other areas where the following characteristics are observed:

1. Homogeneity of traffic in terms of trip purpose and destination,
2. Distinctive peak periods that are highly directional,
3. Positive attitudes toward carpooling or bus use,
4. Extreme delays for existing travel, and
5. Available roadway widths or right-of-way for additional lanes.

While the Pensacola corridor is unique in that the corridor was a direct feeder to the Pensacola Naval Air Station, other corridors in other urban areas have the five characteristics noted above, and a system such as the one designed for Pensacola could be successfully implemented in these areas as well.

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Planning Rail Station Parking: Approach and Application

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The efforts of the Northeast Corridor Improvement Project to revitalize passenger railroad service have entailed planning numerous station improvements such as accommodating increased passenger parking requirements. Results of studies of 3 of the 11 stations along the corridor that are being upgraded to high-speed rail requirements are reported in this paper. A compendium of parking characteristics to enable planning officials to better assess the needs of rail passenger parkers is included. Topics covered are parking demand estimates, passenger trip characteristics, and fiscal considerations of providing parking at rail stations. Planning guidelines of 0.28 spaces/daily boarding Amtrak passenger and 0.32/commuter passenger are suggested. The need for subsidization to make planned parking facilities economically feasible is also emphasized.

The railroad network in the Northeast Corridor is being upgraded to offer reliable high-speed rail passenger service as an alternative to congested East Coast highways and airports. The corridor, as shown in Figure 1, extends from Washington, D.C., to Boston and includes 15 high-speed rail stations.

Every railroad station, whether located in the corridor or elsewhere, will have different factors influencing passenger parking requirements. Parking studies conducted under the auspices of the Northeast Corridor Improvement Project (NECIP) offer an opportunity to examine general relations that can help determine total parking requirements of the respective stations.

Rail station activity entails the three elements of parking demand conceptually presented in Figure 2—passenger demand for both long- and short-term spaces and nonpassenger (station employee, station visitor) demand. This paper focuses primarily on the passenger demand for long-term parking space. It addresses approaches used in determining passenger parking demand and application of the findings to define economic feasibility, as illustrated in the flowchart in Figure 3.

ESTIMATING PASSENGER PARKING DEMANDS

Parking studies were conducted at the Wilmington, New Haven, and Providence stations as part of NECIP. All cities have Amtrak (high-speed rail) as well as commuter (non-Amtrak) train service. Commuter service is provided in Wilmington by the Southeastern Pennsylvania Transportation Authority (SEPTA), in New Haven by Consolidated Rail Corporation (Conrail), and in Providence by the Boston and Maine Corporation (B&M).

Rail Passengers

Wilmington, the most centrally located of the corridor stations surveyed, has the most train activity: More than 75 trains depart daily. Only 26 trains leave from Providence, as detailed in Table 1. New Haven, however, has the most passenger activity of the three stations, primarily because of commuter trips to New York. An average of 1650 passengers depart from New Haven daily. Average daily boarding passenger volumes are 1335 and 760 at Wilmington and Providence, respectively.

New Haven is principally a commuter station; two-

Figure 1. Northeast rail corridor.

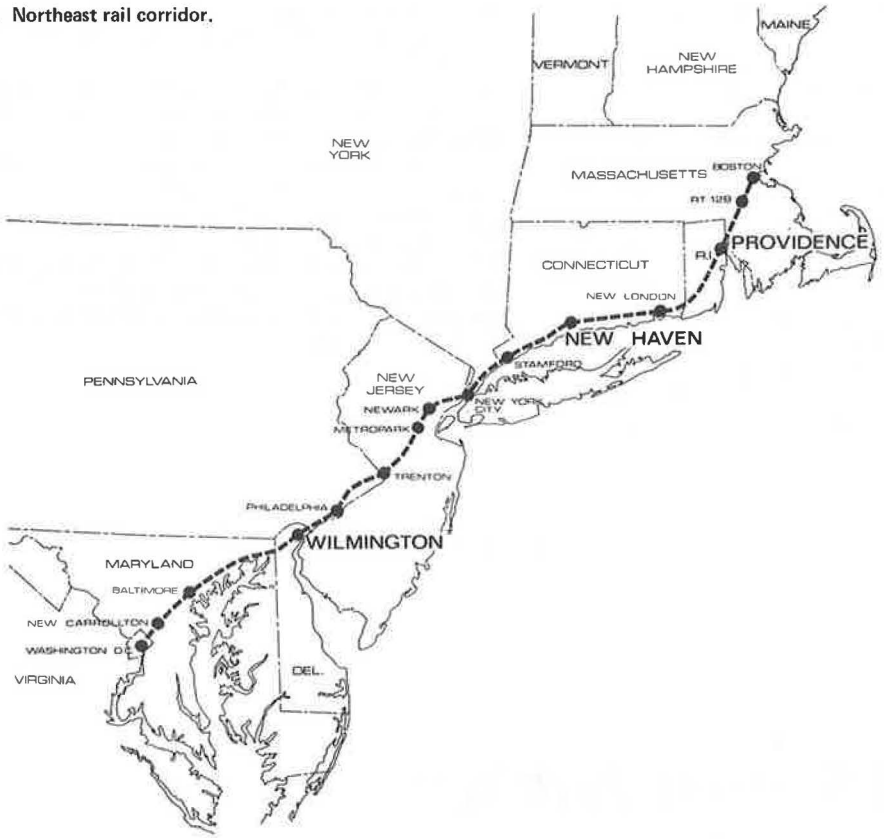


Figure 2. Station parking activity.

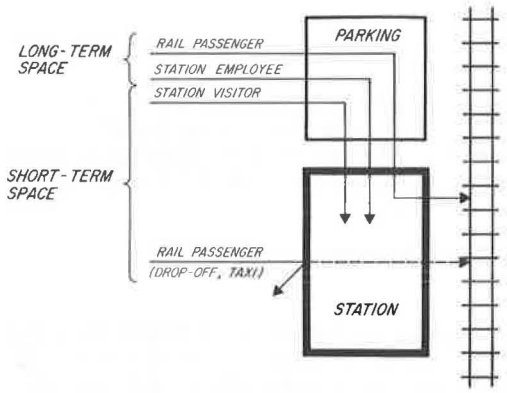
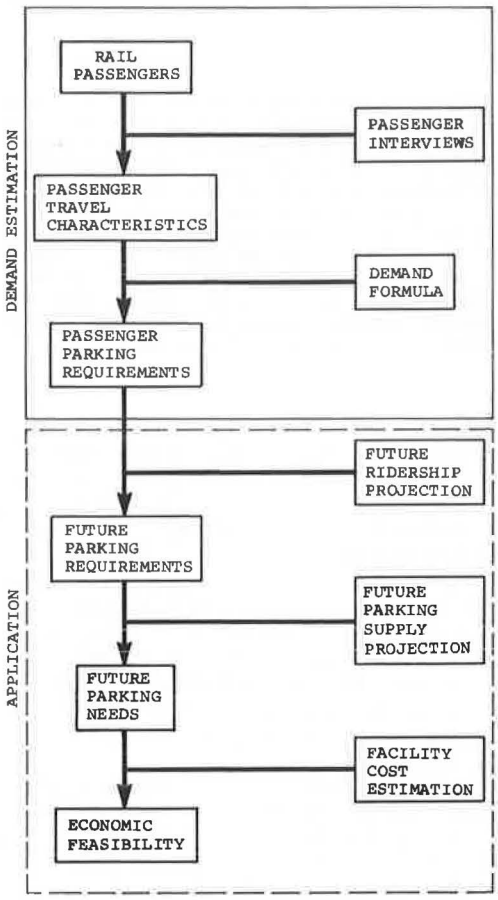


Figure 3. Study approach and application.



thirds of the daily passengers depart on Conrail trains. Conversely, Providence is primarily oriented to Amtrak service; over 70 percent of weekday travel out of Providence is on Amtrak trains. Passenger activity at Wilmington is relatively balanced, approximately 60 percent on Amtrak and 40 percent on SEPTA (commuter).

Before passenger interviews were conducted, it was determined that travel characteristics on Friday differ from those on Monday through Thursday. Passenger volumes are greater and trip durations are longer for weekend traveling. Major generators, such as the University of Delaware near Wilmington, Yale University in New Haven, and Brown University in Providence, as well as the proximity of the stations to major cultural centers such as Boston and New York, greatly influence Friday travel characteristics. Total passenger board-

Table 1. Station activity.

Station	No. of Daily Departing Trains			Average Daily Boarding Passengers in a Typical Week					
				Amtrak		Commuter		Total	
	Amtrak	Commuter	Total	No.	%	No.	%	No.	%
Wilmington	58	18	76	820	61.4	515	38.6	1335	100.0
New Haven	31	23	54	550	33.3	1100	66.7	1650	100.0
Providence	19	7	26	560	73.7	200	26.3	760	100.0

Table 2. Boarding passenger volumes.

Station	No. of Typical Weekday Boarding Passengers			No. of Typical Friday Boarding Passengers		
	Amtrak	Commuter	Total	Amtrak	Commuter	Total
Wilmington	780	510	1290	985	545	1530
New Haven	490	1030	1520	805	1370	2175
Providence	505	200	705	785	190	975

Table 3. Sample sizes.

Passenger Type	Wilmington	New Haven	Providence[a]	Total
Amtrak				
No. of boarding passengers[b]	1766	1425	786	3977
No. of interviews obtained	461	303	527	1291
Percentage of sample	26	21	67	32
Commuter				
No. of boarding passengers[b]	1057	2411	190	3650
No. of interviews obtained	205	637	83	925
Percentage of sample	20	26	44	25
Total				
No. of boarding passengers[b]	2823	3836	976	7635
No. of interviews obtained	666	940	610	2216
Percentage of sample	24	25	63	29

[a] Passenger boardings for Providence represent only Friday activity.
[b] Number of boarding passengers recorded during the survey period; passenger volumes are for two days, a typical Friday and a typical Monday through Thursday weekday.

ings for a typical Friday and a typical Monday through Thursday are presented in Table 2.

Passenger Interviews

Information pertaining to origin-destination patterns, trip purpose, mode of arrival, scheduled time of return, trip frequency, and location of parking, as applicable, was gathered by directly interviewing rail passengers before boarding. Each interview was coded by passenger type (Amtrak versus commuter) and time of departure. To ensure an adequate data base, interviews were conducted over a two-day period from 6:00 a.m. to 9:00 p.m. Friday was always selected as one of the two days, because travel initiated on that day not only incorporates weekday commute-to-work travel but also includes weekend-oriented social and recreational trips.

A predetermined number of interviews per train were conducted, according to passenger volumes. Typically, one out of every three or four boarding passengers was selected for an interview. More than 2200 interviews were conducted in the course of the studies. As outlined in Table 3, the percentage of the sample by station by passenger type was always greater than 20 percent. Approximately 30 percent of all passengers boarding trains during the survey period were interviewed.

The minimum sample size for Amtrak interviews was 300. For attribute sampling, this size is considered to yield reasonably good results. Although the commuter sample size was smaller, the somewhat homogeneous nature of commuters, and the type of survey used, suggests the acceptability of the samples for determining parking demand.

Results of the interviews were expanded to reflect total number of typical weekday and typical Friday boardings. Manual counts of the number of boarding passengers by train were used as control totals for the expansion of the sampled interviews. As a check for the reliability of the survey results and expansion techniques employed, field counts of the number of vehicles accumulated by time period in station-related parking facilities and along the curb were conducted. In all cases, results of the expanded passenger interviews in terms of numbers of parked vehicles and the actual field counts of parked vehicles were similar.

Passenger Travel Characteristics

For information purposes, characteristics of only Friday boarding passengers for each station surveyed are summarized. It should be noted that the data are presented primarily for purposes of comparison, as both Monday through Friday work and business trips and Friday social and recreational trips are represented. In determining parking requirements, characteristics of passengers boarding on all seven days of the week were considered.

Trip Purpose

Trip purposes are classified by work, business, shopping, school, and social and recreational reasons (Table 4). The majority of Friday station activity is directed to travel for reasons other than work, business, school, or shopping. At all stations more than 50 percent of Amtrak departures are for social and recreational trips. With the exception of Providence, few rail passengers use Amtrak service to commute to work. More than 10 percent of Providence Amtrak passengers are workers who frequently use the Amtrak service to

Boston that supplements the B&M commuter schedule. This facilitates the interchange of Amtrak and commuter service when trains are delayed.

Commuter service at both Wilmington and Providence principally accommodates workers. Approximately 50 percent of Wilmington SEPTA passengers and 70 percent of Providence B&M passengers are traveling to work. Although New Haven, as previously stated, is primarily a commuter station, less than one-fourth of Conrail travel is for work purposes. More than 60 percent of New Haven commuter travel is initiated after 10:00 a.m. and is oriented to weekend trips to New York.

Trip Frequency

Average trip frequency of Friday Amtrak passengers is approximately 3 trips/month; passengers on commuter lines travel more frequently; average departures range from 6 to 15/month (Table 5).

Generally, 50-60 percent of Friday Amtrak passengers use rail service less than once a month. Less than 5 percent of Amtrak passengers are daily passengers (5-6 trips/week).

Work-oriented commuter trips at Wilmington and Providence are approximately 57 and 70 percent, respectively, of Friday commuter passengers who are daily rail users. The prevalence of social and recreational commuter trips at New Haven explains the less than 20 percent of Friday rail passengers who are daily passengers.

Trip Duration

Boarding passengers were asked when they would be returning by rail to determine trip duration. Average trip duration of returning Amtrak passengers, as shown in Table 6, ranges from 43 to 49 h; commuter average trip durations are shorter, 15-26 h.

The percentage of Amtrak passengers not returning by rail to the three stations surveyed varies from 15 percent at Providence to 34 percent at Wilmington. The "not returning" category is composed primarily of workers or students traveling by train to the station in the morning and returning by bus or on foot to the station in the evening. These passengers were interviewed on the last leg of a round trip, so they are classified as "not returning." Of returning Amtrak passengers, the majority of trip durations tend to be longer than 24 h. The typical 8-h workday, plus the time for commuting, is reflected in the trip durations of commuters. Approximately one-half of Wilmington SEPTA passengers and three-fourths of Providence B&M passengers have trip durations in the 8- to 12-h range.

Mode of Arrival

Categories for mode of arrival, as detailed in Table 7,

Table 4. Friday passenger trip-purpose percentages.

	Wilmington			New Haven			Providence		
Trip Purpose	Amtrak	Commuter	Total	Amtrak	Commuter	Total	Amtrak	Commuter	Total
Work	5	52	22	5	22	16	11	70	22
Business	34	16	28	17	20	18	12	8	11
Shopping	3	2	3	1	5	4	2	-	2
School	7	4	6	5	5	5	3	3	3
Social and recreational	51	26	41	72	48	57	72	19	62
Total	100	100	100	100	100	100	100	100	100

Table 5. Friday passenger trip-frequency percentages.

No. of Departures per Passenger	Wilmington			New Haven			Providence		
	Amtrak	Commuter	Total	Amtrak	Commuter	Total	Amtrak	Commuter	Total
Less than 1 per month	54	10	39	47	30	36	59	15	50
1-2 per month	26	10	20	32	27	29	23	7	20
3-4 per month	6	4	5	1	3	3	2	1	2
1 per week	8	9	8	10	10	10	6	4	6
2-4 per week	3	10	6	7	10	8	2	3	2
5-6 per week	3	57	22	4	20	14	8	70	20
Average per month	2	13	6	3	6	5	3	15	5

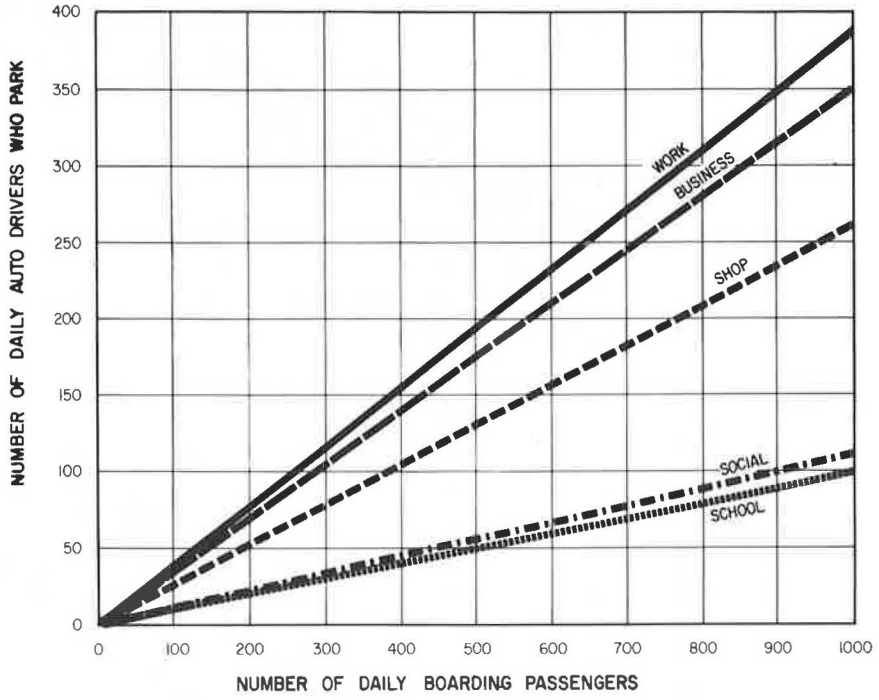
Table 6. Friday passenger trip durations.

Duration of Trip	Wilmington			New Haven			Providence		
	Amtrak	Commuter	Total	Amtrak	Commuter	Total	Amtrak	Commuter	Total
0-4 h	1	3	1	-	-	-	-	-	-
4-8 h	4	10	6	3	8	6	3	2	3
8-12 h	17	47	28	7	24	18	15	75	26
12-16 h	1	9	4	2	11	7	4	1	3
16-24 h	1	-	1	3	4	4	2	2	2
1-2 days	7	1	5	33	18	24	18	1	15
2-3 days	26	7	19	14	8	10	22	2	19
3-4 days	5	9	7	5	1	2	10	2	8
More than 4 days	4	2	3	4	2	3	11	1	9
Not returning	34	12	26	29	24	26	15	14	15
Average, h	45	24	36	43	26	33	49	15	42

Table 7. Friday passenger mode-of-arrival percentages.

Mode of Arrival of Boarding Passengers	Wilmington			New Haven			Providence		
	Amtrak	Commuter	Total	Amtrak	Commuter	Total	Amtrak	Commuter	Total
Automobile driver and park-and-ride	20	29	23	15	22	19	18	42	22
Automobile passenger and park-and-ride	8	11	9	4	6	6	12	12	12
Kiss-and-ride	45	26	38	30	28	29	35	14	31
Bus	13	19	15	16	12	13	11	11	11
Taxi	8	2	6	9	11	10	8	2	7
Walk	5	8	6	19	18	18	15	18	16
Other	1	5	3	8	3	5	1	1	1

Figure 4. Number of automobile parkers by rail trip purpose.



include automobile driver and park-and-ride, automobile passenger and park-and-ride, kiss-and-ride, bus, taxi, walk, and "other." The mode of arrival in the other category is principally by train (e.g., commuter passenger transferring to an Amtrak train).

Automobile drivers account for the mode of arrival of 19-23 percent of all passengers at the three stations surveyed. The principal mode of arrival is kiss-and-ride: 29-38 percent of all rail passengers are dropped off at the station.

New Haven and Providence stations are within a reasonable walking distance of downtown and nearby colleges and universities; approximately 16-18 percent of all passengers arrive at these stations by walking. These passengers are typically college students or workers who commute to New Haven and Providence in the morning and are walking to the station from downtown jobs or school in the evening.

A greater percentage of commuters than Amtrak passengers drive to the station. Automobile drivers account for the mode of arrival of 22-42 percent of commuter passengers as compared to 15-20 percent of Amtrak passengers. Conversely, kiss-and-ride is the mode of arrival of 30-45 percent of Amtrak passengers and 14-28 percent of commuter passengers.

Parker Characteristics

Characteristics of passengers who drive to the station and park were further investigated. As depicted in Figures 4-6, trip purpose, frequency, and duration were related to the number of private-vehicle drivers parking at the station.

There is a general relationship between the purpose of the rail trip and the choice of mode to the station. As indicated in Figure 4, people traveling for purposes of work, business, and shopping tend to drive to the station more often than those traveling for school or other purposes. Therefore, if a rail station accommodates principally the commuting worker, as opposed to the social and recreational trip maker, approximately three times more parking spaces will be required.

The number of automobile drivers and, therefore, the number of parking spaces required are a direct function of trip frequency (Figure 5). As trip frequency increases, the number of automobile drivers and the need for parking space increase.

Figure 6 shows an inverse relation between number of automobile drivers and trip duration. As trip duration increases, the number of automobile drivers decreases. The cost of parking and the risk involved in leaving an automobile unattended influence the relation.

Figure 5. Number of automobile parkers by rail trip frequency.

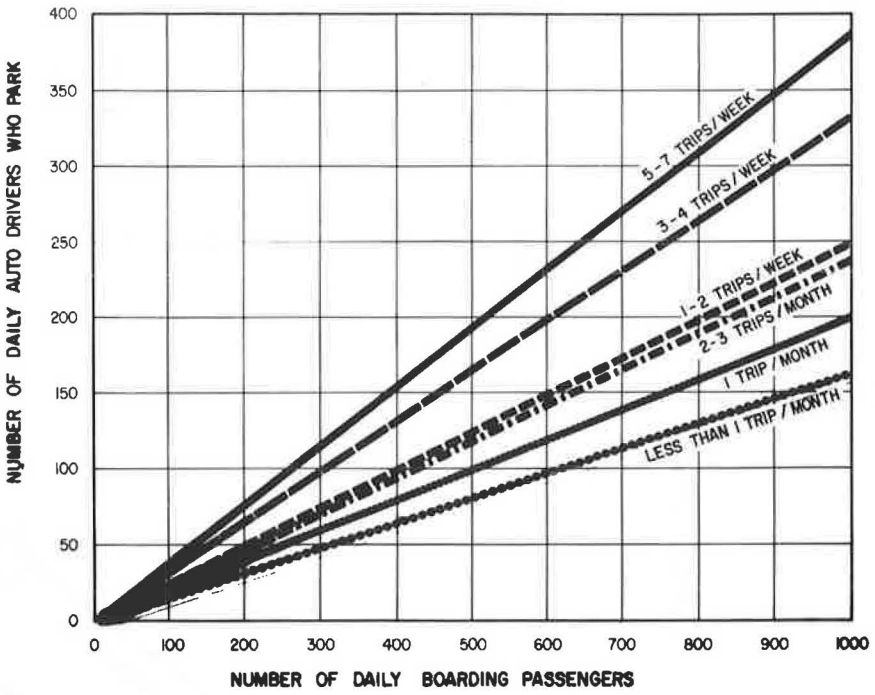
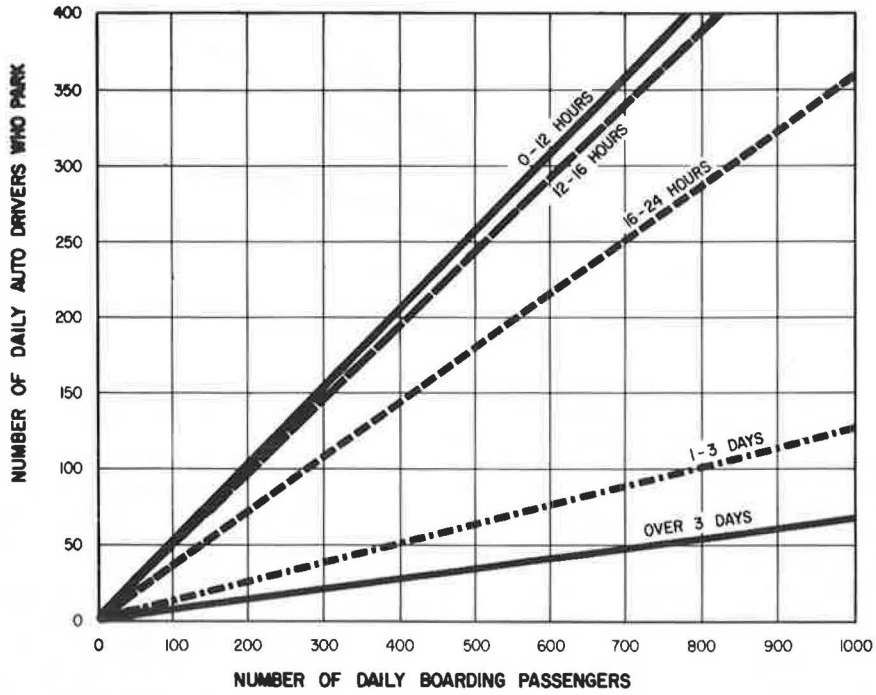


Figure 6. Number of automobile parkers by rail trip duration.



Parking Demand

Characteristics of boarding passengers were analyzed for each survey day to determine the total daily passenger parking demands. Demands were expressed in terms of passenger type (Amtrak versus commuter) for each station. A total daily parking demand of space per boarding passenger was derived based on the proportion of passenger-type volumes to total volumes.

The formula used to derive the demand is

$$N = (A \times B \times C/D)/A \quad (1)$$

where

- A = number of total boarding passengers by type (Amtrak or commuter),
- B = percentage of automobile drivers who park at the station,
- C = maximum accumulation of parked vehicles for given day,
- D = number of daily parkers on given day, and
- N = peak parking demand.

The overnight parker who consumes one space for two or more days is accounted for in the C/D expres-

sion. The number of boarding passengers and the percentage of automobile drivers come from the passenger interview and count information; the maximum accumulation of parked vehicles and number of daily parkers are determined by supplemental field data gathered on the days of passenger interviews.

Parking Requirements

Table 8 presents parking demands ascertained for each station, as well as parking demand planning guidelines. Generally, commuters require more parking spaces than Amtrak passengers, and trip characteristics such as frequency and duration influence the decision on the mode of arrival to the station, which, in turn, translates into parking-space demand.

Commuter parking demands for Providence are considerably greater than for Wilmington and New Haven. This may be due in part to the availability of the relatively inexpensive ($0.75) daily parking in close proximity to the station that influences the passenger mode of arrival. Parking by Amtrak passengers, however, is not greater because of the lack of moderately priced, safe overnight parking. Providence's location at the northern end of the rail corridor may account for the fact that the majority of its Amtrak passengers are bound south on trips of long duration and require overnight parking. General guidelines of 0.32 and 0.28 spaces per daily boarding passenger are suggested for determining commuter and Amtrak passenger parking demand, respectively.

Guidelines can be interpreted in another manner, as is graphically presented in Figure 7. A railroad station offering only commuter service will require more parking spaces than a station serving a large percentage of long-distance Amtrak passengers. The general parking requirements for the majority of the nation's railroad stations, categorized somewhere in between, will be contained within the bank, as shown in Figure 7.

Table 8. Suggested parking demand guidelines.

Station	Daily Parking Space Demand[a] (space/passenger)		
	Amtrak	Commuter	Average
Wilmington	0.33	0.31	0.32
New Haven	0.27	0.32	0.30
Providence	0.20	0.42	0.24
Suggested planning guideline	0.28	0.32	-[b]

[a]Number of daily parking spaces demanded per daily boarding passenger by type.
[b]Total demand is not given, as it reflects a proportion of Amtrak and commuter ridership.

APPLICATION OF DEMAND ESTIMATES

Demand estimates were applied to projections of future rail ridership to develop future parking demands. It was assumed that current patterns of mode of arrival would not be altered in a way that would change the order of magnitude of parking demand in the projection analysis.

Future Rail Passengers

Ridership projections were provided by NECIP. Based on historical trends and speculation on future conditions, the projections were modified to produce a conservative estimate of 1982 rail patronage. Projections were expressed in terms of average daily boarding passengers.

Future Parking Demands and Needs

Results of the three station parking feasibility studies led to a recommendation that two parking garages be built, one in Wilmington and one in New Haven. Because of an abundance of inexpensive parking spaces, only a moderate increase in passenger parking demands, and other factors, a parking facility was not deemed feasible in Providence unless an adjacent office building were developed.

A decision was made to position all new parking spaces in a centrally located facility to maximize passenger convenience. Although the long-term passenger

Figure 7. Estimated parking demands by type of station activity.

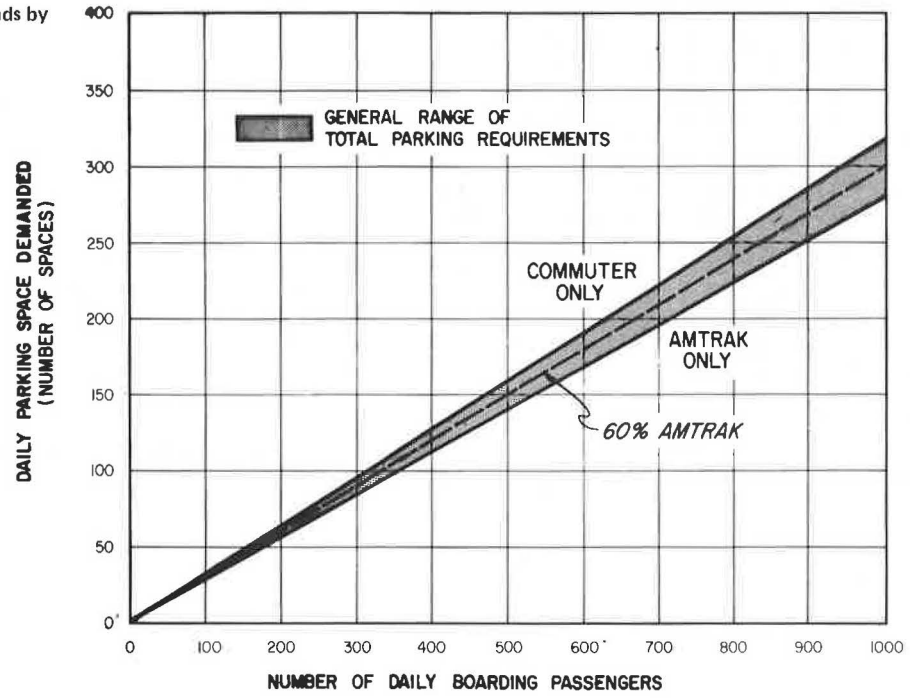


Table 9. Parking charges.

Prevalent Parking Charges	Station Location		
	Wilmington	New Haven	Providence[a]
One hour			
Existing, $	0.25	0.25	-
Recommended, $	0.25	0.25	-
Percentage change	-	-	-
Daily			
Existing, $	2.00	1.50	0.75-1.50
Recommended, $	2.00	2.50	-
Percentage change	-	66	-
Monthly			
Existing, $	15.50	15.00	12.00-25.00
Recommended, $	30.00	20.00	-
Percentage change	94	33	-

[a]Parking supply in Providence is a series of surface lots, each with differing rate schedules. No parking facility is planned for Providence; therefore recommendations for changing charges there are not made.

parking demands total 730 spaces in Wilmington and 610 spaces in New Haven, garage sizes recommended were 600 and 960 spaces, respectively. Parking requirements of other than rail passengers, i.e., visitors, employees, and non-station-related activities, were included in the estimated parking needs. Proposals for development of Union Station in New Haven include approximately 4600 m^2 (50 000 ft^2) of commercial space and a bus and limousine terminal. The parking requirements of these facilities were incorporated into the estimate of future needs. In addition, the anticipated 1982 parking supply was determined to be able to accommodate overall parking deficiencies. As stated, the result was a need for 600 spaces in Wilmington and 960 in New Haven.

Economic Feasibility

The economic feasibility of the proposed facilities was influenced by, among other factors, joint use of the facility and the net gain of parking spaces by the locality. A major determinant of economic feasibility was the Federal Railroad Administration's participation in the form of monetary contribution of 50 percent of total development costs of rail-related spaces.

Existing surface parking lots were selected as the sites for the proposed facilities. Hence, the nonfederal portion of the financing, typically from a local agency, was required to meet the 50 percent of costs to reconstruct preempted spaces. The net gain in spaces, therefore, influenced the decisions of the nonfederal participants relative to the economic feasibility of the project.

Further, it was determined earlier that, without federal monetary participation, the parking garages would not be economically feasible projects. Hence, it can be surmised that for most station situations a subsidy in some form is required to finance parking garages. A review of estimated monetary requirements and parking revenues reveals circumstances that support this premise.

Capital Requirements

As detailed below, the average construction cost per space for the two New Haven and Wilmington proposed facilities was approximately $5650.

Type of Costs per Space	Average Garage-Related Estimated Cost ($)
Average basic construction	5650
Average development	7450
Average annual operating and maintenance	225

When financing requirements and other development considerations were taken into account, the average development cost per space became $7450.

Based on financing charges, other economic considerations, and the low turnover of parkers at railroad stations (basically one parker per space per day), more than $2.00/space daily is implied as the return on investment required to operate at cost a parking garage in the order discussed.

Existing and recommended parking rates for the stations studied are summarized in Table 9. With federal participation, a daily rate of $2.00 or more is required to make the proposed parking facility economically feasible.

It is anticipated that, if monetary assistance is not available for the development of a parking garage, the cost of traveling to work by train would become great enough to discourage train use. In terms of a daily commuter, the monthly commutation ticket (about $100) plus a monthly parking charge (approximately $40.00) would result in a total monthly commutation cost of $140.00. As a planning guideline, 20-30 percent of the cost of a monthly commutation ticket is suggested as an acceptable monthly parking charge.

SUMMARY AND CONCLUSIONS

NECIP has provided the transportation planner with sufficient information to estimate the parking demands of the rail passenger. The experience of proposed projects has also identified key financial implications. The low turnover of rail parkers requires substantial parking charges to finance the facility. If the cost of parking is too high, however, an on-street spillover may occur and the garage will become a financial burden.

It can be concluded, therefore, that the provision of parking at rail stations must be considered in a similar manner as other public utilities and that outside financial assistance is required to make the project economically feasible.

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