) and the Springfield-New Haven traffic accounts for only 2.11 per cent of the traffic from Springfield; yet Springfield-New York accounts for 58.37 per cent of the traffic from Springfield (Table 6).

Table 3

Daily City-City Passenger Potential

City	D.C. 21	Balt. 20	Phila. 19	Trent. 18	Bd.Bk. 17	Newark 16	Kenn. 15	N.Y. 14	T'nk. 13	T'twn. 12
1. Boston	3,295	1,464	5,502	379	624	3,550	2,127	13,297	2,478	1,662
2. Providence	1,126	506	1,920	133	221	1,271	1,346	4,603	892	605
3. Woonsocket	156	70	270	19	31	182	191	677	128	87
4. Webster-Worcester	500	229	807	56	194	561	587	2,094	396	272
5. Springfield	704	324	1,318	95	164	993	1,002	3,691	717	511
6. Windsor Locks - Granby	205	95	390	28	49	302	302	1,122	220	21
7. Hartford-Plainville	1,599	748	3,179	234	420	2,653	2,568	9,802	649	336
8. Waterbury-Meriden	429	202	871	65	118	163	719	2,782	98	53
9. Shelton-New Haven	825	391	1,859	132	247	594	1,713	1,951	365	
10. Stepney	453	220	1,019	79	3	44	23	143	28	
11. Bedford	572	286	1,410	11	18					
12. Tarrytown	1,633	809	4,232	49	83					
13. Teaneck	2,832	1,429	2,102	144						
14. New York	16,335	8,257	13,719	894						
15. Kennedy	4,816	2,393	12,756	165						
16. Newark	4,487	2,295	4,500	329						
17. Bound Brook	982	520	709							83
18. Trenton	775	436	1,259			329	165	894	144	49
19. Philadelphia	14,284	3,942		1,259	709	4,500	12,756	13,719	2,102	4,232
20. Baltimore	6,074		3,942	436	520	2,295	2,393	8,257	1,429	809
21. Washington		6,074	14,284	775	982	4,487	4,816	16,335	2,832	1,633
Below line total	0	6,074	18,226	2,470	2,211	11,611	20,130	39,205	6,507	6,806
Column total	62,082	30,690	76,048	5,282	4,383	26,307	30,708	79,367	12,478	10,353
Above line total	62,082	24,616	57,822	2,812	2,172	10,313	10,578	40,162	5,971	3,547

Daily City-City Passenger Potential

City	B'fd. 11	Stpny. 10	N.H. 9	Wtby. 8	Htfd. 7	W.Lks. 6	Spr. 5	Wor. 4	Woon. 3	Prov. 2	Boston 1
1. Boston	695	674	1,030	682	2,801	114	671	800			
2. Providence	256	252	495	339	762	76	438	621			
3. Woonsocket	37	37	72	11	95	9	57				
4. Webster-Worcester	117	118	233	44	362					621	800
5. Springfield	38	13	232						57	438	671
6. Windsor Locks-Granby	7	3	47						9	76	114
7. Hartford-Plainville	124	50	944					362	95	762	2,801
8. Waterbury-Meriden	19							44	11	339	682
9. Shelton-New Haven					944	47	232	233	72	495	1,030
10. Stepney					50	3	13	118	37	252	674
11. Bedford				19	124	7	38	117	37	256	695
12. Tarrytown				53	336	21	511	272	87	605	1,662
13. Teaneck		28	365	98	649	220	717	396	128	892	2,478
14. New York		143	1,951	2,782	9,802	1,122	3,691	2,094	677	4,603	13,297
15. Kennedy		23	1,713	719	2,568	302	1,002	587	191	1,346	2,127
16. Newark		44	594	163	2,653	302	993	561	182	1,271	3,550
17. Bound Brook	18	3	247	118	420	49	164	194	31	221	624
18. Trenton	11	79	132	65	234	28	95	56	19	133	379
19. Philadelphia	1,410	1,019	1,859	871	3,179	390	1,318	807	270	1,920	5,502
20. Baltimore	286	220	391	202	748	95	324	229	70	506	1,464
21. Washington	572	453	825	429	1,599	205	704	500	156	1,126	3,295
Below line total	2,297	2,012	8,077	5,519	23,306	2,791	9,802	6,570	2,129	15,862	41,845
Column total	3,590	3,159	11,130	6,595	27,326	2,990	10,968	7,991	2,129	15,862	41,845
Above line total	1,293	1,147	3,053	1,076	4,020	199	1,166	1,421	0	0	0

GRAND TOTAL -- 471,283

FIG. 10 POTENTIAL DAILY TRAFFIC DENSITY ALONG HIGH-SPEED LINE

Table 4

Per Cent of Total Traffic Generated by the Following Cities

City	Passengers per Day	Per cent of Total	Cumulative Total
Boston	41,845	8.87	8.87
Providence	15,862	3.36	12.23
Springfield	10,968	2.33	14.56
Hartford	27,326	5.80	20.36
New Haven	11,130	2.36	22.72
New York	148,860	31.59	54.31
Philadelphia	76,048	16.14	70.45
Baltimore	30,690	6.51	76.96
Washington	62,082	13.17	90.13

Table 5

Per Cent of Traffic from Nine Cities Generated by the Other Eight

City	Per Cent
Boston	86.5
Providence	84.2
Springfield	92.0
Hartford	94.0
New Haven	91.3
New York	91.5
Philadelphia	85.6
Baltimore	90.6
Washington	90.8

Table 6

Major City to City Potential vs. Per Cent of Total Potential

Cities	Passenger Potential	Per Cent of Cities' Potential
Boston and		
Providence		
Springfield	671	1.60
Hartford	2,801	6.69
New Haven	1,030	2.46
New York	21,452	51.26
Philadelphia	5,502	13.14
Baltimore	1,464	3.49
Washington	3,295	7.87
Providence and		
Springfield	438	2.76
Hartford	762	4.80
New Haven	495	3.12
New York	8,112	51.14
Philadelphia	1,920	12.10
Baltimore	506	3.19
Washington	1,126	7.09
Springfield and		
Hartford		
New Haven	232	2.11
New York	6,403	58.37
Philadelphia	1,318	12.01
Baltimore	324	2.95
Washington	704	6.41
Hartford and		
New Haven	944	3.4
New York	15,672	57.35
Philadelphia	3,179	11.63
Baltimore	748	2.73
Washington	1,599	5.70
New Haven and		
New York	4,623	41.53
Philadelphia	1,859	16.70
Baltimore	391	3.51
Washington	825	7.41
New York and		
Philadelphia	33,077	22.89
Baltimore	14,374	9.94
Washington	28,470	19.70

Table 6 (cont'd.)

Cities	Passenger Potential	Per Cent of Cities' Potential
Philadelphia and		
Baltimore	3,942	5.18
Washington	14,284	18.78
Baltimore and		
Washington	6,074	19.79

Chapter 4

History of Passenger Travel Within Megalopolis

Introduction

In order to accurately forecast the potential for any type of transportation, some knowledge must be gained about actual present and past passenger travel in the area under study. The determination of the actual number of passengers traveling a specific route is not always an easy matter. Due to the expense involved, very few carriers maintain origin-destination records; thus information of this type must be obtained from whatever other records are available. The information in the following pages is the authors' attempt to show a history of passenger travel within Megalopolis, at five-year intervals since 1947 by the three major commercial passenger carriers--rail, bus, and air.

Rail Passenger Traffic

The data for determining actual intercity rail travel was obtained from the Pennsylvania(6) and New Haven Railroads.(5) However, the data obtained from these two sources varied considerably, as will be explained below.

The most accurate method of determining the number of passengers traveling between any two cities is to count the total number of tickets sold and then relate this number, taking into account round-trips, furlough, family plan, etc., to total passengers. This information was obtained from the New Haven Railroad for the month of January 1962. However, their records for 1952 and 1957 were no longer available. Information for 1947 was obtained from Mr. R. A. Rice, who conducted a similar study when he worked for the New Haven Railroad.

The Pennsylvania Railroad would not permit the use of their records to obtain ticket counts. They did, however, provide information on two origin-destination studies conducted by them for the years 1958 and 1961 concerning the cities between New York and Washington. They also provided records giving the total daily number of passengers on their line for each month from 1947 to 1962.

In order to determine the average daily passengers traveling between any two cities for the years 1947, 1952, 1957, and 1962, the information obtained from the 1958 and 1961 origin-destination studies was utilized as follows: The average daily passengers traveling between each city along the line in 1958 and 1961 were taken as a percentage of the average daily passengers on the entire line for the year. This percentage was then applied to the average daily passengers for the years under study (1947, 1952, 1957, 1962) in order to obtain the average daily passengers traveling between each city on the line. This method gives a fair approximation, but the travel between some cities, New York-Philadelphia for example, does not necessarily follow the over-all trend of the line.

No information was available from either the Pennsylvania or New Haven Railroads concerning the number of passengers traveling between the cities of one line and cities on the other line. The 1958 study conducted by the Pennsylvania Railroad, however, did indicate the average daily passengers traveling from each city on the line to beyond New York, but not their ultimate destination. Similarly, from the New Haven records could be determined the average daily passengers traveling from Boston to beyond New York, but, again, with no ultimate destination.

Table 7 indicates the average daily passenger traffic between the nine major cities within Megalopolis, while tables 8 through 11 indicate the average daily passenger traffic between all the cities along the Boston-Washington corridor for which information was available. Figures 11 and 12 illustrate the daily rail density along the Boston-Washington corridor for 1947 and 1962. Figure 13 is a comparison of the daily rail density along Pennsylvania Railroad's New York-Washington line for 1958 and 1961 (data for this figure was obtained from the two previously mentioned origin-destination studies).

Bus Passenger Traffic

Compared with the data available on rail and air traffic, the information concerning bus traffic was relatively sketchy. This is due mainly to the large number of cash sales made by the bus driver, which makes any information obtained from the ticket counts doubtful. Also, no information was available from any of the bus companies concerning the amount of passenger traffic between cities of Megalopolis.

In order to obtain as accurate an estimate as possible of the bus passengers traveling between the cities of Megalopolis, the following procedure was used: The bus passenger traffic for 1962 was based on a study of intercity bus schedules published in Russell's Official Motor Coach Guide.(7) This required an arbitrary selection of the average load factor and an arbitrary distribution of passengers over successive segments of each bus route. This selection was based on average loads reported by the bus companies whose schedules were included in the study. An arbitrary 15 per cent was added for extra busses.

Table 7

Daily Passengers Between the Major Cities by Rail for the Years Indicated

Cities	1947	1952	1957	1958	1961	1962
Boston and						
Providence	2,448					552
Springfield	149					
Hartford	310					
New Haven	318					134
New York	3,647					1,286
Philadelphia						
Baltimore						
Washington						
Providence and						
Springfield						
Hartford						
New Haven	157					77
New York	1,549					684
Philadelphia						
Baltimore						
Washington						
Springfield and						
Hartford	599					72
New Haven						22
New York	844					451
Philadelphia						
Baltimore						
Washington						
Hartford and						
New Haven	592					134
New York	1,632					891
Philadelphia						
Baltimore						
Washington						
New Haven and						
New York	2,634					1,845
Philadelphia						
Baltimore						
Washington						

Table 7 (cont'd.)

Daily Passengers Between the Major Cities by Rail for the Years Indicated

Cities	1947	1952	1957	1958	1961	1962
New York and						
Philadelphia	13,273	10,029	7,464	6,658	6,858	5,385
Baltimore	2,926	2,211	1,646	1,470	1,254	1,187
Washington	3,872	2,926	2,177	1,943	2,209	1,570
Philadelphia and						
Baltimore	1,845	1,394	1,038	914	896	749
Washington	2,484	1,878	1,397	1,232	1,077	1,008
Baltimore and						
Washington	1,440	1,088	810	726	873	584

Table 8

Daily Rail Passengers 1947

Cities	Wash.	Balt.	Wilm.	Phila.	Trent.	N'ark.	N.Y.	Stam.
Boston							3,647	99
Providence							1,549	35
New London							492	
Springfield							844	
Hartford							1,632	
New Haven							2,634	174
Bridgeport							2,761	302
S. Norwalk							1,215	321
Waterbury								
Stamford							2,278	
New York	3,872	2,926	1,269	13,273	5,970			
Newark								
Trenton	585	144		2,215				
Philadelphia	2,480	1,845	2,791					
Wilmington	378	297						
Baltimore	1,440							

	W'by.	S.Nor.	B'pt.	N.Hav.	Hart.	S'fld.	N.Lon.	Prov.
Boston		18	145	318	310	149	206	2,448
Providence		8	71	157			90	
New London				205				
Springfield					599			
Hartford				592				
New Haven		75	796					
Bridgeport		362						
S. Norwalk								
Waterbury								
Stamford								
New York								
Newark								
Trenton								
Philadelphia								
Wilmington								
Baltimore								

Table 9

Daily Rail Passengers 1952

Cities	Wash.	Balt.	Wilm.	Phila.	Trent.	Newark through Boston
Boston						N
Providence						o
New London						
Springfield						
Hartford						D
New Haven						a
Bridgeport						t
S. Norwalk						a
Waterbury						
Stamford						
New York	2,926	2,211	959	10,029	4,510	
Newark						
Trenton	442	109		1,674		
Philadelphia	1,878	1,394	2,245			
Wilmington	286	224				
Baltimore	1,088					

Table 10

Daily Rail Passengers 1957

Cities	Wash.	Balt.	Wilm.	Phila.	Trent.	Newark through Boston
Boston						
Providence						N
New London						o
Springfield						
Hartford						
New Haven						D
Bridgeport						a
S. Norwalk						t
Waterbury						a
Stamford						
New York	2,177	1,646	714	7,464	3,357	
Newark						
Trenton	329	31		1,246		
Philadelphia	1,397	1,038	1,671			
Wilmington	213	167				
Baltimore	810					

Table 11

Daily Rail Passengers 1962

Cities	Wash.	Balt.	Wilm.	Phila.	Trent.	N'ark.	N. Y.	Stam.
Boston							1,286	76
Providence							684	36
New London							470	11
Springfield							451	11
Hartford							891	40
New Haven							1,845	58
Bridgeport							1,260	112
S. Norwalk							720	
Waterbury							227	
Stamford							2,215	
New York	1,570	1,187	515	5,385	2,422			
Newark								
Trenton	237	58		889				
Philadelphia	1,008	749	1,206					
Wilmington	153	120						
Baltimore	584							

	W'by.	S.Nor.	B'pt.	N.Hav.	Hart.	S'fld.	N.Lon.	Prov.
Boston		7	47	134	0	0	148	552
Providence		4	35	77	1	0	60	
New London		2	21	61	0	0		
Springfield		2	11	22	72			
Hartford		7	52	134				
New Haven		9	128					
Bridgeport	20	62						
S. Norwalk								
Waterbury								
Stamford								
New York								
Newark								
Trenton								
Philadelphia								
Wilmington								
Baltimore								

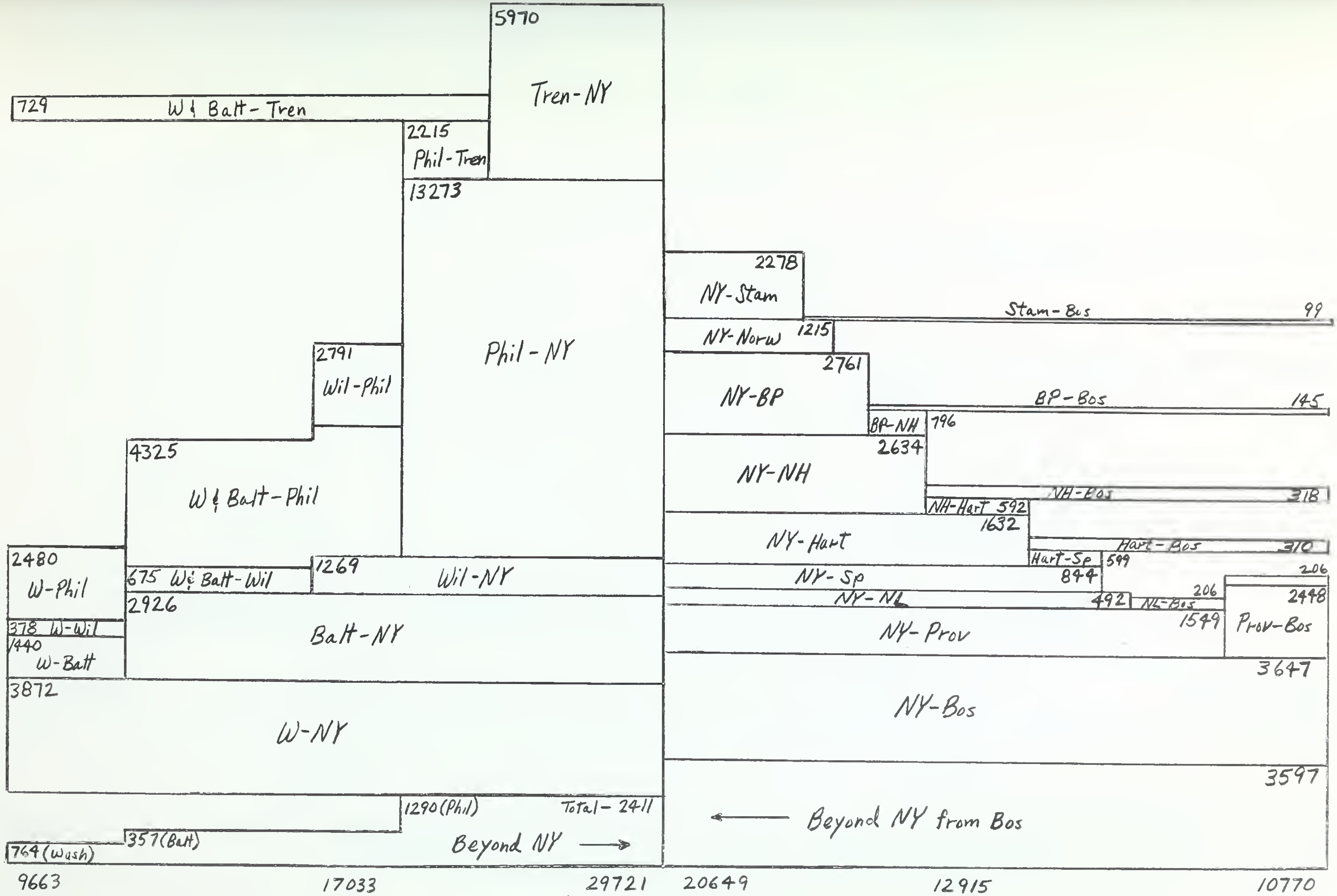


FIG. 11. DAILY RAIL DENSITY (1947)

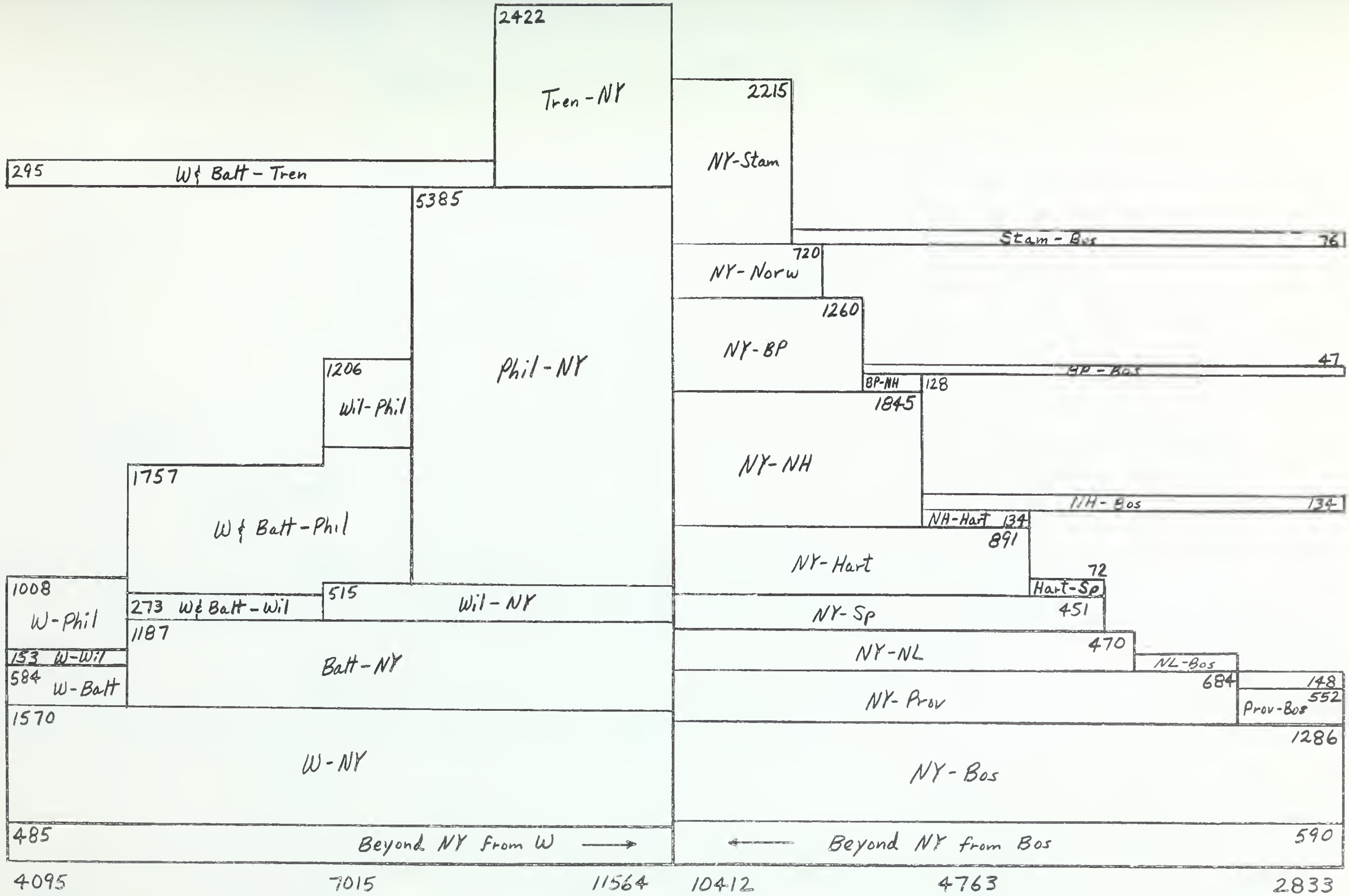


FIG. 12. DAILY RAIL DENSITY (1962)

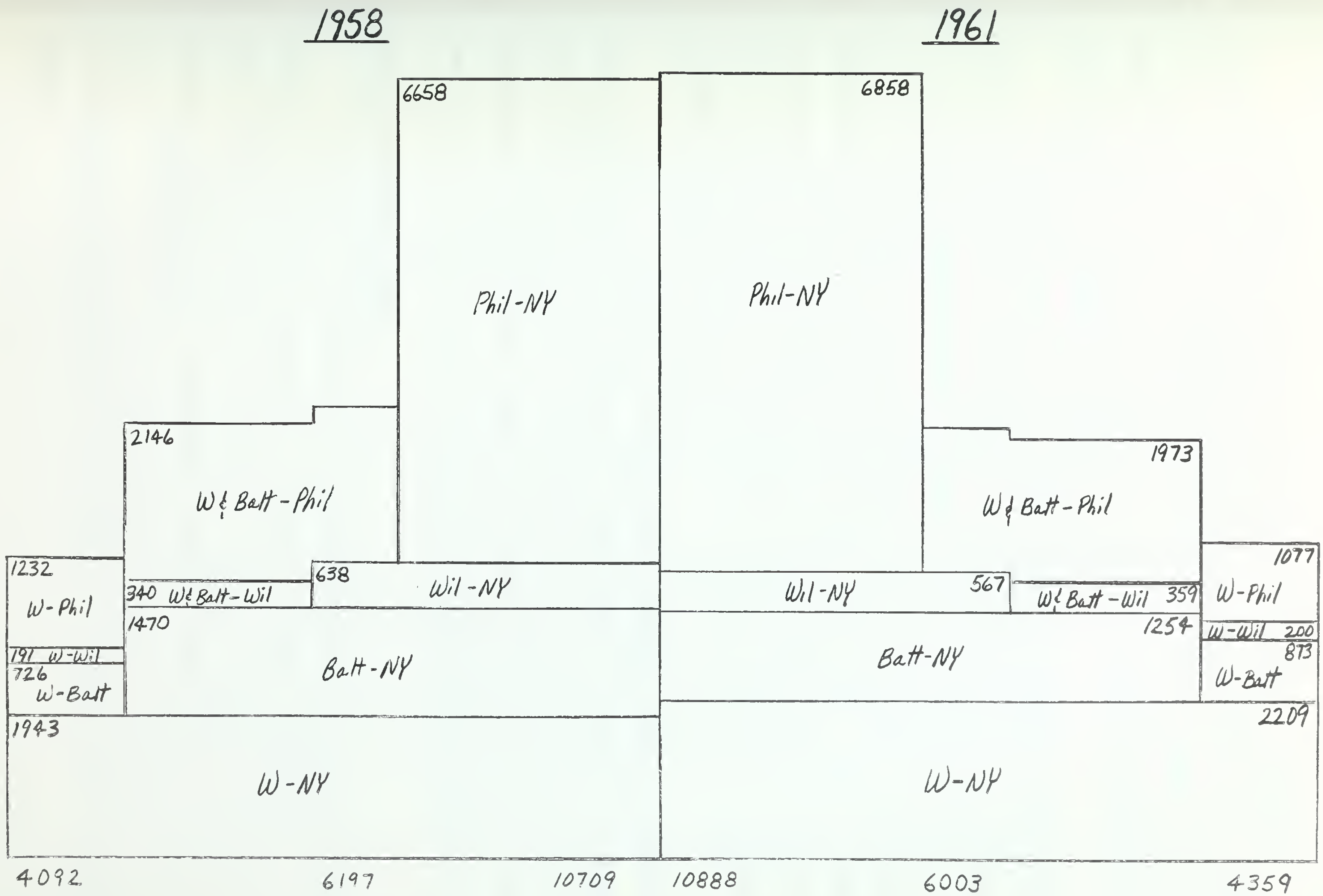


FIG. 13. A COMPARISON OF PENN RR DAILY RAIL DENSITY
— 1958 VS 1961 —

The study was limited to the following carriers: Greyhound Corporation, Eastern Greyhound Lines Division, Safeway Trails, Inc., The Short Line, Inc., and Trailways of New England, Inc. The study was further limited solely to express schedules for the more densely traveled routes, which resulted in slightly conservative data.

In order to obtain the bus traffic data for the years 1947, 1952 and 1957, the 1962 average daily city to city passenger traffic was applied to the total passengers carried that year by all the bus lines in the county to obtain percentages. These percentages were then applied to the total passengers carried for the years under study (1947, 1952, 1957) in order to determine the corresponding city to city passenger traffic. Because of this method of estimation, only the 1962 passenger figures can be given a reasonable degree of reliability.

Table 12 indicates the average daily passenger traffic between the nine major cities within Megalopolis, while tables 13 through 16 indicate the average daily passenger traffic between all the cities along the Boston-Washington corridor for which data was obtained. Figures 14 and 15 illustrate the daily bus density along the Boston-Washington corridor for 1947 and 1962.

Airline Passenger Traffic

The data for determining actual intercity travel by air was obtained from the Air Transport Association of America located in Washington, D. C., which publishes information collected by the Civil Aeronautic Board concerning the number of air passengers traveling between any city pair served by air.[34, 35, 36, 37] The following table indicates how the number of air passengers were determined for the years of interest (1947, 1952, 1957, 1962):

Table 12

Daily Passengers Between the Major Cities by Bus for the Years Indicated

Cities	1947	1952	1957	1962
Boston and				
Providence	998	652	440	392
Springfield	533	349	235	210
Hartford	1,810	1,184	800	714
New Haven	742	486	328	292
New York	2,861	1,872	1,264	1,124
Philadelphia	354	231	156	139
Baltimore	66	43	29	26
Washington	641	420	283	252
Providence and				
Springfield				
Hartford				
New Haven	213	139	94	84
New York	1,168	764	516	459
Philadelphia	53	35	23	21
Baltimore	10	6	4	4
Washington	53	35	24	21
Springfield and				
Hartford				
New Haven				
New York	820	537	363	323
Philadelphia				
Baltimore				
Washington				
Hartford and				
New Haven				
New York	2,223	1,454	961	857
Philadelphia				
Baltimore				
Washington				
New Haven and				
New York	2,265	1,482	998	890
Philadelphia	129	84	57	51
Baltimore	13	8	6	5
Washington	45	29	20	18

Table 12 (cont'd.)

Daily Passengers Between the Major Cities by Bus for the Years Indicated

Cities	1947	1952	1957	1962
New York and				
Philadelphia	7,802	5,104	3,447	3,066
Baltimore	2,049	1,340	905	809
Washington	6,834	4,470	3,020	2,689
Philadelphia and				
Baltimore	1,306	855	577	513
Washington	1,792	1,172	792	704
Baltimore and				
Washington	6,090	3,984	2,691	2,392

Table 13

Daily Bus Passengers 1947

Cities	Wash.	Balt.	Wilm.	Phila.	Trent.	N'ark.	N. Y.	Stam.
Boston	641	66	25	354		94	2,861	
Providence	53	10		53			1,168	
New London							369	
Springfield							820	
Hartford						48	2,175	
New Haven	45	13		129		6	2,259	
Bridgeport	53	6		22			445	
S. Norwalk								
Waterbury								
Stamford								
New York	6,834	2,049	592	7,802	251	2,049		
Newark	498	163	88	1,473	70			
Trenton	60	27	20	185				
Philadelphia	1,792	1,306	654					
Wilmington	533	338						
Baltimore	6,090							

Cities	W'by.	S.Nor.	B'pt.	N.Hav.	Hart.	S'fld.	N.Lon.	Prov.
Boston			195	742	1,810	533	480	998
Providence			53	213				
New London								
Springfield								
Hartford								
New Haven			295					
Bridgeport								
S. Norwalk								
Waterbury								
Stamford								
New York								
Newark								
Trenton								
Philadelphia								
Wilmington								
Baltimore								

Table 14

Daily Bus Passengers 1952

Cities	Wash.	Balt.	Wilm.	Phila.	Trent.	N'ark.	N. Y.	Stam.
Boston	420	43	17	231		615	1,872	
Providence	35	6		35			764	
New London							241	
Springfield							537	
Hartford						31	1,423	
New Haven	29	8		84		4	1,478	
Bridgeport	35	4		15			291	
S. Norwalk								
Waterbury								
Stamford								
New York	4,470	1,340	387	5,104	164	1,340		
Newark	326	106	58	964	46			
Trenton	39	17	13	121				
Philadelphia	1,172	855	428					
Wilmington	349	221						
Baltimore	3,984							

Cities	W'by.	S.Nor.	B'pt.	N.Hav.	Hart.	S'fld.	N.Lon.	Prov.
Boston			128	486	1,184	349	314	652
Providence			35	139				
New London								
Springfield								
Hartford								
New Haven			193					
Bridgeport								
S. Norwalk								
Waterbury								
Stamford								
New York								
Newark								
Trenton								
Philadelphia								
Wilmington								
Baltimore								

Table 15

Daily Bus Passengers 1957

City	Wash.	Balt.	Wilm.	Phila.	Trent.	N'ark.	N. Y.	Stam.
Boston	283	29	11	156		41	1,264	
Providence	24	4		23			516	
New London							163	
Springfield							363	
Hartford							961	
New Haven	20	6		57		21	998	
Bridgeport	24	2		10		2	196	
S. Norwalk								
Waterbury								
Stamford								
New York	3,020	905	262	3,447	111	905		
Newark	220	72	39	651	31			
Trenton	27	12	9	82				
Philadelphia	792	577	289					
Wilmington	235	149						
Baltimore	2,691							

	W'by.	S.Nor.	B'pt.	N.Hav.	Hart.	S'fld.	N.Lon.	Prov.
Boston			86	328	800	235	212	440
Providence			23	94				
New London								
Springfield								
Hartford								
New Haven			130					
Bridgeport								
S. Norwalk								
Waterbury								
Stamford								
New York								
Newark								
Trenton								
Philadelphia								
Wilmington								
Baltimore								

Table 16

Daily Bus Passengers 1962

Cities	Wash.	Balt.	Wilm.	Phila.	Trent.	N'ark.	N. Y.	Stam.
Boston	252	26	10	139		37	1,124	
Providence	21	4		21			459	
New London							145	
Springfield							323	
Hartford							857	
New Haven	18	5		51		19	890	
Bridgeport	21	2		9		2	175	
S. Norwalk								
Waterbury								
Stamford								
New York	2,689	809	223	3,066	99	809		
Newark	196	64	35	583	28			
Trenton	24	11	8	73				
Philadelphia	704	513	257					
Wilmington	210	133						
Baltimore	2,392							

Cities	W'by.	S.Nor.	B'pt.	N.Hav.	Hart.	S'fld.	N.Lon.	Prov.
Boston			77	292	714	210	189	392
Providence			21	84				
New London								
Springfield								
Hartford								
New Haven			116					
Bridgeport								
S. Norwalk								
Waterbury								
Stamford								
New York								
Newark								
Trenton								
Philadelphia								
Wilmington								
Baltimore								

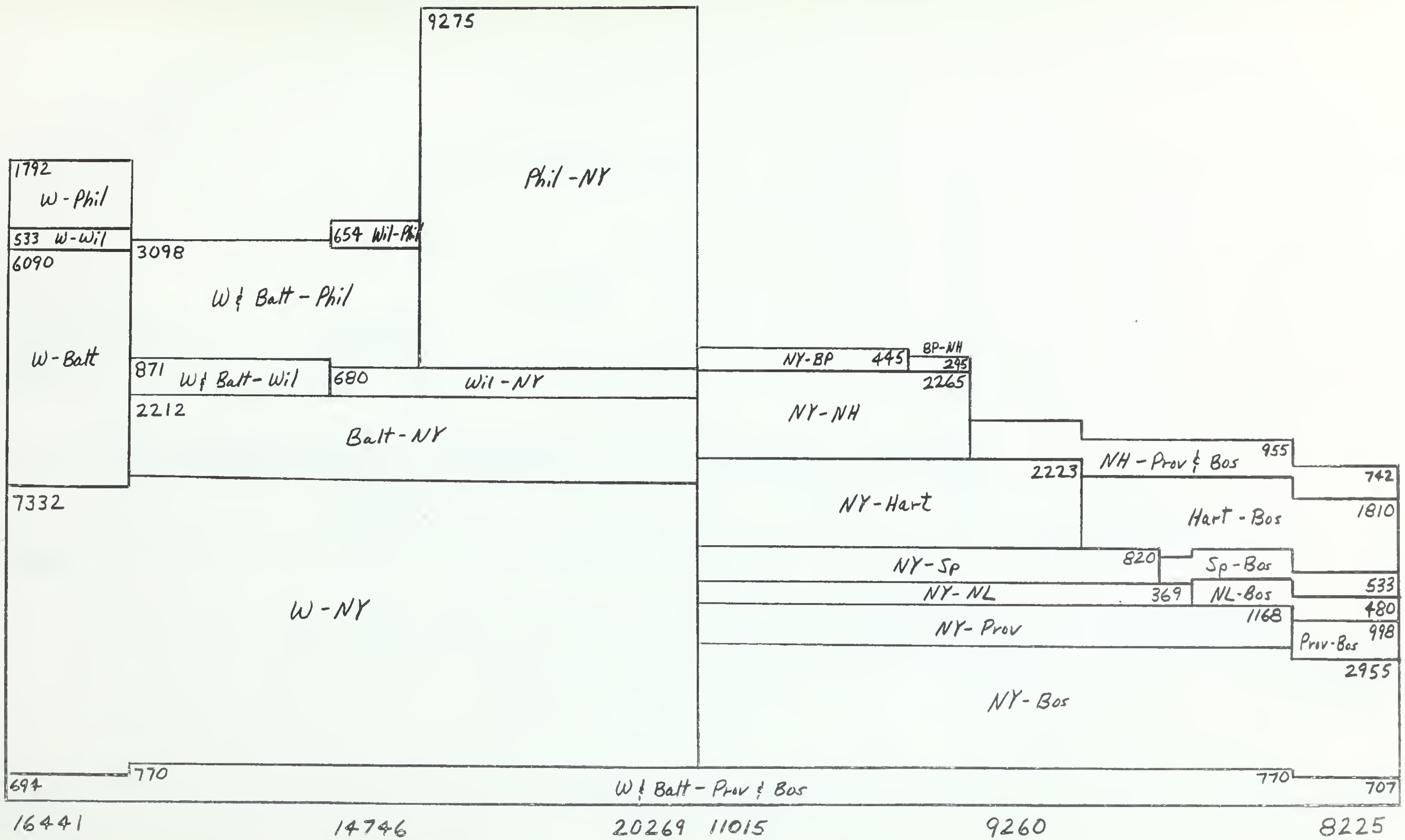


FIG. 14. DAILY BUS DENSITY (1947)

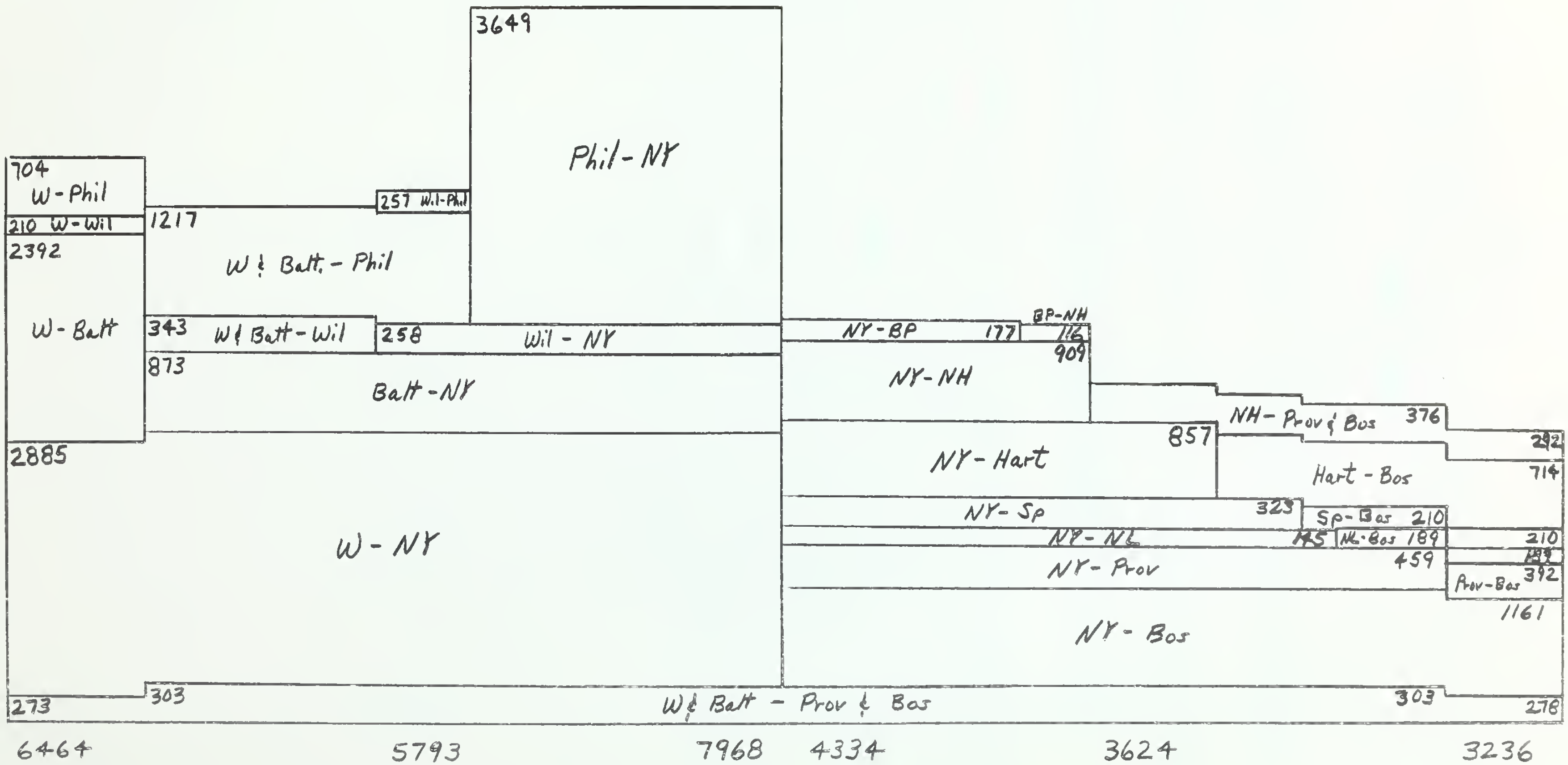


FIG. 15. DAILY BUS DENSITY (1962)

Table 17

Determination of Air Passengers

Year	Type Sample
1947	All tickets sold in March were counted.
1952	All tickets sold during a two-week period in September were counted.
1957	All tickets sold during a two-week period in March were counted.
1962	A continuous 10 per cent sample of all tickets sold during the first quarter were counted.

The number of tickets sold for the periods indicated above were then adjusted to represent average daily air passengers. Table 18 indicates the average daily passenger traffic between the nine major cities of Megalopolis, while tables 19 through 22 indicate the average daily passenger traffic between all the cities along the Boston-Washington corridor which are served by air. Figures 16 through 19 illustrate the daily air density along the Boston-Washington corridor for 1947, 1952, 1957, and 1962.

Table 18

Daily Passengers Between the Major Cities by Air for the Years Indicated

Cities	1947	1952	1957	1962
Boston and				
Providence	12	11	8	6
Springfield	8			
Hartford	96	40	74	37
New Haven	4	4	3	
New York	1,531	1,417	1,794	3,096
Philadelphia	81	149	237	445
Baltimore	22	31	56	118
Washington	127	186	290	521
Providence and				
Springfield				
Hartford		2	2	3
New Haven		2		
New York	252	255	313	285
Philadelphia	10	23	15	47
Baltimore	3	4	7	7
Washington	9	27	40	51
Springfield and				
Hartford				
New Haven				
New York	15			
Philadelphia	3			
Baltimore				
Washington	3			
Hartford and				
New Haven				
New York	101	142	193	241
Philadelphia	7	20	28	78
Baltimore	2	7	1	14
Washington	14	42	60	100
New Haven and				
New York	1	6	4	2
Philadelphia				
Baltimore			1	
Washington		3	4	9

Table 18 (cont'd.)

Daily Passengers Between the Major Cities by Air for the Years Indicated

Cities	1947	1952	1957	1962
New York and				
Philadelphia	47	114	120	165
Baltimore	72	103	177	264
Washington	845	1,268	1,630	2,575
Philadelphia and				
Baltimore	1	2	1	15
Washington	35	101	168	263
Baltimore and				
Washington	17	30	26	30

Table 19

Daily Air Passengers 1947

Cities	Wash.	Balt.	Wilm.	Phila.	Trent.	N'ark.	N. Y.	Stam.
Boston	127	22		81			1,531	
Providence	9	3		10			252	
New London								
Springfield	3			3			15	
Hartford	14	2		7			101	
New Haven							1	
Bridgeport	1						3	
S. Norwalk								
Waterbury								
Stamford								
New York	845	72		47				
Newark								
Trenton								
Philadelphia	35	1						
Wilmington								
Baltimore	17							

Cities	W'by.	S.Nor.	B'pt.	N.Hav.	Hart.	S'fld.	N.Lon.	Prov.
Boston			11	4	96	8		12
Providence								
New London								
Springfield								
Hartford								
New Haven								
Bridgeport								
S. Norwalk								
Waterbury								
Stamford								
New York								
Newark								
Trenton								
Philadelphia								
Wilmington								
Baltimore								

Table 20

Daily Air Passengers 1952

Cities	Wash.	Balt.	Wilm.	Phila.	Trent.	N'ark.	N. Y.	Stam.
Boston	186	31	6	149			1,417	
Providence	27	4	2	23			255	
New London							2	
Springfield-Hartford	42	7		20			142	
New Haven	3						6	
Bridgeport							3	
S. Norwalk								
Waterbury								
Stamford								
New York	1,268	103	5	114				
Newark								
Trenton								
Philadelphia	101	2	1					
Wilmington	4							
Baltimore	30							

	W'by.	S.Nor.	B'pt.	N.Hav.	Hart.	S'fld.	N.Lon.	Prov.
Boston			2	4	40			11
Providence				2	2			
New London								
Springfield-Hartford								
New Haven								
Bridgeport								
S. Norwalk								
Waterbury								
Stamford								
New York								
Newark								
Trenton								
Philadelphia								
Wilmington								
Baltimore								

Table 21

Daily Air Passengers 1957

Cities	Wash.	Balt.	Wilm.	Phila.	Trent.	N'ark.	N.Y.	Stam.
Boston	290	56	12	237			1,794	
Providence	40	7	1	15			313	
New London	2						1	
Springfield-Hartford	60	1	1	28			193	
New Haven	4	1					4	
Bridgeport	2						1	
S. Norwalk								
Waterbury								
Stamford								
New York	1,630	177	6	120				
Newark								
Trenton								
Philadelphia	168	1	1					
Wilmington	7							
Baltimore	26							

	W'by.	S.Nor.	B'pt.	N.Hav.	Hart.	S'fld.	N.Lon.	Prov.
Boston			4	3	74			8
Providence					2			
New London								
Springfield-Hartford								
New Haven								
Bridgeport								
S. Norwalk								
Waterbury								
Stamford								
New York								
Newark								
Trenton								
Philadelphia								
Wilmington								
Baltimore								

Table 22

Daily Air Passengers 1962

Cities	Wash.	Balt.	Wilm.	Phila.	Trent.	N'ark.	N. Y.	Stam.
Boston	521	118	3	445	3		3,096	
Providence	51	7		47			285	
New London	21	1	1	4				
Springfield-Hartford	100	14	1	78	2		241	
New Haven	9						2	
Bridgeport	21	5		6				
S. Norwalk								
Waterbury								
Stamford								
New York	2,575	264	4	165				
Newark								
Trenton	1			1				
Philadelphia	263	15	1					
Wilmington	7							
Baltimore	30							

Cities	W'by.	S.Nor.	B'pt.	N.Hav.	Hart.	S'fld.	N.Lon.	Prov.
Boston			17		37			6
Providence					3			
New London					3			
Springfield-Hartford								
New Haven								
Bridgeport								
S. Norwalk								
Waterbury								
Stamford								
New York								
Newark								
Trenton								
Philadelphia								
Wilmington								
Baltimore								

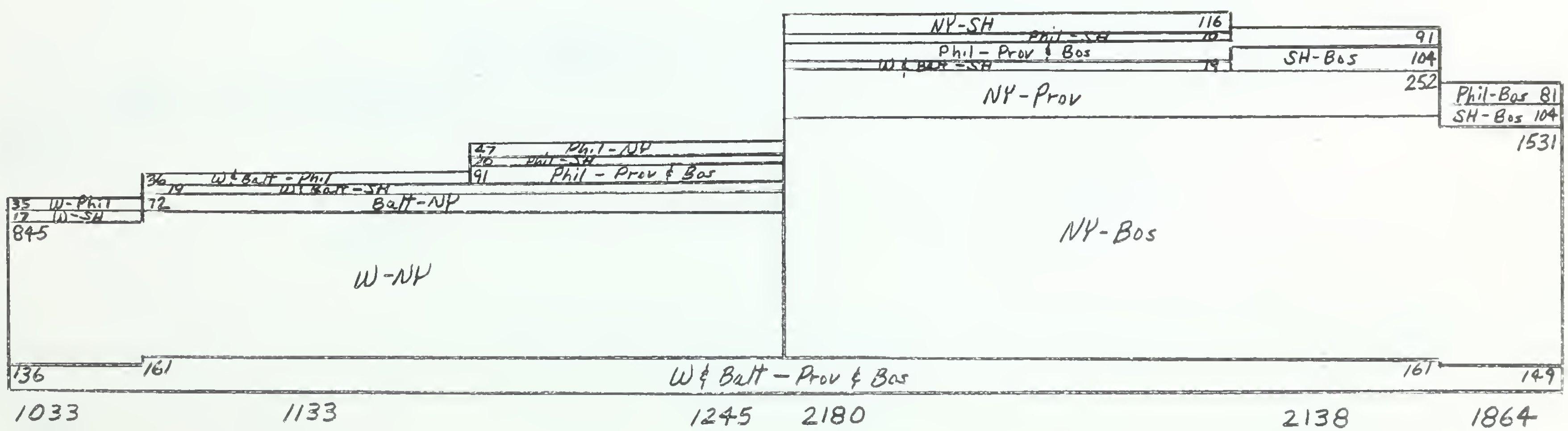


FIG. 16. DAILY AIR DENSITY (1947)

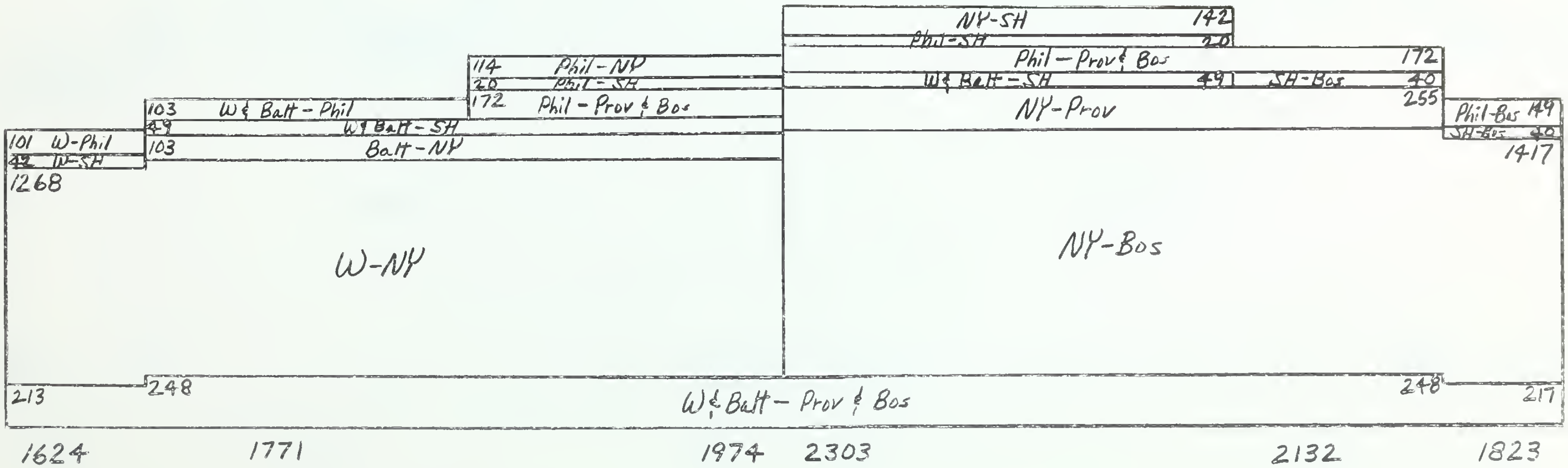


FIG. 17. DAILY AIR DENSITY (1952)

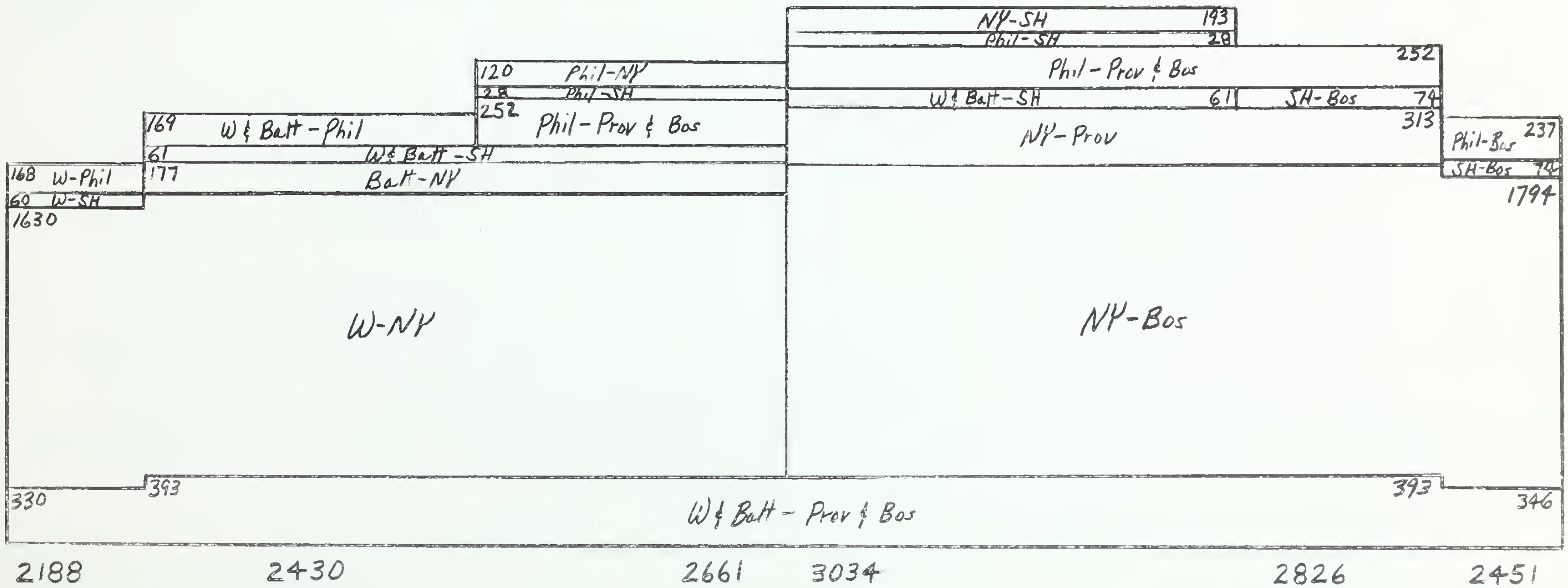


FIG 18. DAILY AIR DENSITY (1957)

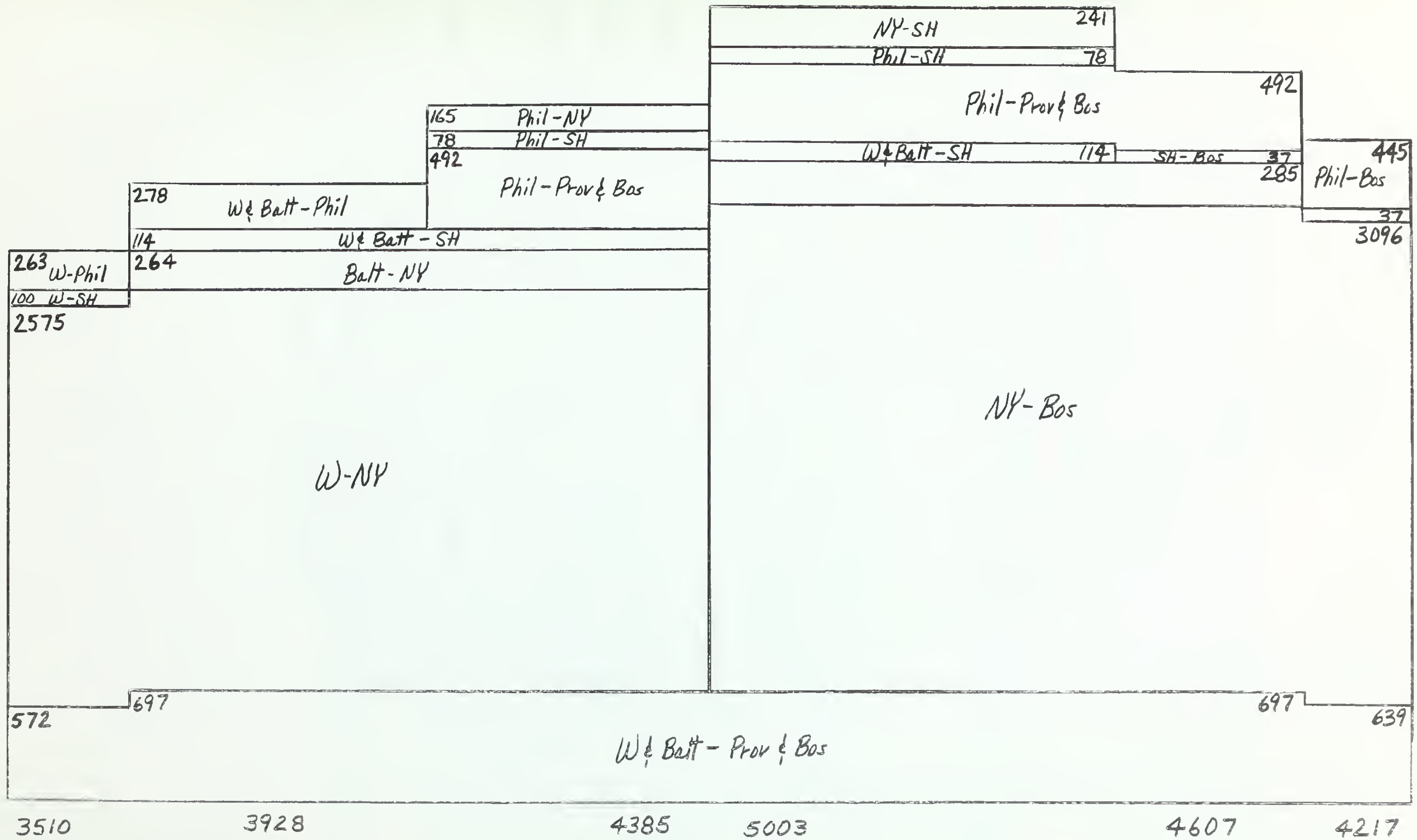


FIG. 19. DAILY AIR DENSITY (1962)

Chapter 5

Evaluation

The decline of commercial passenger traffic in Megalopolis since 1947 is rather evident from the data presented in Chapter 4. Percentage-wise the commercial passenger traffic has decreased 47 per cent from 1947 to 1962, while the population of Megalopolis has increased 18 per cent. With regard to a high-speed rail transportation system, there are two major questions to be answered: What has caused this decline in passenger traffic, and is the trend reversible?

Undoubtedly one of the major causes affecting the loss of commercial passenger traffic has been the increased utilization of the automobile, along with the excellent network of highways in Megalopolis. It will soon be possible to drive from Boston to Washington without ever having to stop for a traffic light. Many of the large metropolitan areas in Megalopolis are either enclosed by a circumferential limited-access highway or have an expressway passing through the center of the metropolitan area, thus allowing the intercity motorist to avoid the central business district if he so desires. To better illustrate the increase in automobile traffic, data obtained from the Connecticut Highway Department showed that the average daily traffic at Stratford and Milford, Connecticut (12 miles west of New Haven), for 1947 and 1962 was as follows:(2)

Location of auto count	1947	1962
W. Cross Parkway at Milford	11,466	21,257
U. S. 1 (Housatonic R.) at Milford	22,000	21,600
Conn. Turnpike at Stratford	-	29,710
Totals	33,466	72,567

Per cent increase -- 117%

The Pennsylvania and New Haven Railroads, instead of attempting to encourage the people to ride their trains after passenger revenue started to decline during the early "fifties," did just the opposite by reducing service (or in some cases canceling service altogether) and raising fares. These two items were accomplished in an attempt to maintain the same revenue; however, the result was that more people stopped riding the trains and started using their automobiles. Between 1947 and 1962 the passenger traffic on the Boston-New York segment of the New Haven Railroad decreased 75 per cent, and, similarly, on the New York-Washington segment of the Pennsylvania Railroad passenger traffic decreased about 50 per cent. The fault does not lie entirely with the railroads, however. They are very heavily taxed in Megalopolis and in 1962 showed only a 1.77 per cent return on their investment.(38)

Airline traffic, on the other hand, has steadily increased in Megalopolis since 1947 due to the expansion of service and the desire of travelers for a more rapid means of transportation. Presently New York-Boston and New York-Washington are the two most densely traveled air routes in the United States.(37)

The reversibility (or irreversibility) of the decline of rail passenger traffic has been a controversial subject. Some people believe that the end of rail passenger service is inevitable, whereas many more believe that rail passenger service is indispensable and cannot be duplicated by any other means of transportation. Railroads are inherently the most efficient means of land transportation in existence. Whether or not they are efficiently utilized is another question.

There are several major factors that may help increase rail passenger traffic in the future, whether or not any improvements are made by the Pennsylvania or New Haven railroads. The most important of these factors is the rapid rate at which the new super highways are becoming overcrowded. It has been estimated that by 1980 the new 41,000-mile National System of Interstate Highways will be inadequate. Another factor is the increase in air travel time caused by many airports being oversaturated with commercial flights, which results in delays of landing and taking off. This condition is especially bad in Megalopolis. Another problem facing the airlines in Megalopolis is the age of their short-haul intercity aircraft. As these planes are replaced with jet aircraft, operating costs will increase with little possibility of an equivalent increase in revenue. This may result in air routes of under 500 miles becoming more unprofitable. The major short-haul airline in Megalopolis, Eastern, is already wrestling with a staggering deficit.

The authors believe that the above factors will ultimately help increase the rail passenger traffic in Megalopolis. However, with the combination of the above factors and the construction of a new high-speed rail system between Boston and Washington, there is no question that the rail passenger traffic would increase. The new high-speed rail system

would provide the following six factors, any four of which usually result in an increase of passenger traffic:

(1) Reduction in fare.

(2) Faster schedule.

(3) Better timing of schedules.

(4) Modern equipment.

(5) Increased advertising and promotion.

(6) Relocation of some terminals and stops.

Another phase of the Transportation Science Program at Princeton University has been to estimate the amount and sources of revenue required to make a high-speed rail system in Megalopolis successful. Based on a construction cost of two-and-one-half billion dollars for the complete system, including equipment, it is estimated that the system should gross about 800 million dollars per year in order to be considered profitable. This 800 million dollars in revenue would come from the following sources: passengers, 150 million; mail and express, 50 million; auto piggyback, 200 million; truck piggyback, 200 million; and bulk freight, 200 million. Based on a revenue of 3.5 cents per passenger mile, an average density of 27,400 passengers per day (13,700 each way) along the high-speed line would be required in order to attain the 150 million dollars from passenger traffic.* This is 31.4 per cent of the estimated potential of 87,130 passengers per day for all commercial carriers (refer to Fig. 10). Table 23 shows a comparison between 1947 and 1962 total commercial passengers (rail, bus and air) for certain intercity pairs in Megalopolis and what percentage of the 1960 potential was achieved.

*(About 10 million end-to-end passengers per year equivalent at a $15 fare for the 450 miles.)

Table 23

Total Commercial Traffic Between Major Cities for the Indicated Years Compared to 1960 Potential

City Pairs	1947	Per Cent Potential	Potential	1962	Per Cent Potential
Boston-Hartford	2,216	79.1	2,801	751	26.8
Boston-New Haven	1,064	103.3	1,030	426	41.3
Boston-New York	8,039	37.4	21,452	5,506	25.6
Providence-New Haven	370	74.7	495	161	32.5
Providence-New York	2,969	36.6	8,112	1,428	17.6
Hartford-New York	3,956	25.2	15,672	1,989	12.6
New Haven-New York	4,900	105.9	4,623	2,737	59.2
New York-Philadelphia	21,122	63.8	33,077	10,089	30.5
New York-Baltimore	5,047	35.1	14,374	2,327	16.1
New York-Washington	11,484	40.3	28,470	7,473	26.2
Philadelphia-Baltimore	3,152	79.9	3,942	1,424	36.1
Philadelphia-Washington	4,311	30.1	14,284	2,044	14.3
Total	68,630	711.3	148,332	36,355	338.8

Traffic loss between 1947 and 1962 -- 47%

Average Potential in 1947 -- 59.2%

Average Potential in 1962 -- 28.2%

In view of the above figures and previous discussion, it appears reasonable to expect that a high-speed rail transportation system between Boston and Washington could realistically generate a volume of passenger traffic necessary for profitable operations.

It was established in Chapter 2 that the most logical area in the United States to construct this high-speed rail system was between Boston and Washington. However, a similar high-speed rail system could also be successfully utilized in the future in other large metropolitan areas, such as:

Sacramento-San Francisco (Oakland)-Los Angeles-San Diego

Milwaukee-Chicago-Detroit-Toledo-Cleveland-Pittsburgh

Chicago-Indianapolis-Cincinnati or
Cleveland-Columbus-Cincinnati

Kansas City-St. Louis-Chicago

Ft. Worth (Dallas)-Houston-New Orleans

Miami-Jacksonville

Portland-Seattle-Vancouver, B.C, etc.

Appendix A

Summary of Schedules and Services

Train Frequency at Major Megalopolis Points

The basic service to be operated in conjunction with the proposed high-speed rail service in the Washington-Boston area is based upon regular through fast trains every other hour to and from each major metropolitan area. In this fashion, with alternate routing available, there is the equivalent of regular hourly fast service among all major city pairs. The following table summarizes this service.

BOSTON MASS	Hourly -Y- shuttle via O.R. to Providence. Hourly N.R. Limiteds to N.Y. consisting of odd-hour -B- nonstops to Penn. Sta., and even-hour -J-1- one-stops (Hartford) to Penn. Sta. and G.C.T. Hourly service to Phila. and Washington consisting of odd-hour -E- limiteds and even-hour -J-2- expresses with walk-up transfer. Also odd-hour -W- shoreline (O.R.) expresses via Providence and New London to New Haven. Thence via N.R. to Grand Central. Summary. Equivalent of hourly service to Providence, Hartford, New York, Phila., and Washington. Two-hourly service to New London, Springfield and Baltimore.
PROVIDENCE R.I.	Hourly -Y- shuttle via O.R. to Boston. Hourly service to New York consisting of odd-hour -P-2- one-stops to Penn. Sta. or G.C.T. and even-hour -J-2- limiteds with walk-up transfer to G.C.T. Both these services (P-2 & J-2) stop at Hartford West. Hourly service to Washington Line consists of thru -J-2- even-hour trains and cross-platform transfer at West-Hartford on odd-hour -P-2- trains. Also even-hour -W- trains via O.R. shoreline to New London, New Haven and N.R. to G.C.T. Summary. About the same as Boston.
NEW LONDON CONN.	Odd-hour -W- service to Providence and Boston via the O.R. and quarter-till-odd-hour -W- service to New York via O.R. to New Haven thence via N.R. to Grand Central. Cross Platform change at New Haven from -W- trains to -C- trains to Penn. Station and Washington.
WORCESTER MASS.	Fifteen-minutes-after even-hour service on -M- trains to South Springfield, Hartford, West Haven, and New York--with choice of either Penn. Sta. or Grand Central. Cross-platform transfer at West Haven to Washington Line via -F- trains. -J- trains stop at South Worcester on the N.R. also giving twenty-after-even-hour service to N.Y., both stations, and to Phila., and Washington.

SPRINGFIELD MASS.	Quarter till odd-hour 2-stop service on -J- trains from Springfield to New York including walk-thru transfer to Washington (N.R.) cars. Thirty minutes after odd-hour service, 3-stops, downtown Springfield to Penn. Sta. and Grand Central via N.R. -P- trains. At 25 minutes after even hours, through -K- trains from Conn. Valley via Old Hartford thence N.R. express to either Penn. Sta. or Grand Central. Twenty-after-even hour service to Providence and Boston via -J- trains. Summary. Hourly service to all of New York City and West Hartford; two-hourly service to Washington Line, Boston and Providence, and to downtown Hartford. Change at downtown Hartford for two-hourly service to local O.R. shoreline points to New York & Phila. By changing at Hartford West on -P- trains, hourly service is available to New Washington Line. (-P- trains to -E- trains.)
HARTFORD CONN.	From Downtown Hartford: Odd-hour -M- service via O.R. and New Britain to N.R. and New York City, either Penn Sta. or G.C.T. Also odd-hour -C- service via O.R. and shoreline to New Haven, Bridgeport, Penn. Sta. and Wash. Line. Even-hour -T- train service via shoreline O.R. to G.C.T. (-T- trains). From West Hartford on New Route: Even-hour -E- trains to Phila. and Wash.; even-hour -P- service nonstop to Penn Sta. or G.C.T. Odd-hour -J- service to New York and to all Wash. Line points. Hourly -P- & -J- trains to Boston and Providence. Summary. Hourly service from West Hartford to Boston, Providence, all of New York, Phila. and Wash., etc. Hourly service from downtown Hartford to Springfield and O.R. shoreline points, including thru cars to Phila. area.
WATERBURY-MERIDEN New Route Sta.	Two hourly -F- trains eastbound at even hours to W. Hartford, Boston and connecting to Providence; and at fifteen minutes after odd hours westbound to Phila. & Wash. N.R. Points.
MERIDEN STA. Old Route	Two-hourly -C- trains to Penn. Sta. and Washington points via old shore line at 20 minutes after odd hours and two-hourly -T- trains via old shore line to Grand Central at 20 minutes after even hours. North-bound hourly -C- and -T- trains at 40 minutes after the hour to Hartford and Bradley Field stations.
NEW HAVEN Old Sta.	Hourly shore-line trains (-C- and -T-) to Bridgeport and New York, alternating G.C.T. and Penn Sta. with latter running through to Washington. Two-hourly New Route Trains, -W- service from New London to G.C.T. at 35 min. after odd hours on N.R. Two-hourly -W- service to New London and Providence at 10 min. after even hours.

WEST NEW HAVEN New Route — Two-hourly -W- service as described above, to N.Y. and New London. Also -F- trains as described for Waterbury-Meriden leaving ten minutes to even hours eastbound and 30 min. after odd hours westbound. Also two-hourly -M-K- trains to Hartford, Springfield and Worcester leaving on same schedules as -F- trains; ditto New York (westbound) -M-K- schedules.

BRIDGEPORT — New Route Station. Essentially same trains as West New Haven. Old Route Station. Essentially same trains as downtown New Haven except -W- trains which run via the New Route.

STAMFORD-NORWALK AREA — New Route Station. Same service as West New Haven & West Bridgeport.
Old Route Station. Same service as Old Route Bridgeport Station.

NEW YORK CITY — All trains except Providence shuttle and -F- service (Wash.-Boston mail trains) service downtown New York.
Penn Station: Hourly N.R. trains to Trenton-Phila.-Balt. & Wash. Two-hourly N.R. trains to Wilmington, Harrisburg & Albany. Two-hourly O.R. trains to Phila., Balt. & Wash.
Grand Central: Hourly N.R. trains to Boston, Providence, Hartford. Two hourly N.R. trains to New London, Old Hartford, Springfield and Worcester. Hourly O.R. trains to New Haven & Hartford.
Penn. Sta. Summary. A, X, Z, C, P-1, K, W, J-1
Grand Central Summary. B, P-2, J-1, M, W, T

TRENTON N.J. — West Trenton - New Line. Two-hourly -F- trains at 30 min. after even hours to Boston (eastbound) with platform transfer at Hartford to -J-2- trains for Providence; westbound at quarter till odd hours to West Phila., Balt., and New York. (Hourly -Z- Clocker service to both Phila. points and New York.) Also two-hourly -CX- service to both O.R. and N.R. Phila.-Wash. intermediate points, westbound, at even hours.
Downtown Trenton Old Route. Two-hourly -CX- trains to New York-New Haven-Hartford (east) at 15 min. after odd hours and both N.R. and O.R. Phila.-Wash. points (westbound) at 15 min. after even hours.
Summary. Trains each 30 min. West Trenton to New York.

PRINCETON-NEW BRUNSWICK, N.J. — New Line Stations. Certain -CX- trains to provide every other hour service at about 8:15-8:30 (even hours westbound) and 9:45-10:00 (odd-hours eastbound) to N.Y. or Washington.
Old Line Stations. -CX- trains will stop about 30 min. after odd hours westbound. Thus a 2-hourly service to all New York and all Phila.-Wash. points. Service to New England is available on all O.R. -CX- trains to Hartford and from West Trenton to Boston and Providence on the -F- trains.

PHILADELPHIA
All Routes

30th Street: Hourly -Z- clocker service via N.R. and Phila. N.W., to West Trenton and Manhattan-Kennedy. Running time to New York one hour from 30th Street. Two-hourly -CX- trains via old Trenton Route from Wash. to N.Y. at quarter till odd hours and two-hourly N.Y.-Wash. -CX- trains via old Wilmington Route at quarter till odd hours.
North Phila.: Two-hourly -CX- trains (N.Y. to Wash.) westbound at half after odd hours with both N.R. and O.R. sections (running times to Wash. 2 hours and 1 3/4 hours respectively). Two-hourly -CX- trains eastbound Washington to New York on the odd hours: running time one hour flat via Trenton. Thru cars to New Haven & Hartford.
New No. Phila. & N.W. Phila.: -Z- clocker trains hourly via West Trenton and New Route to Manhattan.
West Phila.: Hourly -CX- trains to New York alternating via No. Phila. and Old Trenton line (at 30 min. after even hours) and via N.W.Phila. & West Trenton (New Route) at 30 min. after odd hours. Running times one hour via new route and 90 minutes via old Trenton Route.

WILMINGTON
Old Route

Two-hourly clocker -Z- trains via 30th St. and New Route in 75 minutes to Manhattan-Kennedy at 15 minutes before even hours. Two-hourly -CX- service via old Trenton Route to New York at half after even hours in about 90 minutes; thru cars to New Haven and Hartford; change at Penn. Sta. or Hartford for Boston. Two-hourly -CX- service at odd hours westbound to Balt. & Washington.

BALTIMORE
Maryland

Downtown Stations. Hourly -CX- trains to Phila. & N.Y. points, running in two hours, on N.R. connection at 30 min. after the even hours and in two-and-a-half hours via Wilmington-Trenton old route at half after the odd hours. Hourly service locally to Washington via the -CX- trains. Change at W. Phila. for New England.
West Baltimore New Route Stations. Hourly -CX- trains to Phila. and N.Y. points alternating via N.R. all the way and via No. Phila.-Trenton old line. Running times 2 and 2 1/2 hours, respectively. Also two-hourly -F- trains at twenty-after odd hours to New England points and twenty-before even hours to Washington points. Westbound hourly service to Dulles Field via -CX- trains.

WASHINGTON

Dulles Field. Hourly -CX- expresses to New York and Kennedy alternating New Route all the way and via Old Route beyond W. Phila. Cross platform change for New England points at W. Phila. or Newark. Running time 2 to 2 1/2 hrs.
Union Station. Hourly -E- and -J-2- services to Boston and Providence. -J-2- trains run through to Prov. at odd hours, -E- trains run on even hours. Hourly -A- non-stop service to Penn.Station only. Running time 2 hours flat.

Train Service Key to
PROPOSED PRINCIPAL PASSENGER TRAIN SERVICE
Among Key Population Areas in Megalopolis on the
Projected High-Speed Washington-Boston Line

Stations	BOSTON (Prov.)	HARTFORD Area	NEW YORK Stations	PHILA. Area	WASHINGTON & Balt.
Boston	--	E*	*B#	E*	E*
Providence	Y#	J*E**P*	P*J*	J*E**	J*E**
Worcester	--	M*	M*	MF**	MF**
New London	W*	--	W*	W**	W**
So. Worcester	J*	J*M*	J*M*	J*M*	J*M*
Springfield	--	K*P*	K*P*	KP**	KP**
So. Springfield	J*	J*P*K*	J*P*K*	J*P**	J*P**
Hartford	--	--	T*C*M	XC*	XC*
Hartford West	E*J*	--	J*P*	J*E*	J*E*
Meriden Area	F*	T*M*	M*T*XC*	F*XC*	F*XC*
New Haven	W*	W*T*C*	W*T*C*	XC*	XC*
West New Haven	F*W*	M*F*	W*M*	M**F*	M**F*
Bridgeport Stas.	W*F*	T*XC*F*	W*M*T*	XC*F*	XC*F*
Grand Central	W*J*PE*	J*P*M*	--	--	--
Penn. Sta.	*B#	P*C*	--	Z-XC	A#XC
Kennedy	**	**	Z	Z	CX
W. Trenton	F*	F*	Z#	F*Z#CX	F*CX
Trenton	CX-PJ*	CX-PJ*	CX	CX*	CX*
No. Philadelphia	CX-PJ*	CX-PJ*	CX	--	CX
30th St. Philadelphia	CX-PJ*	CX-PJ*	CX*Z	--	CX*Z
W. Philadelphia	J*E*	J*E*	#JE*CX	--	#JE*CX
Wilmington	CX-PJ*	CX-PJ*	Z*CX*	#Z*CX*	CX*
W. Balt.	F*	F*	CX	#F*X*	#F*X*
Baltimore	CX-PJ*	CX-PJ*	XC	XC	#XC
Union Sta. Washington	J*E*F*	J*E*F*	A#	E*J*CX*	--
Dulles Field	CX-PJ*	CX-PJ*	CX	CX	--

#Nonstop *Two-Hourly **Platform Transfer (All trains hourly unless otherwise shown.)

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