Analysis of Regional Park-and-Ride and Express Bus Service

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The results of a study aimed at increasing the transit patronage, reducing the automobile travel, and improving the air quality in the Delaware Valley Region by introducing park-and-ride and express bus service are summarized. For this study, 45 bus corridors connecting 178 parking locations in major shopping areas with 500 or more parking spaces were initially identified. Many of these corridors were eliminated from further consideration to avoid duplication of service and frequent bus stops along the routes. A set of 21 corridors linking 47 parking locations was then tested by using UMTA's UTPS modeling package. Those park-and-ride locations that attracted more than 250 riders from the existing commuter and subway-elevated routes in the vicinity of the parking locations were not included. Other locations that attracted fewer than 50 riders from the use of automobiles were also dropped from further consideration. Based on these criteria, a final network of 14 routes and 25 parking lots is recommended for further detailed analysis and implementation studies. The impact on air quality and energy of the recommended facilities is also presented. Estimates for capital expenditure and operating cost for implementing the park-and-ride and express bus service are also included.

Multiple use of parking facilities in urban regions has occurred occasionally in the past. This limited use has ranged from contractual use of shopping center parking facilities to unauthorized roadside parking.

This study was initiated in 1981 by the transportation air-quality program of the Delaware Valley Regional Planning Commission (DVRPC) for the purpose of reducing automobile emissions and thus improving air quality. The purpose of this study is to select a number of parking facilities with reasonable proximity to major regional highways that, under agreement with their operators or owners, could be used for park-and-ride and express bus service. Basically, such an operation can have a measurable effect on automobile traffic volume and transit ridership. A reduction of the daily automobile trips will reduce highway congestion, improve air quality, and increase transit patronage, thus improving the operating revenues of the regional public transit carriers.

The term park-and-ride has been used in various ways. Some speak of express transit service between a suburban area and some activity center as park-and-ride service. Others use this term to refer to shuttle-bus services connecting parking lots located at the edge of a business district to that district. Still others refer to park-and-ride service as any operation that provides a parking lot at a point of access to any transit line. The terms park-and-ride, fringe parking, remote parking, and peripheral parking are often used interchangeably to describe similar operations. In this study, park-and-ride and express bus service is defined as transit service that encourages an individual to reach an express bus service by a private vehicle, usually an automobile, and permits this individual to transfer from to an express bus to reach his destination. At the point of transfer, the individual may (a) park the vehicle in the space provided or surrender it to an attendant or (b) be dropped off by another driver as in kiss-and-ride service. The return trip operates in the reverse, i.e., express bus to private mode.

As defined here, the express bus patronage may not always involve use of the park-and-ride facilities designated for this purpose. Patrons may reach the bus service by walking or by other modes such as paratransit services and kiss-and-ride service. The park-and-ride lot functions in a manner quite similar to that of a transportation terminal or railroad station.

The park-and-ride and express bus service is designed to link suburban communities with Philadelphia and Trenton central business districts (CBDs). The placement of parking facilities in suburban areas will ensure that suburban residents make relatively short trips to reach the express bus used for line-haul operation. It is assumed that the park-and-ride service will be accompanied by improved reliability of the transit service to deliver the rider to his destination on time and at faster overall speeds.

METHODOLOGY

The methodology followed in this study is divided into four phases: selection of park-and-ride lots, definition of the inner ring, preparation of network coding, and simulation of park-and-ride lots and route volumes.

Selection of Park-and-Ride Lots

The DVRPC 1975 Regional Parking Inventory, as updated, was used to identify the potential parking lots for this study. These parking locations were reviewed by the county officials for their suitability. The updated file of parking lots was used to plot the locations of potential parking lots on the regional map.

Because most of the travel from the outlying areas of the region is directed toward two major urban centers, highway corridors connecting the farthest parking lots in the region with Philadelphia or Trenton CBDs were then mapped. In delineating these corridors, the following criteria were considered:

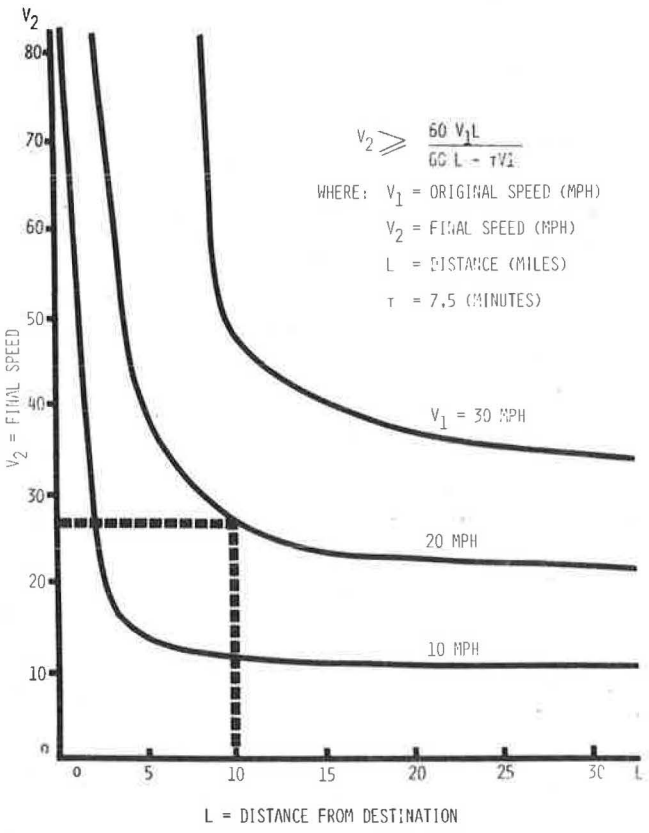
1. Routes with direct access in terms of alignment and speed were selected;
2. Parking lots of 250 or more spaces were linked with each proposed route, with particular emphasis on the lots recommended by county officials; and
3. Some cross-county routes connecting outlying urban centers were also identified.

This effort resulted in the identification of 45 corridors in the region connecting 178 parking lots. The routes were carefully selected to avoid competition with each other and with the existing transit service. The number of stops at the park-and-ride lots for each route was limited to 4.

Definition of Inner Ring

An important consideration in the selection of parking locations is the overall trip time. The use of park-and-ride service connotes a transfer from a car to a bus and therefore involves additional travel time. The total door-to-door time is a critical determinant in the choice of travel mode, and any transfer that would increase the travel time would

Figure 1. Determination of inner ring.



reduce the ridership. For the success of the park-and-ride service, therefore, it is important to increase the speed of the bus service from the parking lot to the place of destination to offset any time lost in transfers.

Assuming that a transfer from car to bus service takes an average of t min, a set of curves (Figure 1) was drawn to relate the final speed (V_2) of the commuter vehicle with the original speed of commuting (V_1) by car. These curves are based on the following relationship:

$$V_2 = 60 V_1 L/(60 L - t V_1)$$

where

V_2 = final speed of commuter vehicle (mph),
V_1 = original speed of travel (door-to-door) (mph),
L = over-the-road distance between the lot and the destination (miles), and
t = additional time for transfer.

For Figure 1, t was assumed to be 7.5 min.

These curves show that when the distance L is small, the speed of commuting by the commuter vehicle V_2 is much higher than the original door-to-door speed V_1 by car. These curves were used to define a ring around the Philadelphia CBD based on the average speeds in various travel corridors. A similar ring was developed around Trenton. Figure 2 shows the location of these rings. Any park-and-ride location within these rings would be impractical due to the difficulty of attaining very high bus speeds.

Preparation of Network Coding

The original list of 45 routes was reduced to the 21 express bus routes shown in Figure 3 to avoid duplication of transit service and frequent stops along the routes. These corridors contain 52 park-and-ride locations, mainly at large shopping centers, totaling more than 42,000 parking spaces.

The express bus service in these corridors was coded for simulation according to the UTPS format and module. This simulation produced ridership on these routes and the number of parkers at each lot as well as the diversion of trips from other travel modes currently serving the corridor.

Simulation of Park-and-Ride Lots and Route Volumes

The preliminary park-and-ride and express bus system was simulated by the DVRPC modal-split and assignment models. The demographic and employment estimates used in the simulation were those for the year 1990 developed as part of the Year 2000 Transportation Plan. The 1990 transit and highway networks were used for this analysis, with the most recent estimates of transit fares and highway operating costs.

As mentioned before, the proposed bus lines were coded for simulation and evaluation. Travel time, headway, fare, and stop locations were used to describe the quality of the bus service. The commuter-shed areas were also identified for all the proposed facilities to identify the areas from which the ridership would originate. Based on the previous studies, the boundary of the shed area at the beginning of a bus route was defined as a hyperbola with a maximum trip length to the parking lot of 10 miles (Figure 4). The shed area for the other bus stops was assumed to be a circle with a 3-mile radius.

This definition of the commuter shed is based on the travel behavior of the commuters with regard to access time, which should be about 5 to 10 min to reach the park-and-ride location.

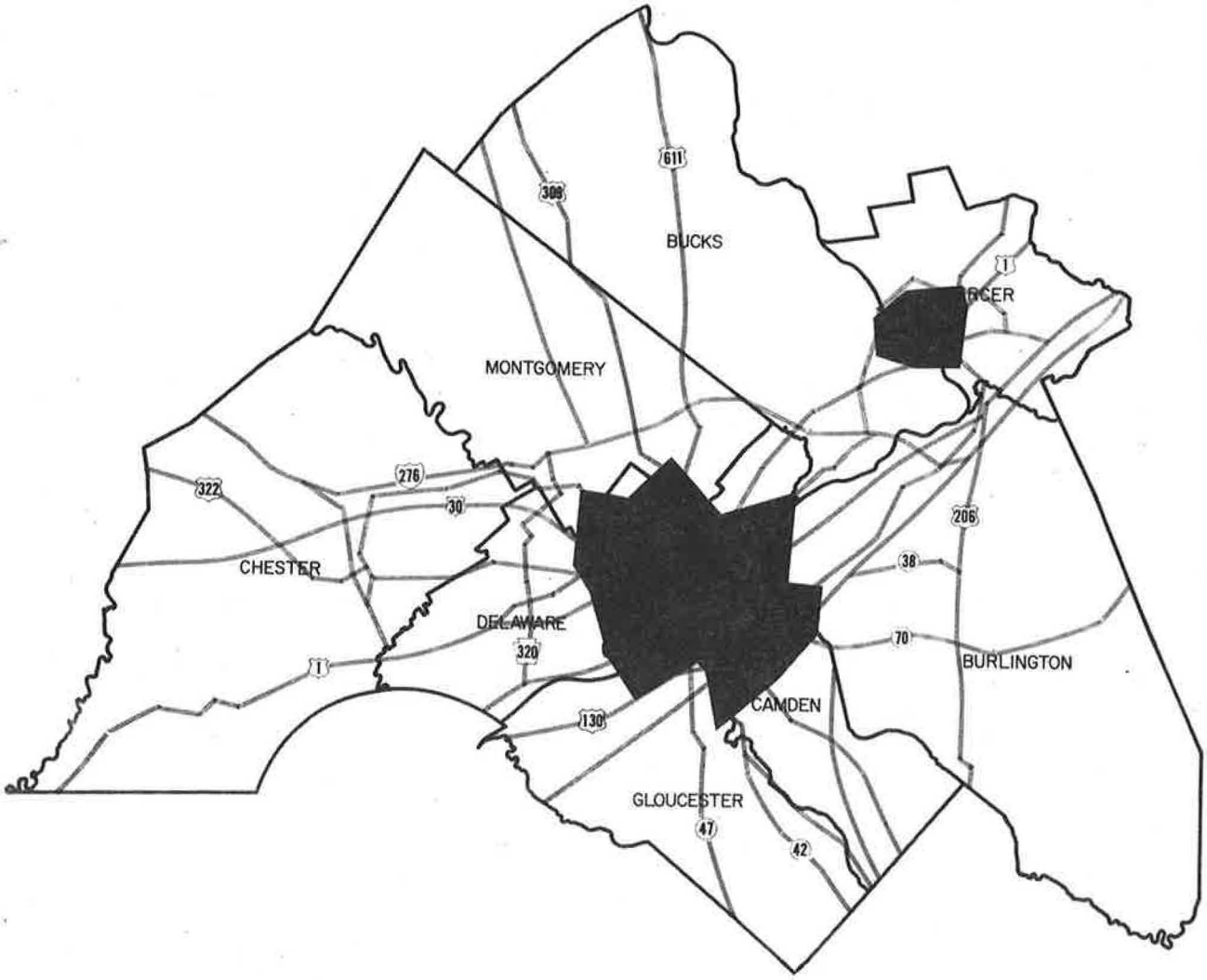
The modal-split and transit assignment models of the UTPS were then run to estimate the bus line and station volumes. The transit volumes on the express bus system were compared with those resulting from the transit network that do not include such a system to determine the diversion of trips from other travel modes.

SIMULATION RESULTS AND ANALYSIS

In Table 1, the daily transit ridership with and without park-and-ride and express bus service is summarized. The provision of these facilities results in an increase of 5,405 daily transit trips over the ridership without park-and-ride service. In Table 1 also, the overall daily ridership on the new express buses is 19,230 trips. In addition to the 5,405 trips diverted from automobile, this service would also divert 7,520 trips from the existing users of the commuter rail, 3,128 trips from the subway and elevated and high-speed lines of the Port Authority of Allegheny County (PATCO), and 3,177 from local bus. The reason for this massive shift from the existing transit modes is that the new express buses provide competitive and, in many cases, faster service. Table 2 presents patronage estimates at each park-and-ride facility on all 21 express routes. Major competition with commuter rail and subway and elevated modes is evident where the park-and-ride lot is located close to an existing commuter rail and subway and elevated station.

Because the objective of the park-and-ride and

Figure 2. Location of inner rings.



express bus service is to increase ridership on public transportation modes, it was necessary to modify the original park-and-ride network to exclude certain bus routes in order to avoid competition with other public transportation modes. Express bus routes or stations that attract more than 250 trips from competing commuter rail and subway and elevated lines were excluded from further consideration. In addition, the bus routes and stations on which the automobile trip diversion is less than 50 trips were excluded from further analysis, because they did not appear to have an effect on increasing transit ridership and improving air quality. As a result, four routes in Pennsylvania and three in New Jersey were eliminated. With some modification in the routing of the remaining bus lines, 14 lines were recommended for detailed studies (Table 3). Figure 5 shows the park-and-ride and express bus network recommended for further implementation studies.

The previous analysis indicates that the park-and-ride service will attract riders from the existing users of the commuter rail system and the subway and elevated lines and bus routes. In addition, some automobile users will also switch to the new bus service. To estimate parking space requirements, the following assumptions were made concerning the proportion of bus users who drive to the parking lots:

1. Bus users diverted from commuter rail, 80 percent;
2. Bus users diverted from subway and elevated lines, 30 percent;
3. Bus riders diverted from local bus, 10 percent;
4. Bus users diverted from automobile, 100 percent.

An average car occupancy of 1.3 persons per car was assumed in estimating the parking spaces required at each park-and-ride lot.

In Table 4, the total parking spaces required at each park-and-ride lot are shown as a percentage of the total parking spaces available at each facility. It will be seen that only 6 percent of the spaces in the parking lots will be needed for the park-and-ride service in Pennsylvania and 4 percent on the New Jersey side of the region.

AIR-QUALITY AND ENERGY IMPACTS

Any reduction in automobile driving will reduce

automobile emissions, gasoline consumption, and operating cost. In Table 5, the impacts of the 14 park-and-ride facilities on person and automobile travel, hydrocarbon (HC) and carbon monoxide (CO) emissions, and fuel estimated for 1987 are shown. In Table 5, 1,710 persons living in Pennsylvania and 2,577 in New Jersey portions of the region would switch from automobile to park-and-ride service, resulting in a decrease of 19,800 daily vehicle miles of travel (VMT) in Pennsylvania and 28,900 VMT in New Jersey. This reduction will eliminate 52.6 kg of HC and 640.3 kg of CO emissions per day. In addition, there will be a daily savings of 2,633 gal of gasoline. On an annual basis, the emission re-

Figure 3. Park-and-ride and express bus network for simulation.

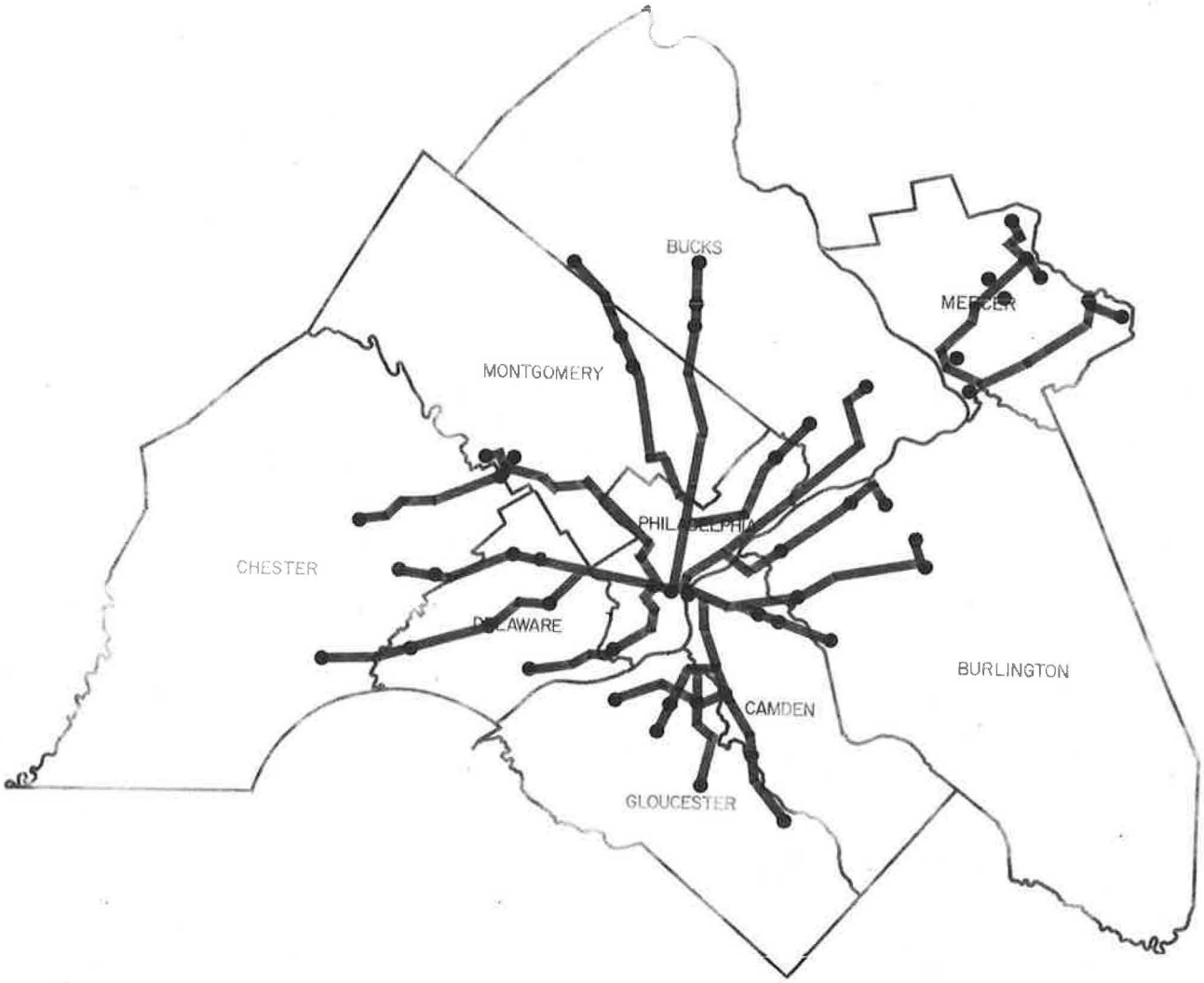


Figure 4. Commuter shed areas.

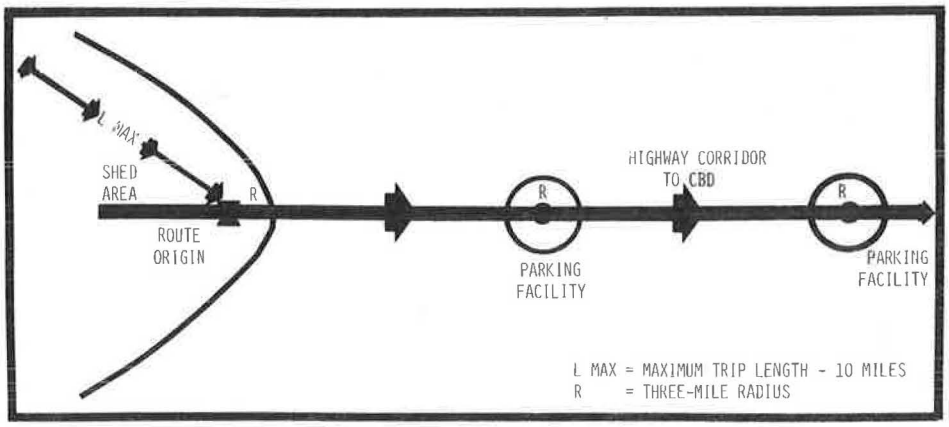


Table 1. Ridership with and without park-and-ride and express bus service.

Ridership	No. of Trips		
	Pennsylvania	New Jersey	Total
Without park-and-ride facilities	927,768	88,992	1,016,760
With park-and-ride facilities	930,376	91,789	1,022,165
Diverted from automobiles to park-and-ride service	2,608	2,797	5,405
Diverted to express bus from			
Commuter rail	7,188	332	7,520
Subway and elevated lines	2,140	988	3,128
Existing local bus	1,145	2,032	3,177
Automobiles	2,608	2,797	5,405
Total express bus trips	13,081	6,149	19,230

ductions would be 15 780 kg of HC, 192 090 kg of CO, and about 790,000 gal of gasoline.

The reduction in the amount of HC and CO emissions is based on the emission factors contained in the Mobile 2 model of the U.S. Environmental Protection Agency (EPA) for the year 1987. The savings in fuel consumption were estimated by using the consumption factors for the highway fleet average expected in 1987.

COST ANALYSIS

The state departments of transportation, transit operating agencies, or the counties may operate and maintain the parking facilities necessary for the service. They may also provide the capital cost re-

Table 2. Ridership estimates for park-and-ride and express bus service by location.

Route Description	Park-and-Ride Facility Location	Ridership Estimates		Ridership Diverted from			
		Park-and-Ride Facility	Route Total	Commuter Rail	Subway and Elevated	Local Bus	Automobile
Pennsylvania							
I-95/I-76	Chester CBD	3,152	4,584	2,467	158	284	243
	Philadelphia Airport (Cargo City)[a]	1,432		259	218	156	799
US-1	Longwood Gardens	196	941	136	0	22	38
	US-202 and US-1	104		92	0	10	2
	Granite Run Mall	366		255	55	29	27
	Springfield Shopping Center	275		74	145	14	42
PA-3	West Goshen Shopping Center	699	2,683	471	63	69	96
	Westtown Center	367		248	33	35	51
	Newtown Shopping Center	569		100	350	27	92
	Broomall Shopping Center	1,048		183	761	30	74
US-202/I-76	Exton Mall	643	844	397	0	69	177
	Valley Forge Music Fair	201		154	22	16	9
I-76	Valley Forge Park[a]	282	332	28	17	36	201
	King of Prussia	50		18	30	0	2
PA-309	Souderton Plaza[a]	174	423	99	0	19	56
	Montgomeryville Plaza[a]	147		75	0	16	56
	English Village[a]	102		0	0	14	88
US-611	Doylestown Center[a]	345	506	188	24	35	98
	Kings Plaza	56		31	6	6	13
	Warrington Shopping Center[a]	105		35	7	10	53
US-1/US-611	Neshaminy Mall[a]	651	1,108	235	91	64	261
	Red Lion Mall[a]	457		166	160	33	98
US-1/I-95	Oxford Valley Mall	1,660	1,660	1,477	0	151	32
Total			13,081	7,188	2,140	1,145	2,608
New Jersey							
US-130 (Hightstown)	Twin Rivers Shopping Center	91	170	0	0	47	44
	East Windsor Shopping Center	79		0	0	41	38
US-206	Whitehorse Bowling Alley[a]	282	282	48	0	122	112
US-1 (Mercer County)	West Windsor Shopping Center	102	200	27	0	39	36
	Penns Neck	98		23	0	39	36
US-1 (Princeton)	Princeton Shopping Center	106	176	26	0	42	38
	Mercer Mall	70		17	0	28	25
US-130 (Burlington, Betsy Ross Bridge)	Jefferson Ward Center (Dolran)[a]	233	561	0	17	112	104
	Willingboro Plaza[a]	328		0	24	158	146
US-130 (Burlington, Betsy Ross Bridge)	Cinnaminson Shopping Center[a]	1,005	1,005	191	242	197	375
NJ-38 (Mount Holly, Ben Franklin Bridge)	Fair Grounds, NJ-541[a]	202	1,230	0	44	82	76
	Lumberton Plaza[a]	478		0	105	194	179
	Moorestown Mall[a]	550		0	28	19	503
NJ-70 (Ben Franklin Bridge)	Marlton Plaza[a]	202	289	0	7	101	94
	Ellisburg Circle	45		0	41	2	2
	Garden State Park	42		0	40	1	1
NJ-42/North-South Freeway (Ben Franklin Bridge)	Williamstown Center[a]	294	505	0	18	144	132
	Jefferson Ward (Turnersville)[a]	211		0	36	91	84
NJ-47/North-South Freeway (Ben Franklin Bridge)	College Town (Glassboro)[a]	353	526	0	78	16	259
	Woodbury Plaza[a]	173		0	38	70	65
NJ-45/North-South Freeway (Ben Franklin Bridge)	Toll House Plaza (Mantua)[a]	261	582	0	58	106	97
	Acme Shopping Center (Woodbury)[a]	321		0	71	130	120
NJ-44/NJ-534/North-South Freeway (Ben Franklin Bridge)	Paulsboro Center[a]	438	623	0	100	176	162
	Deptford Mall[a]	185		0	41	75	69
Total			6,149	332	988	2,032	2,797
Regional total			19,230	7,520	3,128	3,177	5,405

[a]Routes recommended for detailed studies.

Table 3. Park-and-ride facilities and bus routes recommended for implementation studies.

Route Description	Park-and-Ride Facility Location	Ridership Estimates: Park-and-Ride Facility	Ridership Estimates: Route Total	Ridership Diverted from: Commuter Rail	Ridership Diverted from: Subway and Elevated	Ridership Diverted from: Local Bus	Ridership Diverted from: Automobile
Pennsylvania							
I-95/I-76	Philadelphia Airport (Cargo City)	1,432	1,432	259	218	156	799
I-76	Valley Forge Park	282	282	28	17	36	201
PA-309	Souderton Plaza	174	423	99	0	19	56
	Montgomeryville Plaza	147		75	0	16	56
	English Village	102		0	0	14	88
US-611	Doylestown Center	345	450	188	24	35	98
	Warrington Shopping Center	105		35	7	10	53
US-1/US-611	Neshaminy Mall	651	1,108	235	91	64	261
	Red Lion Mall	457		166	160	33	98
Total			3,695	1,085	517	383	1,710
New Jersey							
US-206	Whitehorse Bowling Alley	282	282	48	0	122	112
US-130 (Burlington, Betsy Ross Bridge)	Jefferson Ward Center (Dolran)	233	561	0	17	112	104
	Willingboro Plaza	328		0	24	158	146
US-130 (Burlington, Betsy Ross Bridge)	Cinnaminson Shopping Center	1,005	1,005	191	242	197	375
NJ-38 (Mount Holly, Ben Franklin Bridge)	Fair Grounds–NJ-541	202	1,230	0	44	82	76
	Lumberton Plaza	478		0	105	194	179
	Moorestown Mall	550		0	28	19	503
NJ-70 (Ben Franklin Bridge)	Marlton Plaza	202	202	0	7	101	94
NJ-42/North-South Freeway (Ben Franklin Bridge)	Williamstown Center	294	505	0	18	144	132
	Jefferson Ward (Turnersville)	211		0	36	91	84
NJ-47/North-South Freeway (Ben Franklin Bridge)	College Town (Glassboro)	353	526	0	78	16	259
	Woodbury Plaza	173		0	38	70	65
NJ-45/North-South Freeway (Ben Franklin Bridge)	Toll House Plaza (Mantua)	261	582	0	58	106	97
	Acme Shopping Center (Woodbury)	321		0	71	130	120
NJ-44/NJ-534/North-South Freeway (Ben Franklin Bridge)	Paulsboro Center	438	623	0	100	176	162
	Deptford Mall	185		0	41	75	69
Total			5,516	239	907	1,793	2,577
Regional total			9,211	1,324	1,424	2,176	4,287

Figure 5. Recommended park-and-ride and express bus network.

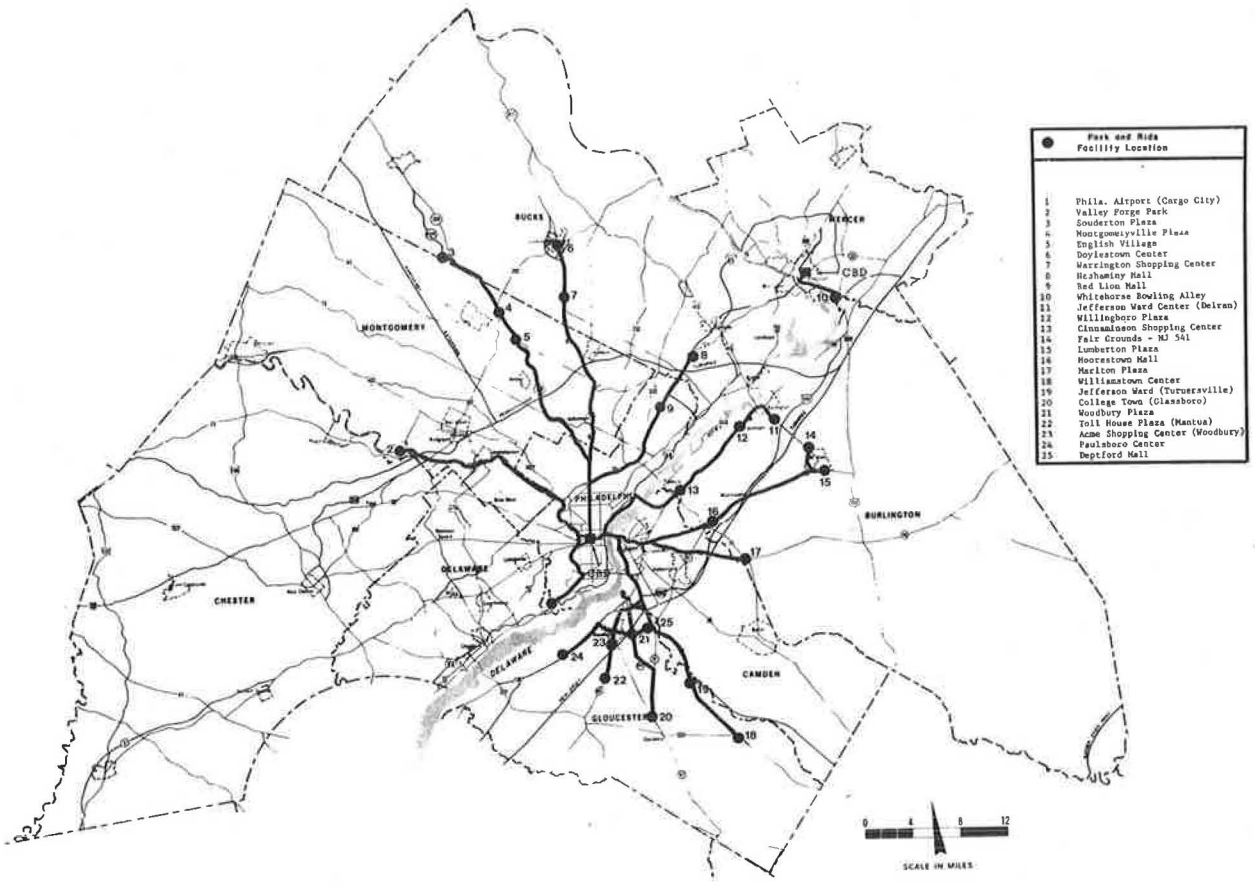


Table 4. Required parking spaces.

Route Description	Park-and-Ride Facility Location	Lot Capacity (no. of spaces)		
			Required for This Service	
		Total	Number	Percent of Total
Pennsylvania				
I-95/I-76	Philadelphia Airport (Cargo City)	1,800	418	23
I-76	Valley Forge Park	560	89	16
PA-309	Souderton Plaza	680	53	8
	Montgomeryville Plaza	585	45	8
	English Village	610	34	6
US-611	Doylestown Center	1,600	62	4
	Warrington Shopping Center	1,900	32	2
US-1/US-611	Neshaminy Mall	8,500	185	2
	Red Lion Mall	1,000	109	11
Total		17,235	1,027	6
New Jersey				
US-206	Whitehorse Bowling Alley	290	62	21
US-130 (Burlington, Betsy Ross Bridge)	Jefferson Ward Center (Dolran)	4,000	46	1
	Willingboro Plaza	4,300	65	2
US-130 (Burlington, Betsy Ross Bridge)	Cinnaminson Shopping Center	1,800	239	13
NJ-38 (Mount Holly, Ben Franklin Bridge)	Fair Grounds–NJ-541	1,165	37	3
	Lumberton Plaza	6,000	89	1
	Moorestown Mall	1,090	197	18
NJ-70 (Ben Franklin Bridge)	Marlton Plaza	1,500	41	3
NJ-42/North-South Freeway (Ben Franklin Bridge)	Williamstown Center	655	58	9
	Jefferson Ward (Turnersville)	990	40	4
NJ-47/North-South Freeway (Ben Franklin Bridge)	College Town (Glassboro)	1,475	109	7
	Woodbury Plaza	1,535	32	2
NJ-45/North-South Freeway (Ben Franklin Bridge)	Toll House Plaza (Mantua)	1,070	48	4
	Acme Shopping Center (Woodbury)	1,200	59	10
NJ-44/NJ-534/North-South Freeway (Ben Franklin Bridge)	Paulsboro Center	570	81	14
	Deptford Mall	5,500	34	1
Total		33,140	1,237	4
Regional total		50,375	2,264	5

Table 5. Estimated daily impact on trips, air quality, and energy of park-and-ride facilities.

Route Description	Park-and-Ride Facility Location	Distance to Destination (miles)	Reduction in				
			Daily Automobile Person Trips	Daily Automobile VMT	HC[a] (kg/day)	CO[a] (kg/day)	Fuel[b] (gal/day)
Pennsylvania							
I-95/I-76	Philadelphia Airport	7.4	799	4,500	4.8	48.9	243
I-76	Valley Forge Park	21.9	201	3,400	3.5	40.3	184
PA-309	Souderton Plaza	29.4	56				
	Montgomeryville Plaza	22.6	56	3,600	4.6	59.1	195
	English Village	20.1	88				
US-611	Doylestown Center	25.6	98				
	Warrington Shopping Center	21.4	53	2,800	3.4	43.0	151
US-1/US-611	Neshaminy Mall	21.0	261				
	Red Lion Mall	16.5	98	5,500	5.4	66.6	297
Total			1,710	19,800	21.7	257.9	1,070
New Jersey							
US-206	Whitehorse Bowling Alley	4.3	112	400	0.5	6.2	22
US-130 (Burlington, Betsy Ross Bridge)	Jefferson Ward Shopping Center	20.9	104				
	Willingboro Plaza	17.6	146	3,600	4.1	50.1	196
US-130 (Burlington, Betsy Ross Bridge)	Cinnaminson Shopping Center	9.8	375	2,800	3.4	42.3	151
NJ-38 (Mount Holly, Ben Franklin Bridge)	Fair Grounds–NJ-541	22.6	76				
	Lumberton Plaza	20.0	179	8,200	8.4	99.7	443
	Moorestown Mall	10.6	503				
NJ-70 (Ben Franklin Bridge)	Marlton Plaza	13.6	94	1,000	1.2	15.9	54
NJ-42/North-South Freeway (Ben Franklin Bridge)	Williamstown Center	22.5	132				
	Jefferson Ward (Turnersville)	16.3	84	3,300	3.5	41.8	178
NJ-47/North-South Freeway (Ben Franklin Bridge)	College Town (Glassboro)	19.2	259				
	Woodbury Plaza	11.4	65	4,400	4.5	53.5	238
NJ-45/North-South Freeway (Ben Franklin Bridge)	Toll House Plaza (Mantua)	15.2	97				
	Acme Shopping Center (Woodbury)	12.4	120	2,300	2.8	36.6	124
NJ-44/NJ-534/North-South Freeway (Ben Franklin Bridge)	Paulsboro Center	19.1	162				
	Deptford Mall	10.4	69	2,900	3.0	36.3	157
Total			2,577	28,900	30.9	382.4	1,563
Regional total			4,287	48,700	52.6	640.3	2,633

[a]Estimated on the basis of Mobile 2 model. [b]Amount of gasoline per day estimated on the basis of the estimated consumption factors for the highway fleet in 1987.

Table 6. Economic analysis of park-and-ride and express bus service.

Annual Cost	Pennsylvania	New Jersey	Total
Capital[a] ($1980)			
Vehicle fleet	531,000	841,700	1,372,000
Parking lots	171,000	225,000	396,000
Total	702,000	1,066,000	1,768,000
Operating and Maintenance[b] ($1980)			
Vehicle fleet	740,000	1,012,000	1,752,000
Parking lots	46,000	56,000	102,000
Total	786,000	1,068,000	1,854,000
Per passenger mile[c] (¢)			
Capital	10.49	10.89	10.73
Operating	11.74	10.92	11.25

[a]The capital cost of vehicles and improvements to the parking lots is expressed annually with an assumption of 10 yr of productive life, no salvage value, and 12 percent social rate of return.
[b]The operating and maintenance expenses of the vehicle fleet include labor, fuel, oil, and all other charges incidental to operating the vehicles. The charges for the parking lots are for snow removal, pavement upkeep and lighting, and so forth.
[c]This travel represents only the new riders switched over from the automobile. It does not include the riders using other transit modes who became attracted to the new service. Annual passenger miles per system are as follows: Pennsylvania, 6,691,000; New Jersey, 9,785,000; total, 16,476,000. Revenue per passenger mile by system is Pennsylvania, 10.50 cents; New Jersey, 19.90 cents; total, 10.70 cents.

quired for minor construction necessary to make the park-and-ride service operational. No land acquisition or other major improvements may be needed, however, because the recommended parking facilities are already functioning; their owners may permit their partial use for park-and-ride service with little or no charge.

It is estimated that the park-and-ride and express bus service will require 44 buses, of which 17 will be needed for providing service in Pennsylvania and 27 in New Jersey. This number is rather small and possibly could be arranged from the existing fleet of vehicles available with the operators of the transit service. The operators may, on the other hand, decide to acquire new, special vehicles for the service. The cost figures for the vehicle acquisition are therefore for illustrative purposes only.

The capital cost of 17 buses for the Southeastern Pennsylvania Transportation Authority (SEPTA) is about $3.00 million and for 27 buses for New Jersey, $4.75 million. The annual cost of operating these buses is estimated to be $740,000 for SEPTA and $1,102,000 for New Jersey operators. The operating cost of vehicles includes labor, fuel, oil, and other expenses for providing the service.

The capital cost for the park-and-ride service includes minor construction items required to improve the accessibility and the proper functioning of the parking lots. This includes clearing and grubbing, shaping the subgrade, shaping and clearing slopes, and fencing. It also includes the cost of park-and-ride signs, bus stop signs, and posting of weatherproof bus schedules. Some of the recommended facilities may require installation of new lighting poles, whereas others may require lighting improvements. The parking spaces designated for park-and-ride use would require identification by colored lines. Finally, every parking facility should provide a shelter for the bus riders to protect them from adverse weather conditions. It is estimated that a total capital cost of $2.2 million ($967,000 in Pennsylvania and $1,273,000 in New Jersey) will be needed to make the park-and-ride lots operational. Annually, the upkeep of the parking lots would require $46,000 from Pennsylvania and $56,000 from New Jersey.

The revenues that would be generated from the park-and-ride and express bus system depend on the fare level. Assuming a base fare of 65 cents (current fare level) and a charge of 8 cents/mile, the annual revenues collected from the fare box by SEPTA and New Jersey operators would be $824,000 and $1,218,000, respectively. Incidentally, the same fare structure was used in estimating the ridership for the new service.

These are the estimates of revenue only for the riders who are attracted from among the automobile users. Estimates for other riders who are attracted from existing transit modes are not included.

Table 6 presents a summary of capital and operating costs implicit in the provision of the service. For the sake of comparison, all capital costs were expressed annually. Table 6 also shows that the capital cost of providing the service is 10.73 cents/passenger mile. The running, maintenance, and operation of the service would cost 11.25 cents/mile. This compares favorably with revenues of 10.70 cents/mile.

AGREEMENT FOR USE OF PARKING FACILITIES

The review of the park-and-ride programs in several states indicates that it has not been difficult for governmental agencies to reach an agreement with the owners of shopping centers to designate a portion of their parking lots for the park-and-ride programs. Nevertheless, government commitments should be made for the proper maintenance and operation of the lots, such as extra lighting, surface maintenance, traffic control devices, and so forth.

Many of the suburban shopping centers have excess parking spaces that are not used on weekdays except perhaps during the holiday season. The park-and-ride service operates during working hours, when parking spaces are plentiful because most shopping is done after work.

The park-and-ride program is also beneficial to shopping centers, because the users of the park-and-ride service are more likely to shop where they have already parked. Furthermore, any advertisement and promotional programs for park-and-ride service may promote sales. The owners of the parking lots may receive benefits that will make the shopping centers more attractive to customers, such as an increase in police patrol and immediate snow removal.

There are various types of agreements that governmental agencies can reach with the owners of shopping centers for the park-and-ride program. The Metropolitan Washington Council of Governments (COG) signed an agreement with the owner of the Eastover Shopping Center to designate a portion of these parking areas for a park-and-ride service. This was formalized through a letter agreement in which it was stated that the shopping center would provide all normal maintenance, lighting, cleaning, and snow removal, whereas COG would provide insurance and Prince Georges County would provide signing and surveillance. A provision for discontinuance was included. A separate agreement was made between COG and Prince Georges County for the provision of trailblazing signing, surveillance, and installation of a shelter. Lighting was normally provided by the shopping center in the evening, although no provision was made for lighting in the morning. Pavement marking, originally planned for, was not deemed necessary because the fringe-parking site was sufficiently removed from the stores to avoid confusion.

IMPLEMENTATION STUDIES

As this study indicates, the provision of a park-and-ride and express bus service in selected corridors can be feasible for implementation because it contributes to the improvement of the air quality

and diverts automobile users in the outlying suburban areas to the new service. Because the new express bus routes have fewer stops en route, overall travel-time savings accruing to the commuters will induce some riders from other existing transit modes. Location of such service in the corridors where good transit service, e.g., commuter rail, already exists should therefore be avoided.

The preceding analyses indicate that 14 corridors connecting 25 park-and-ride locations throughout the DVRPC region show promise for instituting the service. If all the routes are made operational, they will attract approximately 4,300 additional daily riders from the existing automobile users. Some shifts in the ridership of other transit modes will also result, diverting about 4,900 trips to the new service (Table 3).

The next step in this project is to advance the park-and-ride and express bus service to the implementation stage. In view of the fact that the financial resources are becoming increasingly scarce, the transit operating agencies may not be able to implement all corridors at the same time. The work described in this paper will then be expanded to study selected corridors in more detail and refine the demand estimation and operational and physical characteristics of the parking lots and routes. Operational agreements, if any, should be investigated with two or three owners of the parking lots falling in the corridor as well as with the transit operating agency that will provide the express bus service.

ACKNOWLEDGMENT

This paper was financed in part by UMTA and by the Pennsylvania and New Jersey Departments of Transportation. We, however, are responsible for the findings and conclusions, which may not represent the official views or policies of the funding agencies.

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Publication of this paper sponsored by Committee on Bus Transit Systems.

Role of Quantitative Analysis in Bus Maintenance Planning

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Transit maintenance costs increased dramatically between the late 1970s and early 1980s. At the same time, transit funding assistance has become less available. These circumstances require that managers operate their maintenance systems more efficiently and that they adopt new cost-cutting policies. It is proposed that maintenance managers use quantitative techniques in planning the operations and policies of maintenance systems. The suggested quantitative techniques, commonly used in other areas of business, industry, and government, may be employed to plan transit maintenance system policies and operations. A simplified simulation model of a hypothetical maintenance system is presented as an example of the use of analytical techniques in maintenance planning.

More stress has been placed on the performance and efficiency of transit maintenance in the past few years. Although greater emphasis on maintenance is often attributed to the financial pinch between escalating maintenance costs and decreases in the availability of federal and local operating assistance, the reasons for paying more attention to transit maintenance are not so simple. Granted, transit industry maintenance costs have grown in recent years at a rate of approximately $400 million per year while at the same time funding assistance has been reduced; however, financial problems are only the most noticeable symptom of the basic problems facing transit maintenance (1).

Faced with this situation, transit maintenance managers must deal with the following basic questions:

1. What are the causes of escalating transit maintenance costs?
2. How can transit maintenance systems be made more efficient?
3. What are the cost trade-offs for various levels of maintenance service and bus dependability and availability?
4. How do maintenance policies and service requirements affect fleet life-cycle costs?
5. At what level can the transit industry afford to fund maintenance systems?

In this paper, it is shown how analytical tools can be used to aid transit managers in answering the first four questions. More specifically, it is proposed that once sufficient maintenance information exists, analytical planning tools can be used to better understand the relationships among mainte-