Procedure for Estimating Demand for Regional Fringe Parking Facilities

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The purpose of this study was to determine the best location and the optimum feasible quantity of additional parking spaces that would effectively serve potential demand for change-of-mode parking at the interface between highway and passenger rail systems. Selection criteria, such as available land, accessibility to highway system, current rail ridership, and current parking demand, were used to identify 20 potential fringe parking sites. Future demand for parking spaces at the selected sites was determined in four steps. The first step dealt with trip interchanges. All future trip makers who reside in the influence area of each of the potential sites, and whose trip destinations lie in the distribution service area of the passenger rail system, were identified and quantified. In the second step, the market share of each mode was calculated by using a disutility mode-choice model. Disutility rates for the automobile and rail modes were computed for each of the trip origin areas, and the percentage of passenger rail trips was derived from diversion curves. In the third step, the proportion of projected commuter rail patrons demanding parking spaces at each site was established by using a relationship between the distances patrons travel to the station and their access modes to the station. Finally, additional parking spaces over and above the number of spaces already existing or planned were calculated for each site.

Recent federal-aid highway acts provided for the use of Highway Trust Fund monies for the construction of regional fringe parking facilities at the interfaces between major highway routes and commuter railroad and transit lines. In February 1974 the Pennsylvania Department of Transportation (PennDOT) authorized the Delaware Valley Regional Planning Commission (DVRPC) to proceed with a study seeking the best location and optimum feasible quantity of additional parking to effectively serve future demand for change-of-mode parking at the interface between the highway and passenger rail systems within the five-county Pennsylvania portion of the Delaware Valley region. The underlying regional goals of this study were

1. To reduce highway congestion, particularly during the peak periods and in the region core;
2. To reduce projected demand for Philadelphia central business district (CBD) parking space and thus free land and airspace for more productive uses;
3. To provide incentives to attract trip makers to more efficient modes; and
4. To reduce air pollution levels in the CBD.

The four-phase study performed by the DVRPC encompassed site selection and interagency coordination, development of demand estimation methodology, analysis of demand estimates, and community impact analysis. Although all four phases are necessary to move regional fringe parking into the design and implementation phase, the intention of this paper is to show how a regional planning agency might respond to a request to provide design data for a project not normally considered in the long-range urban transportation planning process. Therefore, we have dealt with only the two phases concerning demand estimation.

SITE SELECTION, INTERAGENCY COORDINATION, AND COMMUNITY IMPACT

During the fall of 1973, DVRPC, in association with PennDOT, coordinated a multiagency task force that included representatives of county planning commissions and other concerned agencies. The task force was charged with the review and selection of candidate sites for a regional fringe parking program. The candidate sites would then be subjected to more detailed analyses under each of the study phases.

These agencies cooperated to select 20 potential regional fringe parking sites. These high-priority sites were selected on the basis of available land, compatibility of parking with adjacent land uses, placement within a high-density travel corridor, accessibility to the highway system, and minimization of disruptive impact on the local community. The full list of criteria against which the recommended sites were reviewed is given in Table 1. Recommended sites were not necessarily restricted to existing rail stations, and the recommendation to construct a new station or consolidate a number of stations was considered within the realm of the study.

After the demand estimation process was completed for each of the 20 sites, a preliminary impact analysis based on existing conditions was conducted regarding land use and community development, illegal street and off-street parking, construction or upgrading of access roads, and alleviation of traffic congestion on major highway facilities.

The future impact of additional peak-period traffic on the local access roads to the commuter stations was determined by a forecast that was made of the average annual daily traffic (AADT) on those roads in 1985 and that used growth factors based on trends and future land-use information. The additional parking space demand was equated with additional peak-period vehicles and was added to peak-period traffic volume. The sums represented the total future peak-period vehicle trips on the access roads. Finally, comparison was made with the access roadway capacities (vehicles per lane hour for level of service E), as developed by DVRPC staff, in order to calculate the volume to capacity (v/c) ratios used to determine the impact of the additional peak-period traffic.

DEVELOPMENT OF DEMAND ESTIMATION METHODOLOGY

Four tasks and procedures were required to establish the quantity of additional parking needed on the basis of future demand for change-of-mode parking at each of the selected sites.

Task 1: Relevant Trip Interchanges

We identified and quantified all future trip makers residing in the influence area of each preliminary site that has trip destinations in the distribution service areas of the passenger rail system. Task 1 was subdivided into three parts: (a) delineation of the area of trip origin, (b) delineation of the area of trip destination, and (c) tabulation of the number of trip makers wishing to travel between origin and destination areas for given years in the future.

Origin Area Delineation Procedure

The origin area for each station site was defined as the geographic area in which the patrons of the station reside. For purposes of forecasting future patrons, it was first necessary to delineate the potential future market area of the station. This future market area included the present influence area of the station plus an additional area that would be influenced by the increase in station access opportunities, which is a manifestation of the increased parking supply that would permit more potential patrons to enter the passenger rail system. In enlarging the influence area, expansion should logically occur along highway corridors and into residential areas accessible to these highways.

We chose two potential area sizes: a maximum and a minimum, both based on the core market area as defined for sites at existing station points in SEPACT II (Southeastern Pennsylvania Transportation Compact operations plan for 1975, which included market surveys and an analysis of 1966 operations of the commuter railroads serving metropolitan Philadelphia). This existing core was the area in which 67 percent of the station's patrons resided. The perimeter of this core area was expanded along highway routes that fed into the station and could be used by potential park-and-ride station patrons. Judgment was applied to this expansion process to account for how far (in terms of time and distance) people might actually drive before changing modes and the degree to which they would be willing to back travel (drive to the station in a direction opposite to that of their destinations). The maximum area assumed considerable access and back-traveling distances. The minimum area assumed distances marginally greater than those for the core area. Finally, the expanded perimeter was made to conform with the boundaries of the DVRPC transportation analysis zone.

For new station sites near existing stations, the core areas were merged and the above process continued. For new station sites in far outlying areas not covered by the SEPACT II market analysis, the maximum and minimum areas were determined by assuming a small core and using the expansion process as before.

In this procedure, each site was analyzed independently; that is, the maximum and minimum areas of any one site were not affected by the influence area of any other site. This independent analysis procedure permitted study of each site on its own merits and aided in determining the priority of each site.

Destination Area Delineation Procedure

Analysis of available data revealed that the vast majority of passenger rail trips are bound for the core area of Philadelphia. We decided to limit our study destinations to this city core area in order to make the demand estimation of future rail ridership systematic. Here, also, two sizes of destination areas were selected: The maximum area included all 46 CBD zones and 3 zones from the University City area; the minimum area excluded 11 of those zones that lie along the Delaware waterfront, in the southwest CBD residential area, and in other areas either without an employment base or poorly accessible to the city rail stations (Thirtieth Street, Penn Center, or Reading Terminal).

Since this procedure directly considered only those destinations in the city core, it was necessary to adjust the rail patronage projections to account for rail trips to all other destinations. This adjustment procedure is discussed under task 2.

Tabulation of Trip Interchange Volume Procedure

Once the areas of origin and destination had been defined for each site, the person-trip interchange data from existing DVRPC trip tables were compiled into a travel demand matrix for each combination of maximum and minimum sizes of trip-end areas. These travel demand matrices were then scaled to the project analysis years of 1976, 1980, and 1985 relative to projected trends of the primary transportation variables and actual trends of ground count and passenger ridership data.

Task 2: Modal and Submodal Split

The purpose of task 2 was to determine the proportion of the trip makers who were identified and quantified in task 1 and who would be likely to choose passenger rail as their primary mode (given certain specific assumptions about mode-choice behavior and transportation system attributes). This task was composed of two parts: (a) calibrating the model and (b) assembling model input and calculating passenger rail patronage.

Model Determination

A utilitarian mode-choice model was used to find the proportion of total trip makers on an interchange likely to use passenger rail. The basic formulation of this model was a set of stratified diversion curves relating the percentage of transit trips for any interchange of a given strata to the cost difference of travel by the transit mode and the private automobile mode. Cost in the model was defined for mode X as

$$\begin{aligned}\text{Cost (mode X)} = {} & K_1 \text{ (excess time mode X)} \\ & + K_2 \text{ (running time mode X)} \\ & + \{[\text{monetary cost (mode X)}] \\ & \div [K_3 \text{ (median income of trip makers)}]\} \qquad (1)\end{aligned}$$

K_1, K_2, and K_3 are calibration constants; excess time is out-of-vehicle time; running time is in-vehicle time; monetary cost is any fare, parking charges, tolls, or the like associated with the one-way trip; and median income is median total family income of the aggregated zones of residence in the origin area.

Calibration of the model with 1960 DVRPC survey data yielded the following equations:

$$\begin{aligned}\text{Transit cost} = {} & 1.67 \text{ (transit run time)} + 2.5 \text{ (excess time)} \\ & + \{[\text{fare} + (1\tfrac{1}{2}) \text{ parking charge}] \\ & \div (0.25 \text{ median income})\} \qquad (2)\end{aligned}$$

$$\begin{aligned}\text{Highway cost} = {} & 1.67 \text{ (highway run time)} + 2.5 \text{ (excess time)} \\ & + \{[(\text{cost/mile}) \text{ mileage} + (\tfrac{1}{2}) \text{ CBD parking charge}] \\ & \div (0.25 \text{ median income})\} \qquad (3)\end{aligned}$$

The cost difference or utile rate (U) of the competing modes was then defined as

$$U = (\text{cost transit mode}) - (\text{cost highway mode}) + 200 \qquad (4)$$

The diversion curves were stratified by area type of origin and destination, trip purpose, and principal transit submode. The diversion curve used in this analysis was stratified by origins and destinations in suburban, rural, and open rural areas to CBD areas; home-based work trip purpose; and passenger rail submode.

Table 1. Criteria for selecting potential fringe parking sites.

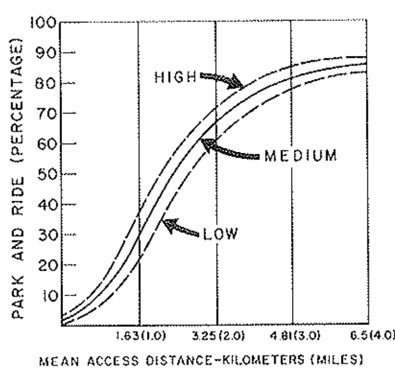
Selection Criteria	Factors
Geographic location	County, township or borough, land use surrounding the site, rail or transit line, distance from CBD (rail), distance from CBD (highway)
Relationship to adjacent highway	Highway adjacent to site, functional classification and funding, status of adjacent highways, traffic volume and existing volume/capacity ratios, projected volume and future volume/capacity ratios
Physical characteristics	Existing ridership and parking spaces available, availability of land for expansion and preliminary cost estimate for land acquisition, parking lot utilization, parking on adjacent streets, present use of land proposed for fringe parking lot
Travel time	Travel time by rail or transit to CBD, travel time by automobile to CBD, multimode travel time to CBD
Travel cost	Transit fare to CBD, total cost of rail trip (including parking, cost of first mode, and personal time worth), total cost of highway trip (including parking and personal time worth)
Access	Adequacy of highway access to site, relationship of parking site to pedestrian, type of intersection (at-grade, grade separated, signalized)
Relationship to community	Traffic flow on local streets from highway to parking site, compatibility with existing or proposed land uses
Rail line adequacy	Frequency of service, potential for increased service, type of cars and potential improvements, consideration of potential new station stop

Table 2. Ranges considered in input variables for determining rail patronage.

Input Variable	Variable Level		
	High	Medium	Low
Transit parking cost, $	Free	0.16	0.25[a]
Destination area excess time, min	A[b]	A + 1.0	A + 2.0
Highway excess time, min	5	4.5	4.0
Highway running time, min	B[c]	0.95 B[c]	0.90 B[d]
Highway out-of-pocket cost per kilometer, $	0.034	0.027	0.023
CBD parking cost, $	2.40	2.10	1.80

Note: 1 km = 0.62 mile.
[a] All pay spaces.
[b] Original calculation A: weighted average time for egress from station in city core and walking to destination.
[c] Original calculation B: time for vehicle to go from origin to destination area.
[d] Considers higher speeds.

Figure 1. Park-and-ride percentage ranges as a function of origin area mean access distance to station.



Model Input and Passenger Rail Patronage

Excess time for passenger rail consisted of station entrance and waiting time (waiting time is equal to half the headway) but not exceeding 7.5 min plus egress and time spent walking to the destination. Excess time for highway was the average of the time spent parking and retrieving the automobile from a CBD parking space plus time spent walking to the destination. Entrance, egress, walking, and parking times were based on past experience and calculated by the staff.

Running time for passenger rail was obtained from published schedules. Running time for the highway was based on probable route selection and DVRPC data on speeds. The freeway network considered in route selection was the portion of the DVRPC freeway network expected to be completed by each of the project analysis years.

Monetary costs for transit included 1970 fares plus half of any station parking cost, and for the highway the average out-of-pocket costs per vehicle kilometer plus half the average CBD parking charge.

Median income for the origin area was based on the 1970 census data aggregated from the analysis zone to origin area level.

The analysis considered different levels of the input variables so as to provide the decision maker with a range of probable values. Table 2 presents three levels of input variables considered in the analysis. The combined effect of the changes made for the individual variables on the mode-choice model results in the range of percentages for each site.

Once the model inputs for a site had been assembled, the utile rate was calculated, and the percentage of transit trips was derived from the diversion curve. This percentage was then applied to the total number of persons making the trip interchange for each of the study years to determine projected rail patronage.

Because task 1, trip interchanges, considered only destinations in the city core, it was necessary to adjust the rail patronage projections calculated in task 2 to account for all probable destinations by rail from the trip origin area of the site. Our procedure was to multiply the core rail trips derived from the mode-choice process of task 2 by the ratio of total rail trip destinations to core area rail trip destinations of existing rail patrons. This ratio is 100 to 86 and has held relatively constant since 1965. This final value is the total rail trip demand for the trip origin area for each study year.

Task 3: Park-and-Ride Estimation

The purpose of task 3 was to establish, from task 2, the proportion of projected passenger rail patrons who will demand parking spaces at each site.

It was hypothesized that there is a relationship between the distances patrons travel to the station and their access modes to the station. This relationship was approximated by a plot of the mean radius of the core market area of each station with park-and-ride facilities against the percentage of rail patrons who park and ride at the

Table 3. Daily person trips between origin area and city core area.

Site Location	1976			1980			1985		
	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Bensalem	3702	3261	2809	4141	3647	3153	5381	4746	4112
Baldwin-Crum Lynne	3708	3349	2990	3818	3448	3078	4057	3665	3273
Radnor	5019	4429	3746	5223	4610	3997	5678	5010	4342
Fort Washington	3583	3167	2752	3806	3364	2923	4320	3819	3318

stations. This plot is shown in Figure 1. The mean radius of the trip origin area of the site was then determined on the basis of the weighted average of the distances the zone centroids are from the site station. This was then used to enter the curve and derive the percentage of total patrons who will park and ride. The curve was structured to provide a range of percentages for each site. That percentage was used to determine the number of park-and-ride patrons. The number of those patrons was then divided by the average automobile occupancy rate to obtain the number of park-and-ride vehicles and thus the number of spaces demanded.

Task 4: Calculation of Parking Needs

The purpose of task 4 was to determine the number of parking spaces, over and above those already existing or planned under other programs, that will be needed to meet projected demand. The three parts of this task are (a) tabulation of all existing and proposed parking spaces for stations serving the trip origin area of the site, (b) allocation of these spaces to the trip origin area of the site, and (c) calculation of additional space needs.

Tabulation of Existing and Proposed Spaces

For each site, a listing was made of all stations whose market areas overlap the trip origin area of the site for both maximum and minimum area levels. The number of existing and planned parking spaces for each of these stations was tabulated. Proposed additional spaces were determined from an application by the Southeastern Pennsylvania Transportation Authority for a grant to improve passenger rail stations and from information solicited from county planning commissions.

Allocation of Parking Spaces to Site Area

Each site area was given a number of the existing and proposed parking spaces of the listed stations. This number was calculated according to the proportion of the market area of the listed station that overlapped the site area.

Calculation of Additional Need

Task 3 determined the future demand for park-and-ride spaces within the trip origin area of the site, and task 4 determined existing and proposed supply within that area. The difference between the projected demand (task 3) and the actual supply (task 4) was the additional parking supply required.

ANALYSIS OF DEMAND ESTIMATES

Interchange Volumes: Task 1 Results

Table 3 presents a sample of the output of task 1 by year for three levels of analysis. The figures represent the number of persons who will travel by all modes between a given trip origin area of a site station to the core area of the city of Philadelphia.

The maximum and minimum trip data were developed by tabulating all person trips from the trip origin area to the destination area at the maximum and minimum levels respectively. The average trip data are simply the average of the maximum and minimum levels.

Passenger Rail Trips: Task 2 Results

Table 4 presents a sample of the output of task 2 for the three levels of input variables. The table further presents the impact of the proposed center city commuter rail connection (CCCC) on the mode choice of trips bound for the city core. (The CCCC is a high priority project of the city of Philadelphia, approved by UMTA, to connect the Penn Central and Reading railroads via a four-track tunnel under the CBD. The connection will transform two stub-end networks into a fully integrated rail system.) The figures represent the percentage of the total trip makers in Table 3 who would choose, according to the mode-choice model, to take a passenger rail train as their primary mode to reach the city core area.

Park-and-Ride Patrons: Task 3 Results

Table 5 presents a sample of the output of task 3 for three levels of estimates of park-and-ride patrons derived as a function of mean access distance in the trip origin area. The mean access distance is based on the weighted average of zone centroid distances to the site station for the average trip origin area. The percentages were derived from SEPACT II data shown in Figure 1. The range of percentages for each mean distance indicates the possible variation in park-and-ride patrons as exhibited in the SEPACT II data, although this variation may be caused by differences in automobile ownership,

Table 4. Percentage of daily person trips by rail with and without center city commuter connection.

	High		Medium		Low	
Site Location	With	Without	With	Without	With	Without
Bensalem	75.0	72.5	53.0	50.5	41.0	38.5
Baldwin-Crum Lynne	83.0	83.0	81.5	80.0	73.5	70.0
Radnor	78.0	77.5	64.0	60.5	53.0	48.5
Fort Washington	83.0	82.0	78.5	75.5	58.5	53.5

Table 5. Percentage of rail patrons who will park and ride as a function of mean access distance to station.

		Rail Patrons (%)		
Site Location	Access Distance (km)	High	Medium	Low
Bensalem	8.13	90.0	89.0	85.0
Baldwin-Crum Lynne	3.25	71.0	66.0	60.5
Radnor	5.41	86.5	83.5	80.5
Fort Washington	4.06	80.5	75.0	70.5

Note: 1 km = 0.62 mile.

Table 6. Parking space supply and demand.

	Supply			Demand (medium case)			Additional Spaces Demanded		
Site Location	Max	Avg	Min	1976[a]	1980[b]	1985[b]	1976[a]	1980[b]	1985[b]
Bensalem	564	466	368	1466	1720	2236	1000	1254	1770
Baldwin-Crum Lynne	196	115	35	1821	1855	1971	1706	1740	1856
Radnor	768	650	532	2237	2464	2677	1587	1814	2027
Fort Washington	486	486	486	1793	1981	2248	1307	1495	1762

[a] Without center city commuter rail connection. [b] With center city commuter rail connection.

local feeder service, and income as well as by traditional preference.

Additional Space Demand: Task 4 Results

Table 6 presents a sample of the output of tasks 3 and 4 for the medium case. The parking space supply is the number of spaces, existing or planned, that are available to the patrons at each level. These figures do not include those spaces used by park-and-ride rail patrons but not designated as part of the station lots (shopping centers, schools, local streets). The demand is the number of vehicles demanding parking spaces in the study years, assuming average trip origin area, medium level modal and submodal split variables, and medium level park-and-ride response. The medium case is presented as the most reasonable projection of parking demand based on the underlying assumptions and the reasonableness of its output in terms of magnitude, impact, and ability to be implemented. Furthermore, the reasonableness of these projections is substantiated by the fact that all sites selected are at the interface between a rail line and an Interstate route or major arterial. A large fraction of projected demand comprises trips diverted from these highway facilities.

The additional spaces demanded are the differences between demand and supply. These figures represent the demand by future potential patrons who reside within the trip origin area for park-and-ride spaces that will not be satisfied by the existing parking supply. Future parking demands for all three levels of analysis were calculated on an unrestrained basis. The analysis assumes that land is available and that the rail system can provide the required level of service and capacity. Restraining the projection by any one of several factors (land, line capacity, frequency of service, or speed) would result in lower parking demands.

Based on the results of this study, four sites have been given priority for development. If and when developed, these sites will have a combined total increase in parking capacity of 6300 spaces by 1980 and 7400 spaces by 1985. These projects were placed in the Transportation Improvement Program for the Delaware Valley region and are now in the final design and detailed traffic impact analysis stage of development under PennDOT's direction.

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Designing a Parking Management Program

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Parking management measures have received considerable attention as a means of controlling automobile use in urban areas, but relatively little attention has been given to the specifics of combining proposed parking strategies into a scheme to help an area realize particular transportation and planning goals. The goal of reducing vehicle kilometers traveled has been selected for the purpose of this discussion, although other goals including reducing peak-period congestion, improving traffic circulation, improving aesthetics, and stimulating retail business should be examined to ensure that the proposed parking strategies are consistent with these goals. This paper focuses on possible traveler responses to various parking control strategies and discusses the implications of these responses for program design. Control of both on- and off-street parking may be necessary in some areas to reduce automobile use. Because parking controls are often fragmented, the coordination of efforts by local and regional agencies is critical to the success of a parking management program.

Parking management is one of the most interesting transportation planning techniques, because it can be used to actually modify automobile-use patterns whereas other techniques are directed toward making alternatives to single-occupant automobile use more attractive. Parking management assumes that the amount, location, and price of parking can affect travel mode choice, trip frequency, and trip destination and that these choices can be modified to produce more desirable travel patterns.

In years past, efforts to manage parking were concentrated on providing an ample supply of spaces at a nominal rate so that retail business could flourish and commuters would find it convenient to drive to work. The Environmental Protection Agency's (EPA) 1973 transportation control plans (TCPs) for a number of cities, including Boston, Denver, and San Francisco, created widespread negative publicity for modifying demand and reducing vehicle use. Measures such as parking surcharges, elimination of on-street parking, and freeze or reduction of off-street parking supplies were proposed to reduce the amount of automobile use in polluted areas so that national air quality standards could be met.

In the December 10, 1973, version of the Energy Emergency Act, the House Committee on Interstate and Foreign Commerce attached a rider forbidding the EPA to impose parking surcharges without the consent of Congress. Surcharges had been included in transportation control plans for 10 areas in California, Massachusetts, New Jersey, and the District of Columbia. Although the Energy Emergency Act was not passed by Congress, the EPA administrator announced that congressional intent on the surcharge issue was clear (1). As a result, all surcharge regulations were withdrawn, and the review date for new parking facilities (to determine their impact on air pollution) was postponed until